McDONALD INSTITUTE MONOGRAPHS

Temple landscapes

Fragility, change and resilience of Holocene environments in the Maltese Islands

By Charles French, Chris O. Hunt, Reuben Grima, Rowan McLaughlin, Simon Stoddart & Caroline Malone

Volume 1 of Fragility and Sustainability – Studies on Early Malta, the ERC-funded *FRAGSUS Project*

Temple landscapes

McDONALD INSTITUTE MONOGRAPHS

Temple landscapes

Fragility, change and resilience of Holocene environments in the Maltese Islands

By Charles French, Chris O. Hunt, Reuben Grima, Rowan McLaughlin, Simon Stoddart & Caroline Malone

With contributions by
Gianmarco Alberti, Jeremy Bennett, Maarten Blaauw, Petros Chatzimpaloglou, Lisa Coyle McClung, Alan J. Cresswell, Nathaniel Cutajar, Michelle Farrell, Katrin Fenech, Rory P. Flood, Timothy C. Kinnaird, Steve McCarron, Rowan McLaughlin, John Meneely, Anthony Pace, Sean D.F. Pyne-O'Donnell, Paula J. Reimer, Alastair Ruffell, George A. Said-Zammit, David C.W. Sanderson, Patrick J. Schembri, Sean Taylor, David Trump†, Jonathan Turner, Nicholas C. Vella & Nathan Wright

Illustrations by
Gianmarco Alberti, Jeremy Bennett, Sara Boyle, Petros Chatzimpaloglou, Lisa Coyle McClung, Rory P. Flood, Charles French, Chris O. Hunt, Michelle Farrell, Katrin Fenech, Rowan McLaughlin, John Meneely, Anthony Pace, David Redhouse, Alastair Ruffell, George A. Said-Zammit & Simon Stoddart

FRAGSUS

Volume 1 of Fragility and Sustainability – Studies on Early Malta, the ERC-funded *FRAGSUS Project*

SEVENTH FRAMEWORK PROGRAMME

European Research Council
Established by the European Commission

This project has received funding from the European Research Council (ERC) under the European Union's Seventh Framework Programme (FP7-2007-2013) (Grant agreement No. 323727).

Published by:
McDonald Institute for Archaeological Research
University of Cambridge
Downing Street
Cambridge, UK
CB2 3ER
(0)(1223) 339327
eaj31@cam.ac.uk
www.mcdonald.cam.ac.uk

ISBN: 978-1-902937-99-1

Cover design by Dora Kemp and Ben Plumridge.
Typesetting and layout by Ben Plumridge.

On the cover: *View towards Nadur lighthouse and Għajnsielem church with the Gozo Channel to Malta beyond, from In-Nuffara (Caroline Malone).*

Edited for the Institute by James Barrett (*Series Editor*).

Contents

Contributors

Dr Gianmarco Alberti
Department of Criminology, Faculty for Social Wellbeing, University of Malta, Msida, Malta
Email: gianmarco.alberti@um.edu.mt

Jeremy Bennett
Department of Archaeology, University of Cambridge, Cambridge, UK
Email: jmb241@cam.ac.uk

Dr Maarten Blaauw
School of Natural and Built Environment, Queen's University, University Road, Belfast, Northern Ireland
Email: marten.blaauw@qub.ac.uk

Dr Petros Chatzimpaloglou
Department of Archaeology, University of Cambridge, Cambridge, UK
Email: pc529@cam.ac.uk

Dr Lisa Coyle McClung
School of Natural and Built Environment, Queen's University, University Road, Belfast, Northern Ireland
Email: l.coylemcclung@qub.ac.uk

Dr Alan J. Cresswell
SUERC, University of Glasgow, East Kilbride, University of Glasgow, Glasgow, Scotland
Email: alan.cresswell@glasgow.ac.uk

Nathaniel Cutajar
Deputy Superintendent of Cultural Heritage, Heritage Malta, Valletta, Malta
Email: nathaniel.cutajar@gov.mt

Dr Michelle Farrell
Centre for Agroecology, Water and Resilience, School of Energy, Construction and Environment, Coventry University, Coventry, UK
Email: ac5086@coventry.ac.uk

Dr Katrin Fenech
Department of Classics & Archaeology, University of Malta, Msida, Malta
Email: katrin.fenech@um.edu.mt

Dr Rory P. Flood
School of Natural and Built Environment, Queen's University, University Road, Belfast, Northern Ireland
Email: r.flood@qub.ac.uk

Prof. Charles French
Department of Archaeology, University of Cambridge, Cambridge, UK
Email: caif2@cam.ac.uk

Dr Reuben Grima
Department of Conservation and Built Heritage, University of Malta, Msida, Malta
Email: reuben.grima@um.edu.mt

Dr Evan A. Hill
School of Natural and Built Environment, Queen's University, University Road, Belfast, Northern Ireland
Email: ehill08@qub.ac.uk

Prof. Chris O. Hunt
Faculty of Science, Liverpool John Moores University, Liverpool, UK
Email: c.o.hunt@ljmu.ac.uk

Dr Timothy C. Kinnaird
School of Earth and Environmental Sciences, University of St Andrews, St. Andrews, Scotland
Email: tk17@st-andrews.ac.uk

Prof. Caroline Malone
School of Natural and Built Environment, Queen's University, University Road, Belfast, BT7 1NN, Northern Ireland
Email: c.malone@qub.ac.uk

Dr Steve McCarron
Department of Geography, National University of Ireland, Maynooth, Ireland
Email: stephen.mccarron@mu.ie

Dr Rowan McLaughlin
School of Natural and Built Environment, Queen's University, University Road, Belfast, Northern Ireland
Email: r.mclaughlin@qub.ac.uk

John Meneely
School of Natural and Built Environment, Queen's University, University Road, Belfast, Northern Ireland
Email: j.meneely@qub.ac.uk

Dr Anthony Pace
UNESCO Cultural Heritage, Valletta, Malta
Email: anthonypace@cantab.net

Dr Sean D.F. Pyne-O'Donnell
Earth Observatory of Singapore, Nanyang Technological University, Singapore
Email: sean.1000@hotmail.co.uk

Prof. Paula J. Reimer
School of Natural and Built Environment, Queen's University, University Road, Belfast, Northern Ireland
Email: p.j.reimer@qub.ac.uk

Dr Alastair Ruffell
School of Natural and Built Environment, Queen's University, University Road, Belfast, Northern Ireland
Email: a.ruffell@qub.ac.uk

George A. Said-Zammit
Department of Examinations, Ministry for Education and Employment, Government of Malta, Malta
Email: george.said-zammit@gov.mt

Prof. David C.W. Sanderson
SUERC, University of Glasgow, East Kilbride, University of Glasgow, Glasgow, Scotland
Email: david.sanderson@glasgow.ac.uk

Prof. Patrick J. Schembri
Department of Biology, University of Malta, Msida, Malta
Email: patrick.j.schembri@um.edu.mt

Dr Simon Stoddart
Department of Archaeology, University of Cambridge, Cambridge, UK
Email: ss16@cam.ac.uk

Dr Sean Taylor
Department of Archaeology, University of Cambridge, Cambridge, UK
Email: st435@cam.ac.uk

Dr David Trump†

Dr Jonathan Turner
Department of Geography, National University of Ireland, University College, Dublin, Ireland
Email: jonathan.turner@ucd.ie

Prof. Nicholas C. Vella
Department of Classics and Archaeology, Faculty of Arts, University of Malta, Msida, Malta
Email: nicholas.vella@um.edu.mt

Dr Nathan Wright
School of Social Science, The University of Queensland, Brisbane, Australia
Email: n.wright@uq.edu.au

Figures

Tables

Preface and dedication

Caroline Malone

The *FRAGSUS Project* emerged as the direct result of an invitation to undertake new archaeological fieldwork in Malta in 1985. Anthony Bonanno of the University of Malta organized a conference on 'The Mother Goddess of the Mediterranean' in which Colin Renfrew was a participant. The discussions that resulted prompted an invitation that made its way to David Trump (Tutor in Continuing Education, Cambridge University), Caroline Malone (then Curator of the Avebury Keiller Museum) and Simon Stoddart (then a post-graduate researcher in Cambridge). We eagerly took up the invitation to devise a new collaborative, scientifically based programme of research on prehistoric Malta.

What resulted was the original Cambridge Gozo Project (1987–94) and the excavations of the Xagħra Brochtorff Circle and the Għajnsielem Road Neolithic house. Both those sites had been found by local antiquarian, Joseph Attard-Tabone, a long-established figure in the island for his work on conservation and site identification.

As this and the two other volumes in this series report, the original Cambridge Gozo Project was the germ of a rich and fruitful academic collaboration that has had international impact, and has influenced successive generations of young archaeologists in Malta and beyond.

As the Principal Investigator of the *FRAGSUS Project*, on behalf of the very extensive *FRAGSUS* team I want to dedicate this the first volume of the series to the enlightened scholars who set up this now 35 year-long collaboration of prehistoric inquiry with our heartfelt thanks for their role in our studies.

We dedicate this volume to:

Joseph Attard Tabone
Professor Anthony Bonanno
Professor Lord Colin Renfrew

and offer our profound thanks for their continuing role in promoting the prehistory of Malta.

Acknowledgements

This volume records research undertaken with funding from the European Research Council under the European Union's Seventh Framework Programme (FP/2007-2013)/ERC Grant Agreement n. 323727 (*FRAGSUS Project*: *Fragility and sustainability in small island environments: adaptation, cultural change and collapse in prehistory* – http://www.qub.ac.uk/sites/FRAGSUS/). All the authors of this volume are indebted to the ERC for its financial support, and to the Principal Investigator of the *FRAGSUS Project*, Prof. Caroline Malone (Queen's University, Belfast, UK), for her central role in devising the project and seeing this research through to publication.

For Chapter 2, we extend warm thanks to the staff of the ^{14}CHRONO centre at QUB, especially Stephen Hoper, Jim McDonald, Michelle Thompson and Ron Reimer, all of whom took a keen interest in the *FRAGSUS Project*. The success of the *FRAGSUS Project* in general and the radiocarbon dating exercise has depended on their work. We thank the Physical Geography Laboratory staff at the School of Geography, University College Dublin, for the use of their ITRAX XRF core scanner. In particular, we would like to thank Dr Steve McCarron, Department of Geography, National University of Ireland, Maynooth and Dr Jonathan Turner, Department of Geography, National University of Ireland, University College, Dublin. We thank Prof. Patrick Schembri for sourcing and collecting the *Acanthocardia* samples from the Natural Museum of Natural History. Sean Pyne O'Donnell thanks Dr Chris Hayward at the Tephrochronology Analytical Unit (TAU), University of Edinburgh, for help and advice during microprobe work. Dr Maxine Anastasi, Department of Classics and Archaeology, University of Malta, helped identify the pottery from the settlement cores. Dr Frank Carroll helped show us the way forward; but sadly is no longer with us. Chris Hunt, Rory Flood, Michell Farrell, Sean Pyne O'Donnell and Mevrick Spiteri were the coring team. They were helped by Vincent Van Walt, who provided technical assistance. Al Ruffell and John Meneely did geophysical evaluation and GRP location of the cores. During fieldwork, Tim Kinnaird and Charles French were assisted by Sean Taylor, Jeremy Bennett and Simon Stoddart. We are grateful to the Superintendence of Cultural Heritage, Malta and Heritage Malta for permission to undertake the analyses and much practical assistance.

For Chapter 5, we would like to thank all at Heritage Malta, the Ġgantija visitor's centre and the University of Malta for their friendly and useful assistance throughout. In particular, we would like to thank George Azzopardi, Daphne Caruana, Josef Caruana, Nathaniel Cutajar, Chris Gemmell, Reuben Grima, Joanne Mallia, Christian Mifsud, Anthony Pace, Ella Samut-Tagliaferro, Mevrick Spiteri, Katya Stroud, Sharon Sultana and Nick Vella. We also thank Tonko Rajkovača of the McBurney Laboratory, Department of Archaeology, University of Cambridge, for making the thin section slides, the Physical Geography Laboratory, Department of Geography, University of Cambridge, and the ALS Global laboratory in Seville, Spain, for processing the multi-element analyses.

For Chapter 6, Reuben Grima wrote the first draft of this contribution, receiving comments and additions from the other authors.

For Chapter 7, Simon Stoddart wrote the first draft of this contribution, receiving comments and additions from the other authors.

For Chapter 9, we thank Sharlo Camilleri for providing us with a copy of the GIS data produced by the MALSIS (MALtese Soil Information System) project. We are grateful to Prof. Saviour Formosa and Prof. Timmy Gambin, both of the University of Malta, who facilitated the donation of LiDAR data, together with computer facilities, as part of the European project ERDF156 *Developing National Environmental Monitoring Infrastructure and Capacity*, from the former Malta

Environment and Planning Authority. A number of individuals were happy to share their recollections of shepherding practices in Malta and Gozo over the last sixty or seventy years; others facilitated the encounters. We are grateful to all of them: Charles Gauci, Grezzju Meilaq, Joseph Micallef, Louis Muscat, Ċettina and Anġlu Vella, Ernest Vella and Renata Zerafa.

Simon Stoddart would like to thank Prof. Martin Jones and Rachel Ballantyne for their advice in constructing Figure 11.4. The editors would like to thank Emma Hannah for compiling the index.

Firstly, the FRAGSUS Project is the result of a very generous research grant from the European Research Council (Advanced Grant no' 323727), without which this and its two partner volumes and the research undertaken could not have taken place. We heartily thank the ERC for its award and the many administrators in Brussels who monitored our use of the grant. The research team also wants to record our indebtedness to the administrators of the grant within our own institutions, since this work required detailed and dedicated attention. In particular we thank Rory Jordan in the Research Support Office, Stephen Hoper and Jim McDonald – CHRONO lab, and Martin Stroud (Queen's University Belfast), Laura Cousens (Cambridge University), Glen Farrugia and Cora Magri (University of Malta), the Curatorial, Finance and Designs & Exhibitions Departments in Heritage Malta and Stephen Borg at the Superintendence of Cultural Heritage. Finally, we thank Fr. Joe Inguanez (Emeritus Head of Department, Department of Sociology, University of Malta) for offering us the *leitmotif* of this volume while a visiting scholar in Magdalene College, Cambridge: '*Mingħajr art u ħamrija, m'hemmx sinjorija*' translating as 'without land and soil, there is no wealth'.

Foreword

Anthony Pace

Sustainability, as applied in archaeological research and heritage management, provides a useful perspective for understanding the past as well as the modern conditions of archaeological sites themselves. As often happens in archaeological thought, the idea of sustainability was borrowed from other areas of concern, particularly from the modern construct of development and its bearing on the environment and resource exploitation. The term sustainability entered common usage as a result of the unstoppable surge in resource exploitation, economic development, demographic growth and the human impacts on the environment that has gripped the World since 1500. Irrespective of scale and technology, most human activity of an economic nature has not spared resources from impacts, transformations or loss irrespective of historical and geographic contexts. Theories of sustainability may provide new narratives on the archaeology of Malta and Gozo, but they are equally important and of central relevance to contemporary issues of cultural heritage conservation and care. Though the archaeological resources of the Maltese islands can throw light on the past, one has to recognize that such resources are limited, finite and non-renewable. The sense of urgency with which these resources have to be identified, listed, studied, archived and valued is akin to that same urgency with which objects of value and all fragile forms of natural and cultural resources require constant stewardship and protection. The idea of sustainability therefore, follows a common thread across millennia.

It is all the more reason why cultural resource management requires particular attention through research, valorization and protection. The *FRAGSUS Project* (Fragility and sustainability in small island environments: adaptation, cultural change and collapse in prehistory) was intended to further explore and enhance existing knowledge on the prehistory of Malta and Gozo. The objective of the project as designed by the participating institutional partners and scholars, was to explore untapped field resources and archived archaeological material from a number of sites and their landscape to answer questions that could be approached with new techniques and methods. The results of the *FRAGSUS Project* will serve to advance our knowledge of certain areas of Maltese prehistory and to better contextualize the archipelago's importance as a model for understanding island archaeology in the central Mediterranean. The work that has been invested in *FRAGSUS* lays the foundation for future research.

Malta and Gozo are among the Mediterranean islands whose prehistoric archaeology has been intensely studied over a number of decades. This factor is important, yet more needs to be done in the field of Maltese archaeology and its valorization. Research is not the preserve of academic specialists. It serves to enhance not only what we know about the Maltese islands, but more importantly, why the archipelago's cultural landscape and its contents deserve care and protection especially at a time of extensive construction development. Strict rules and guidelines established by the Superintendence of Cultural Heritage have meant that during the last two decades more archaeological sites and deposits have been protected in situ or rescue-excavated through a statutory watching regime. This supervision has been applied successfully in a wide range of sites located in urban areas, rural locations and the landscape, as well as at the World Heritage Sites of Valletta, Ġgantija, Ħaġar Qim and Mnajdra and Tarxien. This activity has been instrumental in understanding ancient and historical land use, and the making of the Maltese historic centres and landscape.

Though the cumulative effect of archaeological research is being felt more strongly, new areas of interest still need to be addressed. Most pressing are those areas of landscape studies which often become peripheral to the attention that is garnered by prominent megalithic monuments. *FRAGSUS* has once again confirmed that there is a great deal of value in studying field systems, terraces and geological settings which, after all, were the material media in which modern Malta and Gozo ultimately developed. There is, therefore, an interplay in the use of the term sustainability, an interplay between what we can learn from the way ancient communities tested and used the very same island landscape which we occupy today, and the manner in which this landscape is treated in contested economic realities. If we are to seek factors of sustainability in the past, we must first protect its relics and study them using the best available methods in our times. On the other hand, the study of the past using the materiality of ancient peoples requires strong research agendas and thoughtful stewardship. The *FRAGSUS Project* has shown us how even small fragile deposits, nursed through protective legislation and guardianship, can yield significant information which the methods of pioneering scholars of Maltese archaeology would not have enabled access to. As already outlined by the Superintendence of Cultural Heritage, a national research agenda for cultural heritage and the humanities is a desideratum. Such a framework, reflected in the institutional partnership of the *FRAGSUS Project*, will bear valuable results that will only advance Malta's interests especially in today's world of instant e-knowledge that was not available on such a global scale a mere two decades ago.

FRAGSUS also underlines the relevance of studying the achievements and predicaments of past societies to understand certain, though not all, aspects of present environmental challenges. The twentieth century saw unprecedented environmental changes as a result of modern political-economic constructs. Admittedly, twentieth century developments cannot be equated with those of antiquity in terms of demography, technology, food production and consumption or the use of natural resources including the uptake of land. However, there are certain aspects, such as climate change, changing sea levels, significant environmental degradation, soil erosion, the exploitation and abandonment of land resources, the building and maintenance of field terraces, the rate and scale of human demographic growth, movement of peoples, access to scarce resources, which to a certain extent reflect impacts that seem to recur in time, irrespectively of scale and historic context.

Anthony Pace
Superintendent of Cultural Heritage (2003–18).

Chapter 4

Molluscan remains from the valley cores

Katrin Fenech, Chris O. Hunt, Nicholas C. Vella
& Patrick J. Schembri

4.1. Introduction

Molluscs often have quite specific environmental requirements (Evans 1978, 82; Giusti *et al*. 1995; Schembri *et al*. 2018). Many species require only a few square metres of habitat, so they are excellent micro-habitat indicators. Their shells can be dispersed, for instance by running water, but generally, compared with other biotic materials used in palaeoecology (such as pollen grains or seeds), they do not disperse far from their life habitat and therefore provide important indications of local environments. Alkaline sediments, which are very common in the Maltese Islands, will preserve molluscan shells and other calcareous biogenic material over thousands of years. This makes the analysis of molluscan shells potentially a very important tool for the reconstruction of past environments in Malta.

Geologists and archaeologists recognized the value of molluscs as palaeoenvironmental indicators as early the first quarter of the nineteenth century AD (Conybeare 1824; Preece 1998; Evans & O'Connor 2005, 41). Molluscan analysis is still, however, comparatively rare as a palaeoenvironmental tool, and for instance is less commonly used than pollen analysis (e.g. Preece 1998, 158; Fenech 2007).

In the Maltese Islands, the application of the technique has been limited and there has been no comprehensive palaeoenvironmental study using molluscan analysis. Trechmann (1938), Giusti *et al*. (1995) and Hunt (1997) used the sporadic occurrence of land snails in Maltese Quaternary deposits as an indication that these had accumulated in open, exposed conditions. The highly cemented Quaternary deposits precluded anything other than the production of species lists by these authors. Pedley (1980) suggested a brackish depositional environment for the Pleistocene Fiddien Valley Tufa on molluscan evidence. Fenech (2007) and Marriner *et al*. (2012) analysed cores taken in Holocene estuarine deposits at Marsa and Burmarrad, respectively. These studies showed the progress of the Holocene marine transgression and the infilling of the estuaries, and Fenech (2007) also showed the persistence of open, exposed terrestrial environments in the catchment of the Marsa estuary over *c*. 7000 years. At the Neolithic Xagħra Brochtorff Circle (Schembri *et al*. 2009) and the Neolithic and later temple site at Tas-Silġ (Fenech & Schembri 2015), molluscan analysis demonstrated long histories of anthropogenic disturbance and sparse vegetation since the later Neolithic, but a considerable portion of these studies was done on shells recovered by troweling and dry sieving with a large fraction and therefore subject to a form of taphonomic bias caused by the exclusion of most very small taxa. Analysis of a cave fill near Victoria on Gozo, based on assemblages recovered by sieving, identified a phase of spectacular erosion caused by Classical period agricultural practices, followed by a more stable grazed landscape in the Medieval and post-Medieval periods (Hunt & Schembri 2018). Inevitably, the research done before the start of the *FRAGSUS Project* was very partial in coverage. The environmental history of the Maltese Islands was still largely unknown.

To investigate the environment and landscape of the Maltese Islands and the changes they underwent over time, a full molluscan analysis was made of the material extracted from sectioned sediment cores. The shell assemblages found in the *FRAGSUS* cores were controlled by their depositional environment, surrounding habitats and taphonomic factors. They often included molluscs from all four major habitat-groups: marine, brackish water, freshwater and terrestrial. Although it is logical that species would be limited to particular major habitats and that live individuals from other major habitat types would not occur (for example, a freshwater habitat would not be expected to also support live marine and terrestrial species), the result of the analyses of molluscan assemblages from cores is not always easy to relate to the type of environment when species from different major habitats are admixed. In the present study, it was not always straightforward to determine which snail group is autochthonous (i.e. occurred naturally as live individuals), and which groups are allochthonous (e.g. washed into the coring site from elsewhere by run-off during storm events or by waves during storms or even by tsunamis). Thus for instance, a storm might have overtopped a bay-bar leading to insertion of marine taxa into a non-marine lagoon, but at the same time run-off from heavy rain might have washed land snails into the same deposition site. Additionally, allochthonous recycled material might arrive on a site as sediments and their contained molluscs may have been eroded and redeposited. In some cases, it was possible to discern which species were autochonous and which had been transported to the deposition site from elsewhere.

A further complicating factor is that some deposition sites were at times affected by erosion, for instance scour during fluvial or mud-flow events or by marine storm waves. These erosion events led to non-sequences or hiatuses, sometimes recognizable as very marked and abrupt changes of the molluscan fauna, and by abrupt sediment changes.

Previous studies of non-marine molluscs from various (undated) Quaternary deposits around the Maltese Islands revealed the occurrence of several freshwater or wetland species that are now extinct, indicating the previous occurrence of rare periods characterized by much wetter conditions, at least locally (Hunt & Schembri 1999).[1] On the other hand, several species that occur today, such as the woodland indicator *Lauria cylindracea*, had no palaeontological record (see Trechmann 1938; Thake 1985a & b; Giusti *et al.* 1995; Allen & Eastabrook 2017; Hunt & Schembri 2018). These previous studies form the basis of the research undertaken, together with more recent studies of the ecology of non-marine molluscs in local environmental regimes (Schembri *et al.* 2018) that now allow various species to be more or less reliably assigned to a specific habitat. One of the aims of these ecological studies was to analyse the habitat and micro-habitat distribution of current species and assemblages in order to determine their specificity to different habitat types. On the assumption that the ecology of the species would not have changed significantly in the time spans considered, species and assemblages from archaeological and older contexts might then be used to reconstruct past environments and to study environmental change.

Brackish and freshwater assemblages apart, four present-day terrestrial assemblages were recognized: those from exposed habitats, from sheltered habitats, from habitats dominated by trees or shrubs, and from garrigue. The Maltese low garrigue is also an exposed habitat but quantitatively and to some extent qualitatively, its molluscan assemblages differed from those of other exposed habitats presumably because of its very open nature. However, this study also showed that assemblage composition is determined more by the micro-habitat preferences of the species, especially the spatial and temporal availability of shelter and shade, than by macro-habitat type. Many species were found in more than one macro-habitat, albeit in different relative abundances, very likely because of the extreme mosaic nature of the present day landscape of the Maltese Islands where different habitats may occur within very close proximity to each other, allowing a mixing of molluscan assemblages, especially of the less stenoecious species. The mixing that occurred in the deposits studied here, compounds the problem of the natural 'mixing' of assemblages and therefore only allows broad generalizations to be made about the environment of the catchments of the coring sites.

Stenotopic species (those with narrow environmental tolerances) are most informative about the environments present and we have used these as indications that particular habitats were present at in the catchment of the coring sites. Habitats whose presence was inferred in this way included brackish water (with such species as *Hydrobia* spp. and *Ovatella myosotis*), running freshwater (e.g. *Pseudamnicola* (s.str.) *moussonii*), slower moving water and ponds and lakes (e.g. *Lymnaea truncatula*, *Planorbis* spp., *Gyraulus crista*, *Bulinus truncatus*, *Ancylus fluviatilis*), freshwater wetlands (e.g. *Carychium schlickumi*, *Oxyloma elegans*, *Vertigo antivertigo*), sheltered habitats (e.g. *Oxychilus draparnaudi*, *Oxychilus hydatinus*, *Vitrea* spp.), wooded habitats (*Lauria cylindracea*), and garrigue (e.g. *Trochoidea spratti* and *Muticaria macrostoma*).

The molluscan analyses undertaken here complement the pollen analyses (see Chapter 3) by providing data about the environment and landscape. The changing compositions of the molluscan assemblages further suggest how climatic and weather events and patterns of human activity affected the depositional environment and the catchments of the respective coring sites. While the resolution of environmental reconstruction provided by analysis of the molluscan assemblages may not be as high as that provided by pollen, given the greater number of plant species involved and the habitat specificity of many plants, molluscan assemblages have the advantage of reflecting local conditions, since the transport of molluscs is usually over much shorter distances than for pollen.

This chapter will describe the core material studied and the methods applied. Results of the analysis are discussed core by core. An environmental reconstruction based on the molluscs from the early Holocene to the Late Roman period highlights changes in the landscape through time. The molluscan evidence indicates major erosion events and may be used to suggest their causes. Extinct species, taxa that previously had no local fossil record and some useful indicator species are then discussed in the context of the environmental insights they provide.

4.2. Material

Eight sediment cores from six different locations across the Maltese Islands were analysed (Fig. 2.4). With the exception of the Marsa 2 core, these were taken between 2013 and 2015 (see Chapter 3).[2] The Salina Deep Core and Marsa 2 core had been extracted with a mechanical corer by local companies experienced in geological site investigations.[3] The other cores were taken with an Eijkelkamp percussion auger by *FRAGSUS* team members Chris O. Hunt, Sean Pyne O'Donnell, Michelle Farrell and Rory Flood. These were then cut in half lengthwise at NIU Maynooth and subjected to core logging at University College Dublin. One half of each of the cores, in its' plastic tube and wrapped in cling-film was then sent to Malta for the molluscan analyses. Summary and detailed descriptions of the cores are provided in Chapter 2 and Appendix 3**.**

4.3. Methods

The core sections were consecutively divided into segments between 3 and 13 cm in thickness. All segments were weighed and their Munsell soil colour was recorded. Depending on the size of the samples, small sub-samples weighing between 4 and 20 g were taken from every segment and archived for future reference.[4] The material from the segments was then stirred in water. When necessary, sodium hexametaphosphate was added to facilitate the breaking up of aggregated particles. Once disaggregated, the sediment was wet sieved through nested 500 and 63 micron (μm) test sieves and dried. Stones larger than 8 mm diameter were sorted out from the >500 μm fraction. The material in each fraction was then weighed and the silt/clay content calculated. The dried material from the 500 μm sieve was sorted for shells, other organic remains and artefacts such as pottery under a stereomicroscope. The fine sediments retained by the 63 μm sieve were bagged, but not sorted, as they were found to be sterile apart from tiny charcoal fragments. Mollusc percentage abundances were calculated in TILIA (© Grimm 1987), which also generated the diagrams. The molluscan diagrams were subdivided into Mollusc Assemblage Zones (MAZs) by applying stratigraphically constrained cluster analyses to percentage abundance data using CONISS software in TILIA (Grimm 1987). Several deposits contained no molluscan remains. As TILIA does not recognize 0 as a value for percentage calculations, a nominal value of 1 was given to these deposits in a separate category to allow the calculations.

The molluscs were identified to the lowest taxonomic level possible with the help of: a reference collection, Giusti *et al.* (1995) for the non-marine molluscs, Doneddu and Trainito (2005) and other standard identification manuals for the marine species. The vast majority of shells larger than 2 mm were heavily fragmented. Identification was nonetheless mostly possible at least to genus level because of distinctive shell features. Indeterminate fragments of helicid land snails that could not be quantified in terms of actual numbers, were counted as 1. Similarly, the tests of the rock urchin *Paracentrotus lividus* found in several samples, were noted as 1. Although bivalve valves occur naturally in pairs, they usually occurred singly or in uneven pairs in the samples. Each valve was counted as one individual.[5]

All other shells were counted in actual numbers and then grouped according to their macro-habitat: marine, brackish water-associated, freshwater-associated and land snails. The freshwater-associated molluscs and the land snails were further subdivided and grouped according to their more specific habitat requirements (Table 4.1). The presence of the subterranean, burrowing land snail *Cecilioides acicula* was used as an indicator for erosion events when found in subaqueous deposits. Table 4.1 also lists the previously known fossil record of the species found and their current status. The complete dataset of the shells found per sample/depth for all cores is given in Appendix 5.

4.4. Radiocarbon dates and Bayesian age-depth models

As discussed in Chapter 2, a chronology was built with the radiocarbon dates (Tables 2.3 & 2.4) using Bayesian age-depth modelling techniques (Blaauw & Christen 2011). The molluscan data were plotted onto this time-scale to reveal the changing patterns of occurrence through time.

4.5. Results

For core descriptions, logs and precise location, see Chapter 2. As the Marsa 2 core had been taken previously in 2002, see Appendix 3 for soil colours.

Table 4.1. *List of freshwater molluscs and land snails found in the cores, their locally registered habitat requirement, palaeontological record from Quaternary deposits in Malta and Gozo, and current status and conservation in the Maltese Islands (Giusti* et al. *1995; Schembri* et al. *2018; updated by the present authors)*

Species	**Habitat**	**Fossil record**	**Current status and conservation**
Pomatias sulcatus (Draparnaud 1801) The Maltese populations previously assigned to this species are now regarded as belonging to *Tudorella melitense* (Sowerby 1843) (see Pfenninger *et al.* 2010)	Ubiquitous and very eurytopic	Dwejra (Gozo); Wied tal-Baħrija	Common; not threatened
Pseudamnicola (s.str.) *moussonii* (Calcara 1841)	Running freshwater	Wied tal-Baħrija	Patchily distributed because of the restricted distribution of its habitat; locally endangered
Carychium cf. *schlickumi* Strauch 1977	Freshwater wetlands	Wied tal-Baħrija	Present status unknown but at best likely to have a patchy distribution due to the restricted distribution of its habitat; may be extinct
Lymnaea (Galba) truncatula (Müller 1774)	Ponds, lakes, slow-moving water	Wied tal-Baħrija	Widespread in freshwater habitats but such habitats are scarce locally; vulnerable
Planorbis Müller 1774. Two species occur *P. planorbis* (Linnaeus 1758) and *P. moquini* Requien 1848) which are difficult to tell apart on shell characters alone	Ponds, lakes, slow-moving water	*P. planorbis*: Ta' Sarraflu (Gozo) and archaeological deposits Ta' Vnezja; *P. moquini*: Wied tal-Baħrija	*P. planorbis* is probably extinct; *P. moquini* is rare; its habitats have a restricted distribution locally; vulnerable
Gyraulus (Armiger) crista (Linnaeus 1758)	Ponds, lakes, slow-moving water	Wied tal-Baħrija	Extinct
Bulinus (Isidora) cf. *truncatus* (Audouin 1827) complex	Ponds, lakes, slow-moving water	Ta' Sarraflu (Gozo); Wied tal-Baħrija	Extinct
Ancylus fluviatilis Müller 1774	Slow to fast-moving freshwater	Ta' Sarraflu (Gozo); Wied tal-Baħrija	Common; patchily distributed because of the restricted distribution of its habitat
Oxyloma elegans (Risso 1826)	Freshwater wetlands	Wied tal-Baħrija	Extinct
Vertigo cf. *antivertigo* (Draparnaud 1801)	Freshwater wetlands	Wied tal-Baħrija	Extinct
Truncatellina callicratis (Scacchi 1833)	Leaf litter in shady situations but occasionally also in relatively open environments	Għajn il-Kbira (Gozo)	Previously thought to be rare but now regarded as common and quite widespread; not threatened
Granopupa granum (Draparnaud 1801)	Open country and occupies many micro-habitats in this macro-habitat; eurytopic	Wied tal-Baħrija; Għajn il-Kbira and Xagħra Brochtorff Circle (Gozo)	Widespread; not threatened
Lauria cylindracea (Da Costa 1778)	Woodland usually in forest remnants but also in well developed maquis	No fossil record previous to the present study	Rare mainly due to the dearth of woodland habitats in the Maltese Islands; not threatened
Vallonia pulchella (Müller 1774)	Freshwater wetlands	Wied tal-Baħrija	Present status unknown but rare and at best likely to have a patchy distribution due to the restricted distribution of its habitat
Pleurodiscus balmei (Potiez and Michaud 1838)	Leaf litter in shady environments but occasionally also in relatively open environments	Għajn il-Kbira (Gozo)	Common and widespread; not threatened
Chondrula (Mastus) pupa (Linnaeus 1758)	Ubiquitous and eurytopic	Wied tal-Baħrija; Għajn il-Kbira and Xagħra Brochtorff Circle (Gozo)	Common and widespread; not threatened
Vitrea Fitzinger 1833. Three species occur (*V. contracta* (Westerlund 1871), *Vitrea* sp. Giusti, Manganelli and Schembri 1995, and *V. subrimata* (Reinhardt 1871)) but difficult to tell apart without anatomical examination	Leaf litter in shady environments	Wied tal-Baħrija; Għajn il-Kbira and Xagħra Brochtorff Circle (Gozo)	As a group, relatively widespread and common; not threatened

Table 4.1 *(cont.)*.

Species	Habitat	Fossil record	Current status and conservation
Oxychilus Fitzinger 1833. Two species occur: *Oxychilus draparnaudi* (Beck 1837) and *Oxychilus* (*Mediterranea*) *hydatinus* (Rossmässler 1838); often difficult to tell apart on shell characters alone, especially if juvenile	Leaf litter in shady situations but *Oxychilus draparnaudi* also in relatively open environments	Wied tal-Baħrija; Xagħra Brochtorff Circle (Gozo)	Both species are common and widespread; not threatened
Cecilioides acicula (Müller 1774)	Burrower	Wied tal-Baħrija; Għajn il-Kbira and Xagħra Brochtorff Circle (Gozo)	Frequent and widespread; not threatened
Ferussacia (s.str.) *folliculus* (Gmelin 1791)	Leaf litter in shady situations but occasionally also in relatively open environments	Għajn il-Kbira and Xagħra Brochtorff Circle (Gozo)	Common and widespread; not threatened
Rumina decollata (Linnaeus 1758)	Open country and occupies many microhabitats in this macro-habitat; eurytopic	Widespread in Quaternary deposits and archaeological sites	Common and widespread; not threatened
Muticaria macrostoma (Cantraine 1835) sensu Giusti *et al*. 1995,	Open country mostly in garrigue habitats	Għajn il-Kbira, Xagħra Brochtorff Circle and Dwejra (Gozo)	Common and widespread; not threatened
Papillifera papillaris (Müller 1774)	Mainly open country but also in sheltered habitats; very eurytopic	Għajn il-Kbira, Xagħra Brochtorff Circle and Ta' Sarraflu (Gozo); Wied tal-Baħrija	Very common and widespread; not threatened
Xerotricha Monterosato 1892. Two species occur: *X. conspurcata* (Draparnaud 1801) and *X. apicina* (Lamarck 1822), which are difficult to tell apart on shell characters alone	Open country but also in some sheltered habitats; somewhat eurytopic	*X. conspurcata*, was found at Għajn il-Kbira and the Xagħra Brochtorff Circle (Gozo); *X. apicina* was found in Wied tal-Baħrija	Both species are common and widespread; not threatened
Trochoidea spratti (Pfeiffer 1846, sensu Giusti *et al*. 1995)	Open country, especially in garrigue, but also in some sheltered habitats; somewhat eurytopic	Ubiquitous in Quaternary deposits and archaeological sites	Common and widespread; not threatened
Cernuella Schlüter 1838. Three species occur: *C. caruanae* (Kobelt 1888), *C.* cf *cisalpina* (Rossmässler 1837) and *C.* cf *virgata* (Da Costa 1778); difficult to differentiate based on shell characters alone if juvenile	*C. caruanae* is ubiquitous and *C.* cf *cisalpina* is more restricted by both are eurytopic	Xagħra Brochtorff Circle (Gozo); Wied tal-Baħrija	*C. caruanae* and *C.* cf *cisalpina* are widespread and abundant and not threatened. *C.* cf *virgata* is very probably extinct
Cochlicella acuta (Müller 1774)	Ubiquitous and very eurytopic	Widespread in Quaternary deposits and archaeological sites	Very widespread and abundant; not threatened
Caracollina lenticula (Michaud 1831)	Ubiquitous and eurytopic	Għajn il-Kbira and Xagħra Brochtorff Circle (Gozo)	Widespread and abundant; not threatened
Theba pisana (Müller 1774)	Ubiquitous and eurytopic	Għajn il-Kbira, Xagħra Brochtorff Circle and Ta' Sarraflu (Gozo)	Widespread and abundant; not threatened
Eobania vermiculata (Müller 1774)	Ubiquitous and eurytopic	Widespread in Quaternary and Holocene deposits	Very common and widespread; not threatened
Cantareus apertus (Born 1778)	Open country normally on leafy vegetation and eurytopic	Għajn il-Kbira and Xagħra Brochtorff Circle (Gozo)	Relatively common and widespread; not threatened
Cantareus aspersus (Müller 1774)	Open country normally on leafy vegetation and eurytopic	Wied tal-Baħrija	Very common and widespread; not threatened
Pisidium Pfeiffer 1821. Two species occur: *P. casertanum* (Poli 1791) and *P. personatum* Malm 1855); difficult to differentiate based on shell characters alone	Slow to fast-moving water but also in ponds, and lakes; in Malta can co-occur in the same habitat	Wied tal-Baħrija	Both are presently very rare due to a highly restricted distribution; endangered

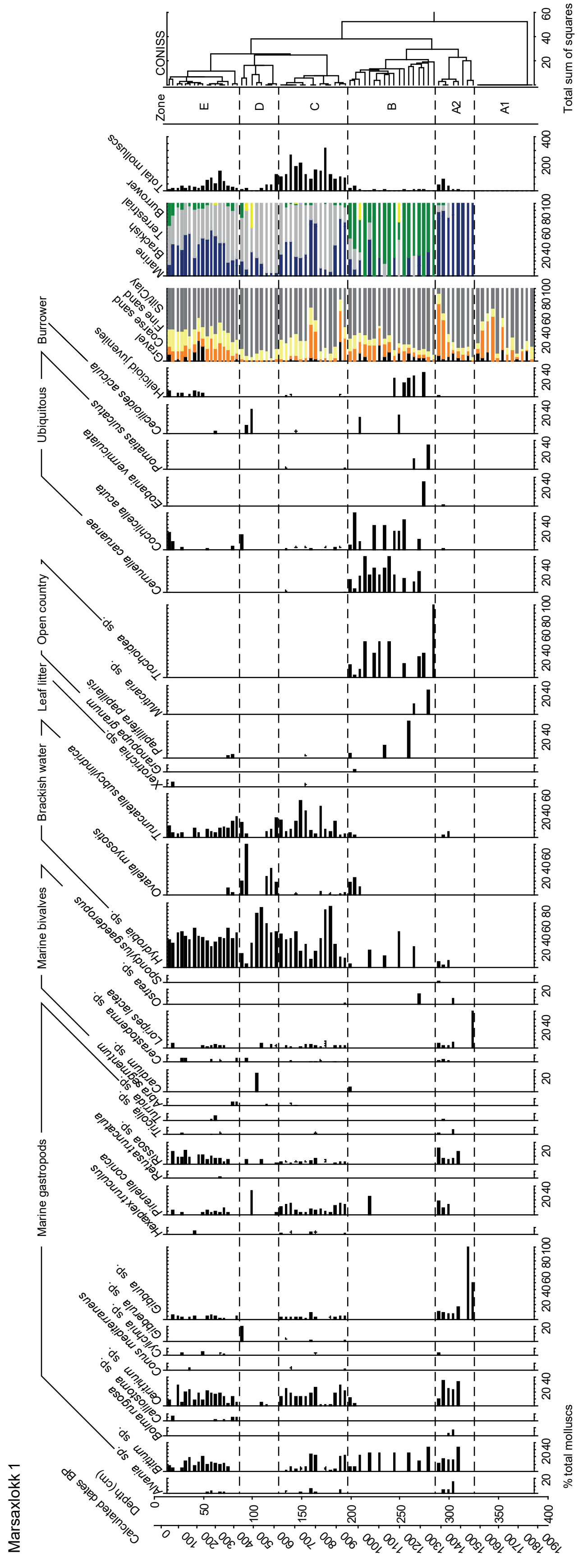

Figure 4.1. *Marsaxlokk 1 molluscan histogram (C.O. Hunt & K. Fenech).*

Table 4.2. *Molluscan zones for the Marsaxlokk 1 core (MX1).*

Zone MX1-	**Depth (cm)**	**Date ranges cal. AD (BP) for the start of each zone (2σ)**	**Molluscan assemblages**	**Environment**
A1	386–326	n/a	Sterile	Bedrock/bedrock interface
A2	326–286	AD 171–523 (1779–1427 BP)	Total of 195 shells, of which *Cerithium* sp. 26%, *B. reticulatum* 15%, *G. adansonii* 10%, *Hydrobia* sp. 6%, *T. subcylindrica* 3% Few fragments of marine molluscs between 326–306 cm; from 306 cm upwards there was a sharp increase in the variety and abundance of marine species; concurrently, appearance of brackish water/saltmarsh species, which were 20% of total molluscs	Shallow marine environment becoming shallower towards the top, as indicated by the appearance of the shoreline species *Truncatella subcylindrica*
B	286–197	AD 422–678 (1528–1272 BP)	Total of 126 shells, of which *C. acuta* 21%, *C. caruanae* 16%, *O. myosotis* 10%, *B. reticulatum* 9%, *Hydrobia* sp. 6% Assemblages with generally less than 20 shells per sample, containing land snails, brackish water and marine species	Major inwash event into a shallow lagoonal or restricted shallow marine environment; land snails reveal an exposed and open environment with rocks/stones and some scrubby patches; reappearance of *Truncatella subcylindrica* and *Ovatella myosotis* suggest a very marginal shoreline and a possible saltmarsh environment
C	197–127	AD 816–1158 (1134–792 BP)	Total of 2078 molluscs, of which *Hydrobia* sp. 43%, *T. subcylindrica* 19%, *Cerithium* sp. 14%, *O. myosotis* 0.8% and *C. acuta* 0.4% Marine and brackish water species dominated the assemblages; number of molluscs generally exceeded 100 per sample, once reaching more than 300; land snails occurred irregularly in small numbers throughout	Saltmarsh or restricted shoreline to very shallow marine lagoonal sedimentation as indicated by the mudsnail *Hydrobia* sp. and the two shoreline species *T. subcylindrica* and *O. myosotis;* fine layering suggests aquatic deposition mainly of land-derived sediments in quiet waters; continued presence of open ground taxa, particularly *C. acuta* suggests open, exposed terrestrial environments while *Xerotricha conspurcata* may indicate the removal of dense vegetation, either through anthropogenic or natural causes
D	127–86	AD 1146–1486 (804–464 BP)	Total of 274 shells, of which *Hydrobia* sp. 46%, *O. myosotis* 23%, T. *subcylindrica* 15%, *C. acicula* 1%, *C. acuta* 0.3% Predominantly brackish water and shoreline species; marine molluscs occurred in very low numbers throughout; land snails were very rare and only found towards the top of the zone; apart from the lowermost sample, the total number of molluscs found was well below 100	Present day sea level is at 125 cm; very close to the previous zone in terms of environment; again, a restricted shoreline to shallow marine or lagoonal environment as indicated by the mud-snail *Hydrobia* sp. and the shoreline/saltmarsh species *T. subcylindrica* and *O. myosotis*; hardly any land snails, but the presence of the burrower *Cecilioides acicula* may indicate erosion events that led to the deposition of land derived sediments on the coring site
E	86–14	AD 1357–1663 (593–287 BP)	Total of 729 shells, of which *Hydrobia* sp. 40%, *Cerithium* sp. 15%, *T. subcylindrica* 10%, *C. acuta* 8% and *O. myosotis* 0.5% Mixed assemblages containing mainly marine and brackish water molluscs; land snails were found in most samples, but exceeded 20% of all molluscs only in the uppermost 10 cm	This part also lies above the present day sea level and it is likely that the marine molluscs and the brackish water mud-snail *Hydrobia* sp. were washed on land through wave action; the saltmarsh species *O. myosotis* is no longer found beyond 70 cm, but the shoreline species *T. subcylindrica* occurs throughout; the land snails suggest an open and exposed environment; *X. conspurcata* was only found once close to the top of core, indicating dense vegetation

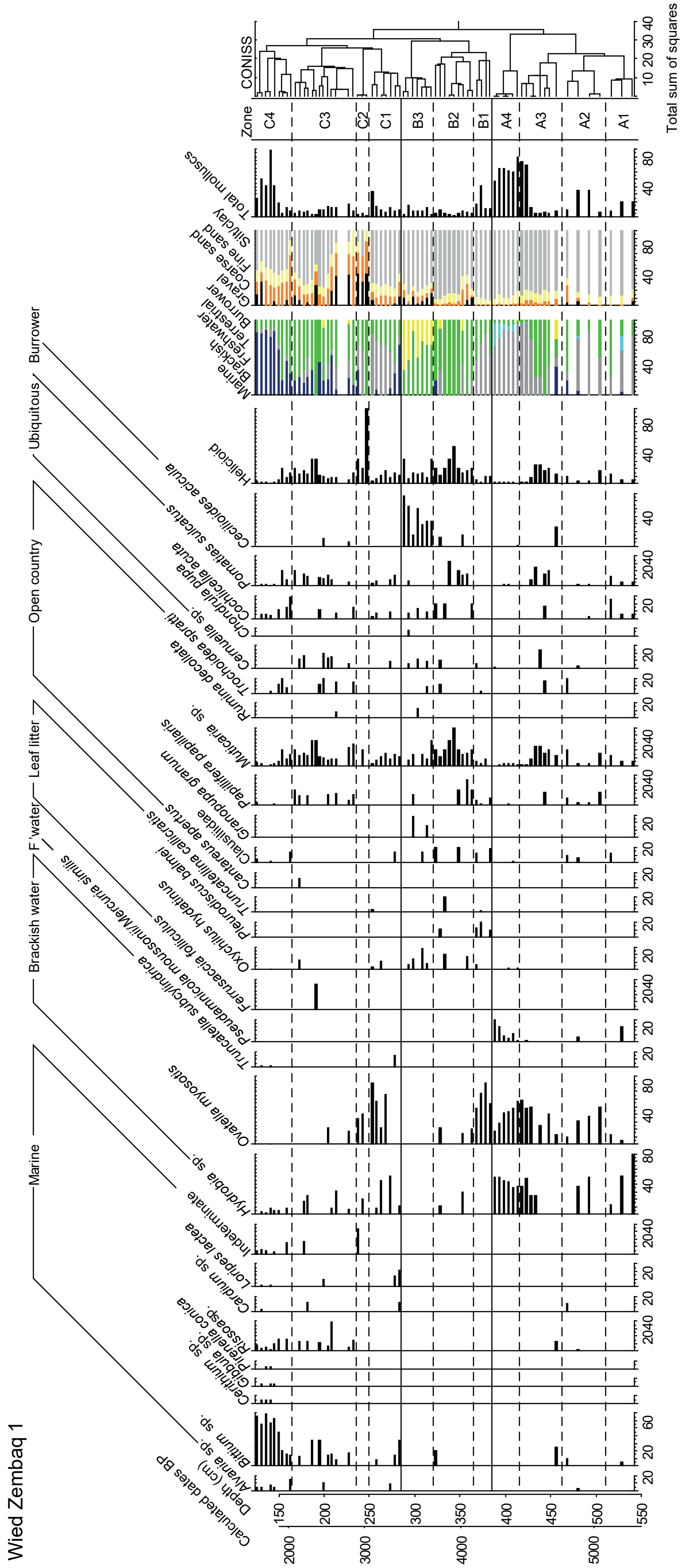

Figure 4.2. *Wied Żembaq 1 molluscan histogram (C.O. Hunt & K. Fenech).*

Table 4.3. *Molluscan zones for the Wied Żembaq 1 core (WŻ1).*

Zone WŻ1-	Depth (cm)	Date ranges cal. BC/AD (BP) for the start of each zone (2σ)	Molluscan assemblages	Environment
A1	548–510	3587–3352 BC (5537–5302 BP)	Total of 48 shells, of which *Hydrobia* sp. (56%), *O. myosotis* (4%), *P. moussonii* (8%), *Muticaria* sp. (6%) Mixed assemblages from the major habitat groups, but less than 20 specimens per sample; freshwater molluscs at 515 cm	Key indicators are *Hydrobia* sp. and *Ovatella myosotis*, suggesting shallowing brackish water, possibly indicating the development of a bay-bar at sea margin to the inlet; presence of freshwater species *Pseudamnicola moussonii* is consistent with inwash from a freshwater stream; very open and erosive terrestrial environments; *Muticaria* sp. are likely derived from the rocky *wied* sides, while *Cochlicella acuta, Pomatias sulcatus* and the helicoids may be associated with very lightly vegetated steppe or garrigue
A2	510–462	3272–2993 BC (5222–4943 BP)	Total of 86 shells, of which *Hydrobia* sp. (35%), *O. myosotis* (33%), *Muticaria* sp. (6%) and *P. moussonii* (2%) Similar to A1, but a sharp rise in the number of brackish water species	Further shallowing of the brackish water and clear transition to salt marsh as indicated by the increased presence of *O. myosotis*; evidence of freshwater stream; increase in karstland species *Papillifera papilaris* and *Muticaria* sp. coupled with a decrease of taxa associated with very lightly vegetated steppe or garrigue may suggest removal of natural vegetation
A3	462–415	2993–2639 BC (4943–4589 BP)	Total of 181 shells, of which *O. myosotis* (48%), *Hydrobia* sp. (35%), *Muticaria* sp. (5%), *C. acicula* (1%) and *P. moussonii* (0.5%) Sudden decrease of brackish water species but increase in land snails; towards the top of this zone, the situation is reversed again; only freshwater snail found	Continuous strong presence of saltmarsh species *O. myosotis*, particularly towards the top of the zone; karstland species like *Muticaria* sp. occur throughout, evidence of a freshwater stream only once (at 423 cm); increase again of species characteristic of lightly vegetated steppe and garrigue like *Cochlicella acuta* and *Pomatias sulcatus*; presence of the burrower *Cecilioides acicula* at the base of this zone may point to an erosion event, perhaps in relation with a storm, as suggested also by the presence of marine taxa
A4	415–385	2698–2284 BC (4648–4234 BP)	Total of 377 shells, of which *Hydrobia* sp. (43%), *O. myosotis* (41%), *P. moussonii* (11%) and *Muticaria* (1%) Sudden increase in freshwater snails, reaching 28% at the top of this zone; dramatic decrease in land snails (now less than 5% throughout); zone is clearly dominated by brackish water species; marine taxa are absent	The freshwater channel may have meandered closer to the coring site or may reflect an increase in precipitation, as indicated by the presence of *P. moussonii*, which requires running, perennial freshwater; very brackish lagoonal to saltmarsh conditions are suggested by an increasing presence of *Hydrobia* sp., while the initial dominance of *O. myosotis* decreases from 60% to 20% at the top of the zone; the very few land snails indicate a landscape similar to the previous zones
B1	385–365	2495–2072 BC (4445–4022 BP)	Total of 80 shells, of which *O. myosotis* (64%), *P. balmei* (14%), *C. acicula* (5%), *Muticaria* sp. and *P. papillaris* (each 4%) Sharp decrease in the number of shells found. No more freshwater snails, but a steady increase in land snails, reaching 50% at the top of this zone; first appearance of leaf litter species; brackish water species consist only of *O. myosotis*; marine molluscs are absent	Saltmarsh conditions indicated by a high number of *O. myosotis* and the sudden absence of *Hydrobia* sp.; breakdown of denser vegetation, washing leaf litter species like *Pleurodiscus balmei* into the channel; open country/karstland species *Muticaria* sp. and *P. papillaris* occur throughout; taxa indicative of light vegetation are rare

Table 4.3 *(cont.).*

Zone WŻ1-	Depth (cm)	Date ranges cal. BC/ AD (BP) for the start of each zone (2σ)	Molluscan assemblages	Environment
B2	365–320	2386–1936 BC (4306–3886 BP)	Total of 47 shells, of which *Muticaria* sp. (19%), *O. myosotis* (9%), *O. hydatinus* (4%) and *C. acicula* (4%) Dramatic decrease in the number of shells found; assemblages consisted chiefly of land snails, brackish water species were rarely found; one marine shell occurred at the top of this zone, together with land snails, possibly due to an inwash event	Continuous absence of the fresh water snail *P. moussonii* may point to an aridification of the landscape, due to natural and/or anthropogenic causes; this may have accelerated the breakdown of denser vegetation with more leaf litter species being washed into the channel through increased erosion together with open-country and ubiquitous taxa; the presence of the burrower *C. acicula* suggests severe erosion events; these would have overwhelmed the brackish water taxa at times by the sediment flux
B3	320–285	2014–1644 BC (3964–3594 BP)	Total of 55 shells, of which *C. acicula* (40%), *O. hydatinus* (9%), *Muticaria* sp. (9%), *C. acuta* (5%) Dramatic decrease in the number of shells per sample, rarely exceeding 10; the assemblages consisted exclusively of land snail taxa associated with leaf litter, open country/karstland and lightly vegetated environments	The permanent presence and proportion of the burrower *C. acicula* increased steadily, indicating continuous severe erosion, which included the inwash of stones; the shade species *Oxychilus hydatinus*, which also lives underneath stones, was the only leaf litter species found, indicating a further aridification of the landscape; open country/karstland species, mainly *Muticaria* sp., occurred in low numbers throughout, while species associated with light vegetation such as *C. acuta* were rare
C1	285–250	1714–1371 BC (3664–3321 BP)	Total of 90 shells, of which *O. myosotis* (46%), *Hydrobia* sp. (13%), *Muticaria* sp. (8%) and *O. hydatinus* (2%) Assemblages were dominated by marine and brackish water associated molluscs; land snails occurred throughout, but unlike in the previous zone, the burrower *C. acicula* was absent	Increasing sand may reflect the proximity of the shoreline or may result from higher-energy stream-flows; the coherent molluscan assemblages do not suggest violent inwash events; succession of marine-brackish taxa is indicated by *Cardium* and *Loripes,* which are typically shallow-marine taxa from sheltered locations; these are succeeded by the lagoonal *Hydrobia* sp. and then followed by the salt-marsh *O. myosotis,* pointing to shallowing marginal marine then lagoonal water passing into salt marsh; *Muticaria* sp. suggests inwash from the rocky sides of the *wied* and *C. acuta, P. sulcatus* and the helicoids suggest very lightly vegetated terrestrial habitats
C2	250–235	1403–2033 BC (3353–2983 BP)	Total of 9 shells, *O. myosotis* (33%), *Hydrobia* sp. (11%) and *Muticaria* sp. (11%) Assemblages contained only 1 to 5 molluscs per sample, all heavily fragmented and belonging to marine, brackish water and terrestrial environments	The stony deposits could reflect vigorous flows in the *wied*, but may also be consistent with the approach of the open shoreline with rising sea levels; the continuation of *O. myosotis* and *Hydrobia* sp. points to a marginal lagoon/saltmarsh environment
C3	235–165	1231–907 BC (3181–2857 BP)	Total number of shells: 116, of which *Bittium* sp. (11%), *Rissoa* sp. (9%), *Hydrobia* sp. (8%) and *Muticaria* sp. (15%) Number of molluscs increases irregularly up to 17 shells per sample; most samples contained an admixture of marine, brackish water and land snail species; brackish water species were generally the least common	Coarse sand and stones continue to dominate the lower half of this zone, again reflecting vigorous flows and possibly wave action with continuously rising sea levels, as also indicated by the increase in marine species like *Bittium* and *Rissoa* spp.; *O. myosotis* continues to decline, the persistence of *Hydrobia* sp. is consistent with a lgaoonal environment; leaf litter species were few and only found in the upper part of the zone, probably as a result of inwash events; the other terrestrial species are consistent with open, exposed habitats, with *Muticaria* sp. and *P. papillaris* suggesting inwash from the rocky sides of the *wied* and *T. spratti, Cernuella* sp., *C. acuta* and *P. sulcatus* indicating very lightly vegetated ground

Table 4.3 *(cont.)*.

Zone WŻ1-	Depth (cm)	Date ranges cal. BC/AD (BP) for the start of each zone (2σ)	Molluscan assemblages	Environment
C4	165–115	477 BC–AD 124 (2427–1826 BP)	288 shells in total, mainly *Bittium* sp. (56%); *Hydrobia* sp. (5%); *Muticaria* sp. (3%) Increasing dominance of marine molluscs in the mixed assemblages, reaching more than 80% at the top of this zone; brackish water species are rare and generally less than 10%; the remainder are land snails, decreasing from 80% at the base to around 10% at the top	The persistence of *Hydrobia* sp. in this zone points to a lagoonal environment; the marine taxa were all very small and associated with sandy/muddy bottoms and marine algae, possibly washing into the inlet; leaf litter species were reduced to only one specimen in the entire zone (*O. hydatinus*), while the open country species generally persisted throughout, as did species associated with very light vegetation

Table 4.4. *Molluscan zones for the Wied Żembaq 2 core (WŻ2).*

Zone WŻ2-	Depth (cm)	Date ranges cal. BC/AD (BP) for the start of each zone (2σ)	Molluscan assemblages	Environment
A1	521–478	3495–3097 BC (5445–5047 BP)	Total of 212 shells, of which *O. myosotis* (59%), *Hydrobia* sp. (16), *Muticaria* sp. (8%), *P. moussonii* (0.5%) Mixed assemblages, at times from all the major habitat groups; one freshwater mollusc at 503 cm	Key indicators are *Hydrobia* sp. and *Ovatella myosotis*, suggesting shallowing brackish water and development of a saltmarsh; presence of one specimen of the freshwater species *Pseudamnicola moussonii* was inwashed from a freshwater stream; presence of a few leaf litter species indicates dense vegetation in the vicinity. *Muticaria* sp. and the other open country species are likely derived from the rocky *wied* sides, while *Pomatias sulcatus* and the helicoids may be associated with very lightly vegetated steppe or garrigue
A2	478–379	3170–2781 BC (5120–4731 BP)	Total of 192 shells, *O. myosotis* clearly dominating (70%). *Hydrobia* sp. (7%), *Muticaria* sp. (5%), *P. balmei* (2%) Fewer marine molluscs and land snail species than in A1; sharp rise in the saltmarsh species *O. myosotis*	Further shallowing of the brackish water and clear transition to salt marsh as indicated by the sharply increased presence of *O. myosotis*; at the base of this zone, this is coupled with an increase in coarse sand; no more evidence of freshwater stream; decrease in leaf litter taxa and the karstland species *Muticaria* sp. coupled with a decrease of taxa associated with very lightly vegetated steppe or garrigue
B1	379–336	2469–1926 BC (4419–3876 BP)	Total of 54 shells; no clearly dominating species. *Muticaria* sp. (11%), *O. myosotis* (7%), leaf litter species (9%), *C. acicula* (2%) Sharp decrease in the number of shells found; no more marine or freshwater snails, brackish water species occur irregularly in small numbers only	Sharp decrease in brackish water species, coupled with an increase in land snails; beginning of breakdown of denser vegetation, washing leaf litter species like *Pleurodiscus balmei* into the channel; erosion is indicated by *C. acicula*; open country/karstland species *Muticaria* sp. and *P. papillaris* occur throughout, taxa indicative of light vegetation are also present
B2	336–300	2138–1579 BC (4088–3529 BP)	Total of 40 shells, dominated by the land snails *C. acicula* (33%). *O. hydatinus* (10%), *Muticaria* sp. (8%) Further decrease in the number of shells found; assemblages consisted chiefly of land snails, brackish water species were rarely found; only one marine shell occurred at the top of this zone, together with land snails, perhaps due to an inwash event	Significant breakdown of vegetation and stark increase in erosion inwash events indicated by *C. acicula* and the appearance of stones; this may point to aridification of the landscape, which may have accelerated the breakdown of denser vegetation with leaf litter species continuously being washed into the channel through increased erosion together with open country and ubiquitous taxa; the strong presence of the burrower *C. acicula* suggests severe erosion events; like in WŻ1, the sediment flux would have overwhelmed the brackish water taxa at times

Table 4.4 *(cont.)*.

Zone WŻ2-	Depth (cm)	Date ranges cal. BC/AD (BP) for the start of each zone (2σ)	Molluscan assemblages	Environment
C1	300–273	1825–1258 BC (3775–3208 BP)	Total of 82 shells; *Bittium reticulatum* (34%), *Rissoa* sp. (8%), *Hydrobia* sp. (12%), *O. myosotis* (5%), *Muticaria* sp. (4%) Assemblages showed a strong component of marine and brackish water associated mollusk; land snails occurred throughout, but unlike in the previous zone, the burrower *C. acicula* only occurred once at the base of this zone	Strong presence of stones and increasing coarse sand may reflect the proximity of the shoreline or may result from higher-energy stream-flows; the molluscan assemblages may perhaps suggest one violent inwash event (at 285 cm) in this initially coherent sequence, where marine taxa (mainly *Bittium* sp.) are succeeded by the lagoonal *Hydrobia* sp.; the land-derived inwash event carried *O. myosotis* and various land snails from open country onto the site; after this event, *Hydrobia* sp. briefly dominate the assemblages, while more land snails like *Muticaria* sp. suggests inwash from the rocky sides of the *wied* and *C. acuta, P. sulcatus* and the helicoids suggest very lightly vegetated terrestrial habitats; marked decrease in diversity and abundance of leaf litter species may point to aridification of the landscape
C2	273–228	1584–944 BC (3534–2894 BP)	Total of 155 shells; *Bittium reticulatum* (30%), *Hydrobia* sp. (8%), *Muticaria* sp. (6%), *C. acicula* (2%) Assemblages contained between 2 and 36 molluscs per sample, increasing towards the top of the zone; all were heavily fragmented and belonged to marine, brackish water and terrestrial environments	Again, the stony deposits could reflect vigorous flows in the *wied*, as indicated by the overwhelming presence of land snails at the base of this zone, including the erosion indicator/burrower *C. acicula*; the following increase in sand may perhaps be consistent with the approach of the shoreline, but land derived erosion continues to wash in open country and ubiquitous land snail species, including *C. acicula*; perhaps as a result of aridification, only one leaf litter species was found in the entire zone; the continuation of *O. myosotis* and *Hydrobia* sp. points to a marginal lagoon/saltmarsh environment, which gradually shows stronger marine influence towards the top of this zone
C3	228–178	1127–375 BC (3077–2325 BP)	Total of 52 shells; *Bittium reticulatum* (33%), *Hydrobia* sp. (10%), *O. myosotis* (21%), *Muticaria* sp. (8%) Number of molluscs varies between 4 and 21 per sample, increasing irregularly to up to 17 shells per sample; most samples contained an admixture of marine, brackish water and land snail species, but one sample contained only land snails (at 193 cm); brackish water species were generally the least common	Coarse sand and stones continue to occur in this zone, again reflecting vigorous flows and possibly wave action with continuously rising sea levels, as also indicated by the increase in marine species like *Bittium* sp. *O. myosotis* features strongly at the base of this zone but then occurs only once again (at 185 cm); the persistence of *Hydrobia* sp. is consistent with a lagoonal environment; leaf litter species were only found once, at the base of the zone, probably as a result of inwash events; the other terrestrial species are consistent with open, exposed habitats, with *Muticaria* sp. and *T. spratti* suggesting inwash from the rocky sides of the *wied*
C4	178–115	566 BC–AD 241 (2516–1709 BP)	Total of 493 shells; *Bittium reticulatum* (44%), *Hydrobia* sp. (9%), *Muticaria* sp. (3%), *T. subcylindrica* (2%) Increasing dominance of marine molluscs in the mixed assemblages, reaching more than 75% from 161 cm upwards; brackish water species are found in low numbers in most samples; the number of land snails varies greatly	Several stony deposits, possibly consistent with the approach of the open shoreline with rising sea levels, as also indicated by the overwhelmingly marine taxa; also here, the persistence of *Hydrobia* sp. in this zone points to a lagoonal environment; the marine taxa are more diverse and numerous than in WŻ1, but also here they were all very small and associated with sandy/muddy bottoms and marine algae, possibly washing into the inlet; leaf litter species were found only once in the entire zone (*O. hydatinus*), while the open country species persisted throughout, as did species associated with very light vegetation. *C. acicula* at the top may be the result of recent burrowing

4.5.1. Marsaxlokk (MX1)[6]

The coring site was located on the northern shore in the inner harbour in Marsaxlokk Bay on a field at a distance of less than 100 m from the sea. The multi-period site of Tas-Silġ, occupied between the Neolithic Temple Period and Late Roman era is located less than 1 km uphill to the north (Bonanno & Vella 2015). The coring site is 1.25 m above present day sea-level. The Marsaxlokk 1 core (MX1) had a total reported depth of 3.86 m and consisted of four core-tubes.

The basal date is likely to be *in situ*, but the dates above and the pottery fragment recovered from the core are most certainly recycled. The Bayesian model is used for the interpretation of the various zones, which show one major inwash event (MX1-C), while the rest of the core shows a fairly steady small-scale sedimentation since the early first millennium AD (Fig. 4.1; Table 4.2).

The land snail assemblages in this core from Marsaxlokk showed a predominantly open country (garrigue and karstland) environment. Only one leaf litter species was present (*Xerotricha* sp.), and it occurred only twice, possibly indicating the past occurrence of shrubs. The majority of land snails belonged to the ubiquitous group, which may reflect a disturbed environment.

The brown sediments which directly overlay the bedrock are indicative of a buried B horizon of a well developed palaeosol (see Chapter 5), in which any land snails have weathered out long ago and only fragments of marine species survived. Given its position below present day sea level and the fact that marine-linked quiet water sedimentation occurred one metre further up, it is possible that there may have been fairly recent tectonic displacement here.

The section shows strong inwash of terrestrial material, but there are also signs for gentle, fairly continuous sedimentation close to a shoreline behind a bay-bar, in some kind of shallow lagoon with a marine connection or in a shallow embayment only slightly connected with the open sea.

4.5.2. Wied Żembaq (WŻ)

Two cores were retrieved at a location close to St George's Bay in Birżebbuġa in a flat area at the mouth of Wied Żembaq. The coring site is 1.05 m above present day sea level and the distance from the present shoreline is around 250 m. Close by, on a hill overlooking the coring location, are the Neolithic remains of Borġ in-Nadur and remnants of a Bronze Age settlement and wall (Tanasi & Vella 2011a & b).

The Wied Żembaq 1 core (WŻ1) extended to a depth of 5.48 m and consisted of five tubes, but bedrock was not reached. The Wied Żembaq 2 core (WŻ2) was taken at a distance of around 5 m from WŻ1 and extended to 5.25 m, also without reaching bedrock. The Bayesian model provides the date frames for both cores, shown in Figure 4.2 and Tables 4.3 and 4.4.

Similarities can be observed between the coring sites WŻ1 and WŻ2, because of their proximity. Differences in the zones in both cores may be because the *thalweg* (i.e. the main channel) is quite narrow and meandering, with the meanders migrating through time. This may have led to a cut-and-fill stratification, where WZ2 would have missed the channel deposits containing *Pseudamnicola moussonii* in Zone A, but received an increased stone inwash in Zone C. Table 4.5 compares and combines the data of both cores.

4.5.2.1. Conclusion: Wied Żembaq

The cores cover a good part of the Temple Period from around 3500 cal. BC and following periods up to cal. AD 115–829 (see Tables 2.3 & 2.4). They revealed several changes in the palaeogeography and palaeoenvironment. It appears that the relative sea level was still rising at Wied Żembaq, possibly because of local tectonics, but it is also possible that what can be seen as marine deepening and shallowing may reflect meandering of the channel and coastal change rather than sea level oscillations.

Molluscs in Zone A, dated from *c*. 3500 to *c*. 2300 cal. BC in WŻ1 and WŻ2 (up to *c*. 2200 cal. BC), indicated that during the Temple Period, the landscape in Wied Żembaq was dry and open, despite the presence of a perennial, running freshwater stream, as indicated by *P. moussonii*. Evidence for this stream occurred only sporadically in zones A1 and A2 of WŻ1 and A1 of WŻ2, but was clearly manifest in A4 of WŻ1, indicating a distinctive humidity event that possibly led to the establishment of shrubs or dense vegetation further upstream. It appears from WŻ1 that the end of this zone (2300±200 cal. BC) may reflect events at the end of the Temple Period. Immediately following the humidity event, a progressive breakdown of the landscape can be observed in both cores (Zone B), where now leaf litter shells (i.e. *Lauria cylindracea*) were washed into the valley as a result of landscape degradation. It is unclear whether this breakdown is a result of anthropogenic pressure or severe aridification or a combination of the two that led to the end of the Temple Period, as evidence for the freshwater stream did not reappear after this date. Erosion events, so strong that even stones and the burrower *Cecilioides acicula* were moved in the mud-flows, progressively accelerated to the end of this zone at about 1543±172 cal. BC (see Table 2.2) in the Bronze Age. Some sort of stabilization can be observed in Zone C in both cores, where however freshwater species remain absent, leaf

Table 4.5. *Integration of molluscan zones from Wied Żembaq cores 1 and 2.*

Date/Period cal. BC/AD (2σ)	Zone	Description	Environment
c. 3500–2300 BC in WŻ1 *c.* 3200–2200 BC in WŻ2 Temple Period to Bronze Age	A	Both cores show broad similarities in the particle size distribution and molluscan assemblages, though WŻ2 has the occurrence of *P. moussonii* only once, towards the base of this zone; sediments datable to the end of the Temple Period were only found in WŻ1	Dry and open landscape, lightly vegetated steppe or garrigue; denser vegetation probably further upstream; shallowing of lagoon and expansion of saltmarsh; presence of a perennial, running freshwater stream
c. 2300–1500 BC in WŻ1 *c.* 2200–1500 BC in WŻ2	B	Strong similarities with regards to molluscan assemblages and particle size distribution	Aridification of the landscape, disappearance of freshwater stream; breakdown of denser vegetation, increase in erosion; sharp decline in saltmarsh species, probably due to high influx of land-derived inwash of eroded sediment
c. 1500 BC–AD 500 in WŻ1 and WŻ2	C	Broad similarity in the molluscan assemblages but differences in the particle size distribution, probably due to a meandering of the channel	Reappearance of saltmarsh environment, which however again progressively declines as lagoonal/marine species increase due to rising sea level; continuous aridification leads to sharp decrease in dense vegetation, open country/karstland and light vegetation dominate

litter species were scarce and the open country and ubiquitous species persisted throughout, while marine influence grew steadily, marginalizing the saltmarsh.

4.5.3. Mġarr ix-Xini (MĠX)

The coring location was less than 100 m away from the present-day shoreline and in a level area towards the middle of an elongated alluvial plain at the mouth of Wied Mġarr ix-Xini that opens on the south-eastern coast of Gozo. The catchment area for the valley is approximately 4.5 sq. km. There are no Neolithic remains in the immediate vicinity, but rock-cut trenching pans and vats, thought to be late Punic or Roman, have been found close by.[7] The sediment core had a total reported length of 709 cm and extended from 0.34 to 7.43 m depth. It consisted of eleven core-tubes (see description in chapter on cores). The Bayesian model provides the date frame for the core and the molluscan zones are shown in Table 4.6.

4.5.3.1. Conclusion: Mġarr ix-Xini

The earliest sediments retained in this core were datable to the Punic period. Older sediments had not been preserved at this site. Although a large quantity of sediments was washed through fluvial action down the valley of Mġarr ix-Xini, evidence for a perennial freshwater stream was not found. It is possible that, as in Wied Żembaq, there may have been a stream in the more distant past, but run-off was already ephemeral by the time sedimentation started in the Punic period. The light vegetation and karstland of the area is evident from the land snail faunas. Only the very rare occurrences of leaf litter taxa suggest a little denser vegetation at times. Numerous strong storm events caused inwash of land snails and often fragmentary marine molluscs, together with coarse sand and gravel. These alternated with quieter phases characterized by fine-grained sediments and lagoonal faunas. The continuously varied stratigraphy mirrored the changing influences governing the site, with bay-bars forming and breaching repeatedly. Evidence for viticulture was found from the late Punic Period until a severe erosion event, probably around the third/fourth centuries AD, which may perhaps have destroyed the vineyard.

4.5.4. Marsa 2

The floodplain at Marsa, today largely covered by the Marsa Sports Grounds, lies at the base of the largest catchment in the Maltese Islands (43.8 sq. km) and is surrounded by numerous archaeological sites that testify human presence at least from the Ġgantija phase onwards (*c.* 3450–3200 cal. BC) (Fenech 2007). The core had been extracted by a mechanical corer in June 2002, prior to the building of a sports complex on the site at a distance of *c.* 200 m from the present shoreline, and at a spot 1.18 m above mean sea level. As this core was not part of the *FRAGSUS* coring programme, soil colours and additional information are in Appendix 3.[8]

The core had a total length of 9.4 m, which translated into 143 segments of 5 cm, divided in two halves. Problems were encountered when extracting the Marsa 2 core, caused by wet sandy sediments that could not be retained in the core and stones/boulders that caused gaps in the stratification.

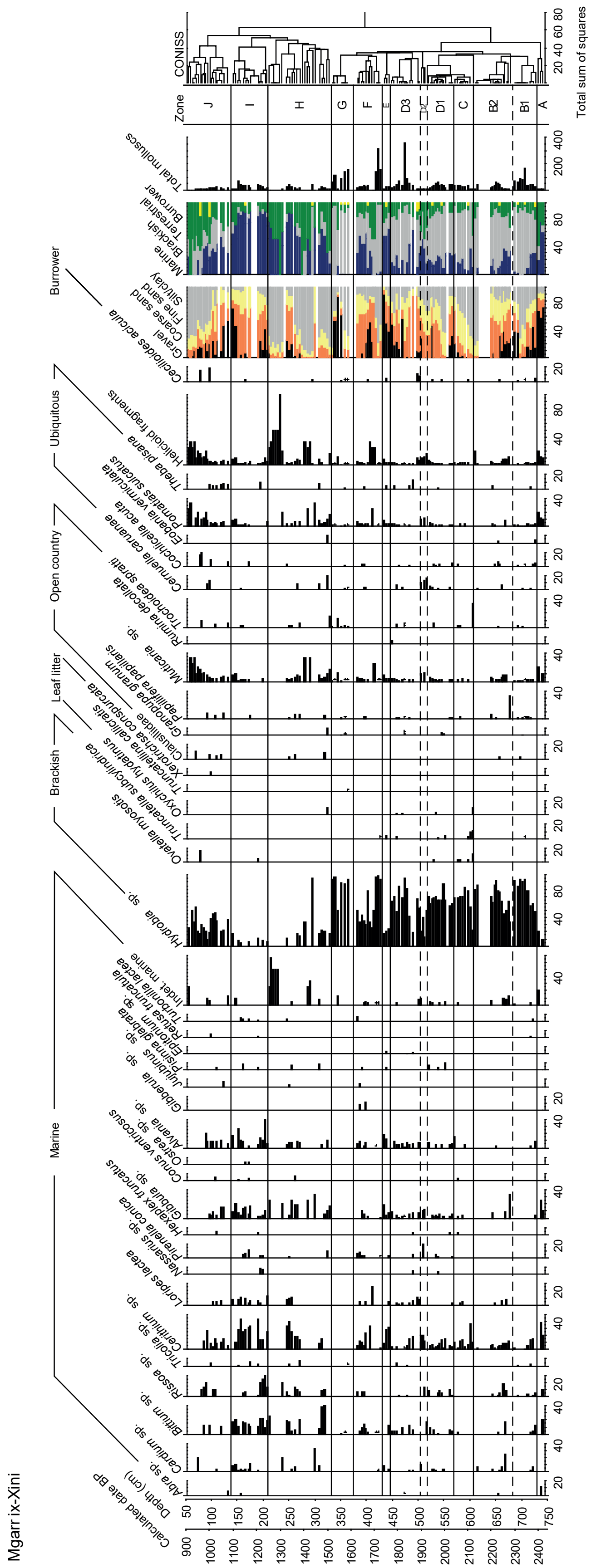

Figure 4.3. *Mġarr ix-Xini molluscan histogram (C.O. Hunt & K. Fenech).*

Table 4.6. *Molluscan zones for the Mġarr ix-Xini 1 core (MĠX1).*

Zone	Depth (cm)	Date ranges cal. BC/ AD (BP) for the start of each zone (2σ)	Molluscan assemblages	Environment
A	743–730	no date	Total of 23 shells, of which *Cerithium* sp. (22%), *Gibbula* sp. (14%), *Hydrobia* sp. (9%), *Muticaria* sp. (9%) Cracked bedrock interface with sand and mud, containing molluscs from marine, brackish water/lagoonal and terrestrial environments	Mixed marine environment, dominated by sandy bottoms (*Cerithium* sp.) with hard substrate close by (*Gibbula* sp.); the few land snail fragments washed in were mainly *Muticaria* sp., *P. sulcatus* and a few heliciid fragments, indicating a predominantly open, karstland environment with very little vegetation in the valley
B1	730–683	at 702 cm: 487–236 BC (2437–2186 BP)	Total of 610 shells, of which *Hydrobia* sp. (85%), *Cerithium* sp. (3%), *Muticaria* sp. (1%) General fining up of sediments and increase in the overall number of molluscs, but an inwash with stones again at the top of the zone; land snails are present throughout, marine molluscs decrease while brackish water species increase considerably	Possible formation of a bay-bar may have led to increasingly brackish water conditions; a combination of gravel, land snails and marine molluscs at the base of this zone may point to a flood and storm event, with soil erosion indicated by the presence of the burrower *C. acicula*; the presence of grape seeds of *Vitis vinifera* attests viticultural activity in the vicinity, in a landscape that was predominantly open, with light vegetation and grassland, surrounded by karstland (*Muticaria* sp., *C. acuta, P. sulcatus*)
B2	683–607	448–194 BC (2398–2144 BP)	Total of 340 shells, of which *Hydrobia* sp. (75%), *Cerithium* sp. (4%), *Muticaria* sp. (3%) Stones with coarse sand dominate most of this zone, silt/clay at the top; marine molluscs in varying amounts were present in most samples, as were land snails; brackish water species were the most common	Continuation of brackish water conditions with lagoonal and marine influence; as in the previous zone, there appears to have been another fluvial flood event in combination with a wave-based storm event; the increase in marine diversity and coarse sand compared to the previous zone may be due to stronger wave action; the land snails, chiefly *Muticaria* sp. and *P. sulcatus*, indicate a predominantly open country/karstland with little vegetation and grassland; seeds of *Vitis vinifera* indicate the continuation of viticulture in the vicinity
C	607–568	288–24 BC (2238–1974 BP)	Total of 186 shells, of which *Hydrobia* sp. (72%), *Cerithium* sp. (10%), *O. myosotis* (2%), *Muticaria* sp. (2%) Number of shells decreased, possibly due to rapid sedimentation; silty brownish grey sediments at the base progressively getting lighter in colour and coarsening up to the top of the zone; increase in sand and stones is coupled with an increase in marine molluscs, while the land snail numbers remains relatively steady, but low	Possibly another storm event, where the waves would winnow finer material and once in suspension it would flow out to the sea as a gravity current and be lost to the site, as indicated by the coarsening-upward pattern; strong soil erosion is suggested by the burrower *C. acicula*; seeds of *Vitis vinifera* indicate continuation of viticulture in the vicinity; absence of lagoonal species, but good presence of the infra-littoral sand species *Cerithium* sp. throughout in a brackish water environment dominated by *Hydrobia* sp.; presence of a saltmarsh is indicated by *O. myosotis* and the coastal species *T. subcylindrica*; first appearance of the leaf litter species *O. hydatinus*. *Muticaria* sp. and *T. spratti* indicate continuation of open country/karstland conditions, grassland is suggested by *C. acuta.*

Table 4.6 *(cont.)*.

Zone	Depth (cm)	Date ranges cal. BC/AD (BP) for the start of each zone (2σ)	Molluscan assemblages	Environment
D1	568–518	204 BC–AD 59 (2154–1891 BP)	Total of 440 shells, of which *Hydrobia* sp. (66%), *Cerithium* sp. (6%), *Muticaria* sp. (2%), *C. acicula* (2%) Increase in the number of shells found; sediments were light grey and very sandy, coarsening upwards; stones were found in only one sample, probably as a result of a fluvial inwash event, as indicated by the high number of land snails and the burrower *C. acicula*; one sample at the base of the zone contained no land snails, all other samples had a mixture of marine, brackish water and land snails, with the brackish water species *Hydrobia* sp. dominating the assemblages	Predominantly a brackish water environment with growing lagoonal/ marine influence; decreased presence of saltmarsh species *O. myosotis* and coastal *T. subcylindrica*; larger diversity of land snails, indicating a mosaic of dense and light vegetation and persistence of open country/ karstland; severe terrestrial erosion is suggested by the burrower *C. acicula*
D2	518–504	98 BC–AD 168 (2048–1782 BP)	Total of 47 shells, of which *Hydrobia* sp. (40%), *Cerithium* sp. (11%), *Muticaria* sp. (4%) In this thin sandy zone, the brackish water *Hydrobia* sp. were a minority, a variety of land snails and marine molluscs dominated, suggesting another storm event	The marine molluscs washed onto the site came from sandy, lagoonal and rocky habitats, suggesting disturbed waters through wave action during a storm; *Hydrobia* sp. were present, but at much lower numbers than in the previous zones; no leaf litter species were found, the land snail assemblages consisted chiefly of the karstland species *Muticaria* sp. and the ubiquitous *C. caruanae* and *P. sulcatus.*
D3	504–447	67 BC–AD 197 (2017–1753 BP)	Total of 740 shells, of which *Hydrobia* sp. (79%), *Cerithium* sp. (3%), *Alvania* sp. (3%), *Muticaria* sp. (1%) Light grey sandy sediments, often with stones; sediments initially fining upwards, indicating quieter times of sediment input but then coarsen upwards again, suggesting an event; amounts of shells per sample greatly varied between 9 and 353 individuals; all assemblages contained marine, brackish water and land snails	Mixed assemblage of marine species from lagoonal, sandy and rocky habitats suggest strong wave-induced movement at the seafloor during windstorms; these storms were likely combined with heavy rainfall as indicated by the presence of land snails throughout, including the occurrence of the burrower *C. acicula*; the land snail spectrum was very similar to zone D1, indicating little change in the environment; brackish water conditions persisted, but there was no longer evidence of a saltmarsh
E	447–430	AD 59–318 (1891–1632 BP)	Total of 60 shells, of which *Hydrobia* sp. (22%), *Cerithium* sp. (27%), *Gibbula* sp. (5%), *Muticaria* sp. (5%), *C. acicula* (2%) Mixed assemblages in all samples, very high stone and sand content	Due to the high stone and sand content, the mud snail *Hydrobia* sp. was no longer dominant; the stone influx may be due to a fluvial inwash event, as indicated by the presence of land snails, notably the karstland *Muticaria* sp. and the ubiquitous *P. sulcatus*, the latter being associated with soils, as is the burrower *C. acicula*; as before, the inwash event may have been in combination with a severe storm, which through wave action would have washed the proportionally high number of marine mollsucs, mainly associated with sand and rocky bottoms onto the site; continuation of viticultural activity close by

Table 4.6 *(cont.)*.

Zone	Depth (cm)	Date ranges cal. BC/AD (BP) for the start of each zone (2σ)	Molluscan assemblages	Environment
F	430–375	AD 96–356 (1854–1594 BP)	Total of 782 shells, of which *Hydrobia* sp. (86%), *Cerithium* sp. (2%), *Muticaria* sp. (1%) Mixed assemblages throughout, but the base of this zone shows a strong dominance of the brackish water mudsnail *Hydrobia* sp.; a sudden increase of sand and stones is accompanied by a strong increase in marine and land snails	Initially the zone shows a fairly quiet brackish water environment with only very few marine molluscs and land snails being washed in, with *Hydrobia* sp. reaching more than 300 individuals in one sample (at 423 cm); the situation changes soon afterwards with a sudden influx of stones, coarse and fine sand, fining up to the end of this zone, but with silt/clay remaining reduced to around 10% only; during this episode, sand- and rock-associated marine molluscs are washed in, but the overall number of molluscs per sample decreases dramatically; the land snails contained no leaf litter-associated species and again reflect open country/karstland and lightly vegetated surroundings
G	375–333	AD 218–474 (1732–1476 BP)	Total of 569 shells, of which *Hydrobia* sp. (92%), *T. spratti* (2%), *Muticaria* sp. (1%), *C. acicula* (0.5%) Assemblages consisted chiefly of the brackish water *Hydrobia* sp. with little to no marine molluscan influx; initially, also the land snails were rare, but with the sudden inwash of stones and coarse sand, possibly during a predominantly fluvial event, their numbers increased	Possibly due to a heightened bay-bar, the marine influence is very little in this zone, which is characterized initially by brackish water sandy muds; *Hydrobia* sp. reaches the highest percentages in the core, indicating a fully blown brackish water environment; there was inwash of an array of land snails, predominantly open country/karstland species; grape seeds suggest that viticulture was still practised at this time; a storm event led to the inwash of limestone pebbles accompanied by open country/karstland species, and heavily fragmented marine molluscs
H	333–210	AD 313–566 (1637–1384 BP)	Total of 289 shells, of which *Hydrobia* sp. (22%), *Cerithium* sp. (15%), *B. reticulatum* (12%), *Muticaria* sp. (4%) Despite the length of this zone, the number of molluscs found was comparatively low, indicating dilution during rapid sedimentation; the molluscan assemblages are mixed, with a very strong marine and terrestrial input, considerably diminishing the brackish water influence, except at 296 cm, where for the last time a clear brackish water environment was detected	The land snails show that the terrestrial environment was highly open and exposed, throughout; there is no further evidence of viticulture being practised in the area; at the base of this zone, there is an increase in coarse and fine sand; this is coupled with an increase in marine shells and decrease in land snails, indicating strong marine influence; it is suggested that the severe event at the end of zone G may have led to the breakdown of the bay-bar, dramatically diminishing the brackish water body and increasing marine influence in the bay; the subsequent silt/clay unit was associated with a rise in *Hydrobia* sp. suggesting re-establishment of the brackish lagoon; coarsening sediments, which become predominantly stony, are then associated with a sharp decline in *Hydrobia* sp. and rise in marine molluscs; the final sediments in the zone are silt/clays, but contain mostly unidentifiable fragments of land and marine shells, while brackish water species are no longer present

Table 4.6 *(cont.).*

Zone	Depth (cm)	Date ranges cal. BC/ AD (BP) for the start of each zone (2σ)	Molluscan assemblages	Environment
I	210–138	AD 598–818 (1352–1132 BP)	Total of 391 shells, of which *Cerithium* sp. (28%), *B. reticulatum* (13%), *Hydrobia* sp. (5%), *Muticaria* sp. (2%) The sediments consisted mainly of marine sands, at times with stones and throughout with very little silt/clay; this was reflected in the molluscan assemblages, which were dominated by an array of marine molluscs from all kinds of substrates, with sand dominating	Predominantly a sandy marine environment, where the influx of stones and silt/clay appears to be mainly land-derived through fluvial events, as indicated by the presence of land snails; the occurrence of *O. myosotis* points to a saltmarsh in the vicinity of the severely diminished brackish water body as indicated by the low numbers of *Hydrobia* sp. found; land snails occurred in low numbers in all samples, once also including the burrower *C. acicula*, indicating land-derived erosion
J	138–50	AD 753–982 (1197–968 BP)	Total of 217 shells, of which *Hydrobia* sp. (32%), *Cerithium* sp. (8%), *Alvania* sp. 5%, *Muticaria* sp. (7%) Most of the molluscan assemblages contained marine, brackish water and land snail species, in low numbers; the number of marine molluscs decrease as the presence of land snails increases; the silting-up of the bay is also indicated by the increase in silt/clay and changing sediment colour to light brown	The last zone shows the silting up of the bay and turning it from marine to terrestrial through increased land-derived erosion; marine wave action plays a diminishing role, brackish-water shells also occur, but in very low numbers; here *C. acicula* may be intrusive as a burrower; the land snails continue to attest the open country/karstland of the previous zones; leaf litter is scarce, there is very light vegetation and grassland as suggested by e.g. *T. pisana* and *C. acuta*

As there was a lack of suitable material for dating in the lower three metres of the core, the first date obtained was at 6.17 m, placing that part of the core into the end of the Late Bronze Age. The Bayesian model was adopted to calculate the age against the depth of the core from this date onwards. With the help of the CONISS analysis, the core could be sub-divided into five major zones (Fig. 2.4; Table 2.7).

4.5.4.1. Conclusion: Marsa

Despite the 9.4 m length of the core, the sediments that presumably belonged to prehistory could not be securely dated and hardly contained any land snails. As such, it is difficult to draw any conclusions about the prehistoric environment other than 'open and lightly vegetated'.

The area of the coring site was formerly subjected to numerous high-energy events, which included land-derived flooding, during which vast amounts of sediments that often contained stones were carried into the harbour. An unknown amount of these deposited sediments may have then been subjected to further erosion. Wave-action during windstorm events also could have led to the removal and redeposition of marine sediments at the coring site.

Nonetheless, the eventful stratigraphy also showed that in the past there was an array of freshwater bodies in the vicinity: a perennial running freshwater stream, slow moving water/ponds and associated wetlands at least since the end of the Late Bronze Age onwards, until the harbour silted up. During the era of the Knights of St John, the area was described as a swamp, and the water of the freshwater stream was collected in a reservoir (Abela 1647).

The terrestrial environment throughout appeared to be predominantly open, with some light vegetation. Evidence for dense vegetation/scrub was found from the end of the Late Bronze Age onwards, but could have, like the freshwater environments, existed before as these shells were found in the same levels. The noted reduction of the freshwater environments in Zone D also had an impact on the leaf litter snails and it is possible that this may have been because of progressive aridification. The lack of vegetation cover may have led to more intense erosion, which then eventually led to the silting up of the harbour, gradually turning it eventually into a terrestrial environment.

4.5.5. Salina Deep Core

The coring site lies at the end of the Burmarrad Plain, a large alluvial plain at the base of the second largest catchment in Malta, with an area of 34.8 sq. km. Numerous archaeological remains, including two Neolithic temples in the vicinity, date back to the Temple

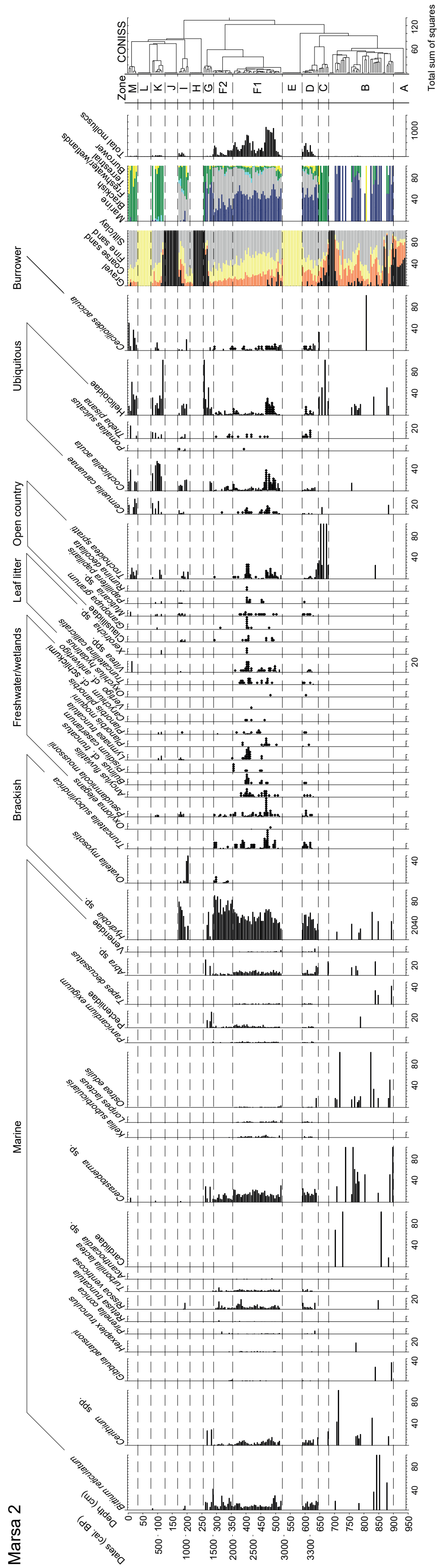

Figure 4.4. *Marsa 2 molluscan histogram (C.O. Hunt & K. Fenech).*

Table 4.7. *Molluscan zones for the Marsa 2 core (MC2).*

Zone MC2-	Depth (cm)	Date ranges cal. BC/ AD (BP) for the start of each zone (2σ)	Molluscan assemblages	Environment
A	943–900	no date	Bedrock and sterile sediments at the base	
B	900–680	no date	Total of 97 shells, of which *Cerastoderma* sp. 24%, *Ostrea* sp. 13%, *Cerithium* sp. 11%, *Hydrobia* sp. 9% and *C. acicula* 2% Despite the length of the zone, only a few molluscs were found, most of them heavily fragmented; the molluscan assemblages were predominantly marine, but often mixed with a few brackish water and land snails	A marine environment is clearly suggested by the number and variety of marine molluscs found, indicating fluctuations between lagoonal (e.g. *Cerastoderma* sp.), marine (e.g. *B. reticulatum* and *Cerithium* sp.) and brackish water conditions (*Hydrobia* sp.); the predominantly sandy/gravelly sediments are likely gravity-flow deposits spreading out across the bottom of the harbour from floods in the catchment; the deposited sediments which included stones and boulders, at times also contained land snail fragments, while many samples were completely sterile, indicating rapid deposition, especially at the top of the zone; severe land-derived erosion is also indicated by the burrower *C. acicula*; the few land snails point to open country with light vegetation (*T. spratti* and *C. acuta*)
C	680–645	no date	Total of 22 shells, of which *T. spratti* 45%, *Cerithium* sp. 5%, *C. acicula* 5% Mainly land snail assemblages with only a few marine molluscs; high stone and coarse sand content, fining upwards	A sudden mass of land derived sediments and molluscs at the beginning of this zone suggest very strong erosion of open country soils into the harbour basin
D	645–590	at 617 cm: 1521–876 BC (3471–2826 BP)	Total of 2122 shells, of which *Hydrobia* sp. 41%, *Cerastoderma* sp. 15%, *B. reticulatum* 10%, *P. moussonii* 0.7 %, *T. spratti* 2%, *C. acicula* 2% The molluscan assemblages at the base consisted of a few land snails only, but gradually get mixed with marine, brackish water and freshwater molluscs, dramatically increasing the total number of shells per sample; only a few stones found, but sand increased to around 50%	Lagoonal and brackish water biota dominate again and increase strongly in number in muddy sandy sediment; severe soil erosion, however, continues as evidenced by the burrower *C. acicula*; an array of freshwater molluscs was also washed onto the site, indicating perennial running water (*P. moussonii)* as well as slow moving water, ponds (e.g. *Lymnaea* sp.), and wetlands (e.g. *C. schlickumi*) in the vicinity; the presence of dense vegetation is suggested by the leaf litter snails (e.g. *Vitrea* sp.)
E	590–523	1407–765 BC (3357–2715 BP)	The zone was missing due to wet sandy sediments	Likely rapid deposition of sandy sediments, possibly due to a very severe storm event
F1	523–355	1164–593 BC (3114–2543 BP)	Total of 15019 shells, of which *Hydrobia* sp. 43%, *Cerastoderma* sp. 14%, *B. reticulatum* 9%, *P. moussonii* 1%, *C. acuta* 2%, *C. acicula* 1% Molluscan assemblages are predominantly marine, with a very strong brackish water signature; freshwater molluscs and land snails occur throughout, the total number of shells per sample vary significantly throughout; some stones occurred towards the base, but the sandy muddy sediments broadly portray a fining upwards trend	The brackish water snail *Hydrobia* sp. was the most common species found, but marine and lagoonal influence remained noticeable; Strong soil erosion continued throughout this zone, as the burrower *C. acicula* was present throughout; the floodwaters also carried freshwater molluscs out of perennial freshwater bodies into the harbor; a stream, slow moving freshwater bodies, ponds and associated wetlands are indicated; the leaf litter snails suggest dense vegetation/scrub, while open country species were also washed in; the grassland species *C. acuta* was proportionally most common in the lower third of the zone but they occurred throughout alongside other Helicioids, indicating light vegetation

Table 4.7 *(cont.).*

Zone MC2-	Depth (cm)	Date ranges cal. BC/AD (BP) for the start of each zone (2σ)	Molluscan assemblages	Environment
F2	355–290	292 BC–AD 215 (2242–1735 BP)	Total of 2105 shells, of which *Hydrobia* sp. 67%, *Cerastoderma* sp. 6%, *B. reticulatum* 12%, *P. moussonii* 0.04 %, *C. acuta* 2% Mixed molluscan assemblages throughout, predominantly brackish water, with waning marine influence; land snails occurred in all samples, the freshwater snail diversity was greatly diminished and the total number of shells per sample was lower than in the previous zone; the sediments were mainly silty clays that contained less sand than before, with the coarse sand content fining upwards	Dramatic change in the environment; mainly brackish water, as suggested by *Hydrobia* sp., with a saltmarsh close by (*O. myosotis*); marine and lagoonal influences appear less pronounced than in the previous zone; freshwater bodies and wetlands seem to have significantly diminished: only the perennial running freshwater *P. moussonii* was found in small numbers intermittently; a slow moving water/pond is only once suggested by *P. planorbis*; the reduction of the freshwater bodies may be due to anthropogenic interventions in the swampy plain or due to aridification; erosion continued to occur, but leaf litter species were no longer found, and even open country species were rare; the few ubiquitous species indicate light vegetation/grassland
G	290–255	AD 268–575 (1682–1375 BP)	Total of 120 shells, of which *Hydrobia* sp. 32 %, *Bittium reticulatum* 27%, *C. acuta* 3% and *C. acicula* 2% This zone marks the beginning of another event, coarsening up to a boulder in the next zone; the number of shells strongly decreased progressively, the uppermost sample of this zone only contained one shell; concurrently, the stone content increased dramatically	Predominantly marine environment with a strong brackish water influence, as suggested by the diminished number of *Hydrobia* sp.; no freshwater or wetland shells were found in this zone; the very few land snails are indicative of grassland (*C. acuta*) and light vegetation (Helicioid fragments); the erosion indicator *C. acicula* was found at the base of the zone, which, coupled with the increase in the stone content, marked yet another severe erosion event
H	255–210	AD 490–775 (1460–1175 BP)	No shell content; this unit consists of a boulder	The boulder probably reflects a storm
I	210–168	AD 701–1047 (1249–903 BP)	Total of 449 shells, of which *Hydrobia* sp. 53%, *P. moussonii* 5%, *C. acuta* 8%, *T. spratti* 4% The assemblages were mixed, although marine molluscs occur only once; brackish water species generally dominated, land snails were found in all samples, freshwater shell occurred occasionally; the sediments were coarsening up towards the top of the zone	A saltmarsh seems to have occurred briefly at the base of this zone, indicated by *O. myosotis*; brackish water environments then became established; a running perennial freshwater stream and slow moving water are indicated nearby; dense vegetation is suggested once by *Vitrea* sp.: the other land snails indicate open country/garrigue (e.g. *T. spratti*), light vegetation and grassland is suggested by the ubiquitous species and *C. acuta;* the presence of the burrower *C. acicula* in these waterlain deposits points to severe soil erosion
J	168–125	AD 917–1266 (1033–684 BP)	No shell content; this unit consists of a boulder	The boulder probably reflects a storm
K	125–77	AD 1148–1496 (802–454 BP)	Total of 203 shells, of which *C. acuta* 42%, *C. caruanae* 10%, *T. spratti* 4%, *P. moussonii* 2%, *Lymnaea* sp. 2% The assemblages above the second stone contained no marine or brackish water species; a few freshwater molluscs were interspersed with the land snails	The former brackish water environment has now turned into a terrestrial one – the assemblages contained only land snails and a few freshwater snails; apart from this change, the shells found indicate similar terrestrial and freshwater environments as in zone I; dense vegetation in the vicinity is suggested by the presence of *Xerotricha* sp. *C. acicula,* formerly an indicator of erosion, may now be authochtonous; there is no evidence for a saltmarsh
L	77–33	AD 1427–1717 (523–233 BP)	The sediments were wet and sandy and could not be retrieved by the corer	Continuation of silting up of the former harbour

Table 4.7 *(cont.).*

Zone MC2-	Depth (cm)	Date ranges cal. BC/ AD (BP) for the start of each zone (2σ)	Molluscan assemblages	Environment
M	33–0	AD 1699–1901 (251–49 BP)	Total of 70 shells, of which *C. acuta* 17%, *C. caruanae* 16% *T. spratti* 10%, *Vitrea* spp. 1% The assemblages exclusively contained land snails; the sediments contained a small stone only once, and generally showed a stable sand/silt/ clay content	The zone shows a terrestrial environment, which no longer had a notable freshwater influence, possibly as a result to anthropogenic action as the swamps had been drained and the freshwater source diverted to a reservoir (Abela 1674); the land snails point to similar environments as before, with dense vegetation in the vicinity (*Vitrea* spp.), open country (*T. spratti*), grassland (*C. acuta*) and light vegetation (*C. caruanae*); the presence of the burrower *C. acicula* may here be intrusive and not the result of erosion events

Period (Evans 1971). The Salina Deep Core (SDC) was extracted in January 2014 from beside the sea water channel (Is-Sukkursu) by the Salina salt pans using a mechanical corer. The core reached an overall depth of 28.5 m, but as a result of loss of material in the first 11 m while coring, caused by hydro-collapse of wet and sandy sediments, only material from 11 m downwards could be analysed (see Chapter 2). The segments of core studied varied in length between 3 and 13 cm. Freshwater and land snails were identified and counted (Fig. 4.5; Table 4.8). Marine and brackish water species were also identified and counted, but as their species diversity and abundance was disproportionately larger than the non-marine molluscan assemblages, they were plotted separately (Fig. 4.6; Table 4.8).

The Bayesian model provides the date range for this core from about 8000 to 2000 cal. BC (see Table 2.2). With the help of the CONISS analysis, the non-marine molluscs in the core could be sub-divided into twelve zones.

4.5.5.1. Conclusion: Salina Deep Core

A high sedimentation rate affected the area since at least *c*. 6000 cal. BC. In the space of 1500 years alone, nearly 12 m of sediments filled the sea water channel (Is-Sukkursu), although the actual sedimentation is likely to have occurred through severe storm episodes rather than at a steady pace, as indicated by the presence of the burrowing snail *C. acicula*. From earliest prehistoric times to at least 2000 cal. BC, there was ample perennial freshwater in the plain, forming slow moving water bodies and perhaps ponds, with associated wetland vegetation (Fig. 4.6; Table 4.9), as is indicated by the aquatic freshwater taxa. The availability of freshwater may have encouraged dense vegetation, allowing the leaf litter snail species to form a prominent group in this analysis, but open country/karstland species also occurred throughout.

The marine taxa present in the lowest parts of the core are in terrestrial sediments of probable Late Pleistocene age. These assemblages are thus very likely to be recycled. The CONISS clustering groups some of these with the basal assemblages of the Holocene marine transgression. This is perhaps suggestive that the marine environments in which these molluscs lived during previous temperate phases were very similar to those during the initial stages of the Holocene transgression, with turbid, turbulent waters, perhaps of slightly abnormal salinity.

As the marine transgression continued, the Salina Inlet rapidly achieved normal marine salinities. Two mildly eutrophic phases, marked by fairly restricted faunas with high *Corbula gibba*, are apparent early in the transgression, during the base of zone C and during zone E. *C. gibba* is able to flourish in oxygen-poor waters and is thus regarded as a marker for eutrophication. In the deep sea, for instance in the Adriatic (e.g. Siani *et al*. 2000) the S1 Sapropel (a layer highly organic mud formed as a result of widespread eutrophication) is contemporary with the second and more marked of these phases of eutrophication, thus suggesting that Malta was affected by an event of regional significance. These events in the Salina borehole are contemporary with pollen diagram phases marked by high *Pistacia* scrub and interpreted as indicative of periods of higher rainfall at about 6700–6600, 6300–6200, 4300–4100 and 3400–2800 cal. BC (see Fig. 3.3). It is tentatively suggested that leaching during these phases led to nutrient enrichment and thus eutrophication in the confined waters of the Salina Inlet and more widely throughout the central Mediterranean.

A further phase marked by low diversity and high *C. gibba* and suggestive of eutrophication is present in zone H, at 22 m. This coincides with the first appearance of cereal pollen and coprophilous fungal spores. It can therefore be suggested that eutrophication

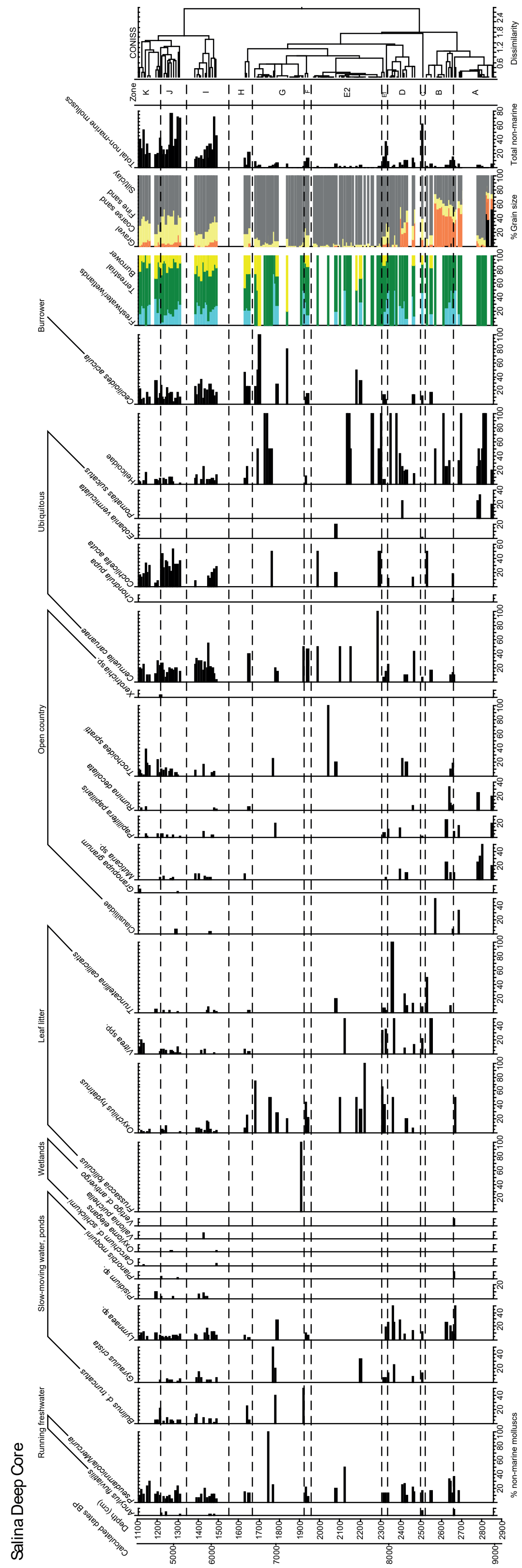

Figure 4.5. *Salina Deep Core molluscan histogram (C.O. Hunt & K. Fenech).*

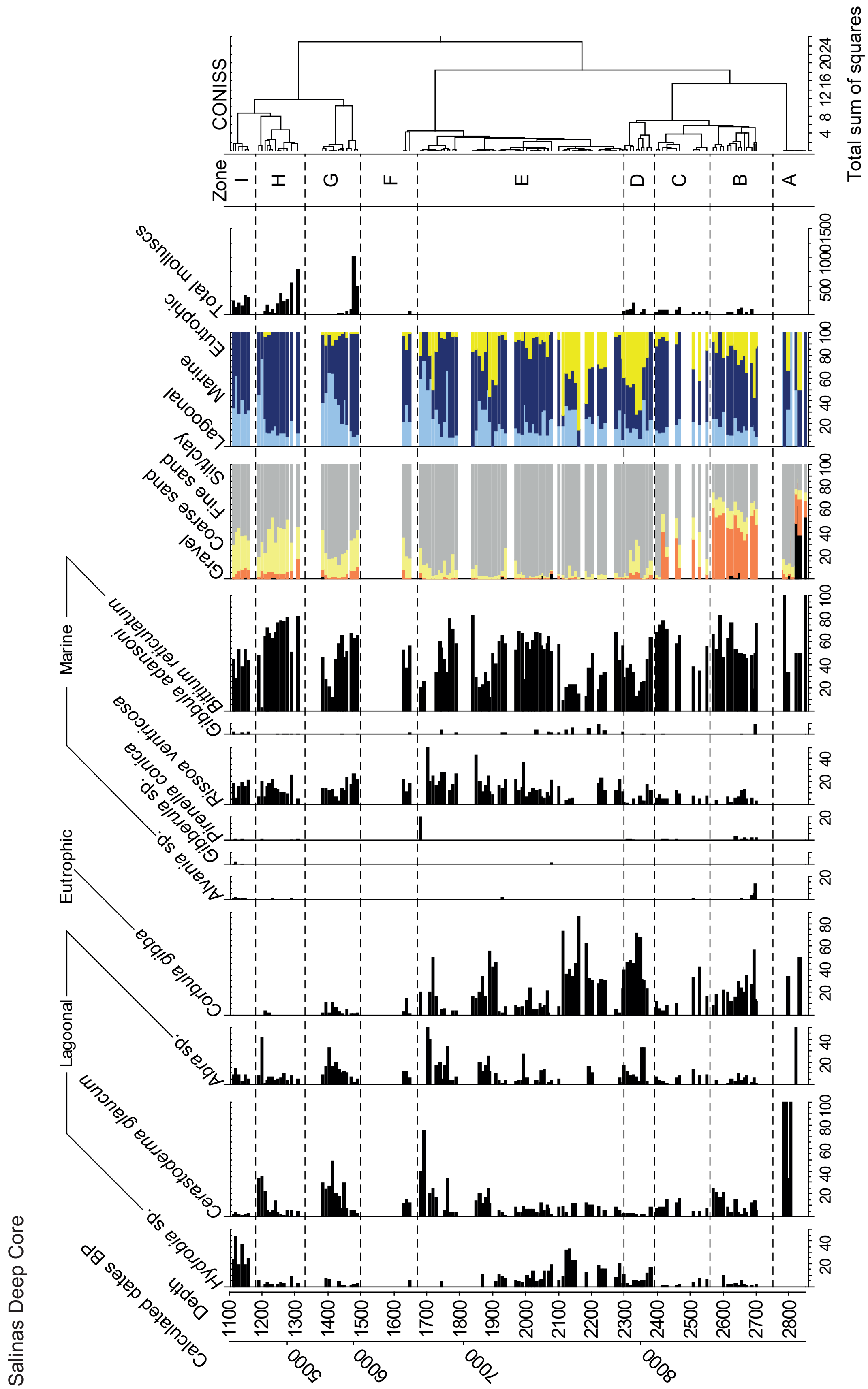

Figure 4.6. *Marine molluscan histogram for the Salina Deep Core (C.O. Hunt & K. Fenech).*

Table 4.8. *The non-marine molluscan zones for the Salina Deep Core.*

Zone	Depth (cm)	Date ranges cal. BC/AD (BP) for the start of each zone (2σ)	Molluscan assemblages	Environment
A	2850–2680	7737–6811 BC (9687–8761 BP)	Among 2183 marine and brackish water molluscs, a total of 39 freshwater and land snails, of which *P. moussonii* 15%, *Muticaria* sp. 15%, *P. sulcatus* 9%, *Lymnaea* sp. 6%, *O. hydatinus* 3% Assemblages consisted of only land snail fragments at the base of the zone; freshwater shells were found from 2690 cm onwards, together with land snails; the sediments at the base were initially very stony, then predominantly silty/clayey and then very sandy at the top of the zone	Basal part possibly belongs to the Late Pleistocene and includes recycled marine and possibly non-marine molluscs; marine Holocene starting at around 2696 cm; predominantly an open country/ karstland environment (*Muticaria* sp.) with very light vegetation (Helicioidae); Evidence of running freshwater stream (*P. moussonii*) and shortly after of shallow pond (*Lymnaea* sp.) and associated wetlands from *c.* 9000 BP onwards; concurrently, appearance of denser vegetation/scrub (*O. hydatinus*)
B	2680–2518	6925–6494 BC (8875–8444 BP)	Among 6267 marine and brackish water molluscs, a total of 44 freshwater and land snails, of which *P. moussonii* 16%, *Lymnaea* sp. 11%, *Vitrea* spp. 9%, *T. spratti* 9%, *C. acuta* 9% and *C. acicula* 2% Several samples devoid of land- and freshwater shells, especially in samples that contained more than 70% of sand, indicating marine events, particularly in the upper half of the zone	Presence of running freshwater stream (*P. moussonii*) and shallow pool with poor conditions (*Lymnaea* sp.), as well as grassland (*C. acuta*), open country/ karstland and garrigue (*T. spratti*) particularly in the lower part of the zone; no evidence for wetlands throughout; the upper part suggests a breakdown of the dense vegetation, where leaf litter species (*Vitrea* sp.) were also washed onto the site; severe soil erosion is suggested by *C. acicula* in the upper part of the zone
C	2518–2500	6502–6146 BC (8452–8096 BP)	Among 664 marine and brackish water molluscs, a total of 63 freshwater and land snails, of which *Vitrea* sp. 22%, *P. moussonii* 16%, *Lymnaea* sp. 13%, *C. acicula* 13% and *C. caruanae* 6% Sharp increase in the number of shells found; silty/clayey sediment was mixed with substantial amount of fine sand	Strong erosion washed in a large number of shells, indicating a fast running freshwater stream (*P. moussonii* and *A. fluviatis*), slow moving water/pond rich in vegetation (*Lymnaea* sp. and *G. crista*), dense vegetation (*Vitrea* sp.), as well as open country and patches of light vegetation (*C. caruanae*), but again, and hereafter, no evidence for wetlands
D	2500–2335	6468–6114 BC (8418–8064 BP)	Among a total of 7963 marine and brackish water molluscs, 70 freshwater and land snails, of which *P. moussonii* 14%, *Lymnaea* sp. 13%, *T. callicratis* 10%, *C. caruanae* 10%, *T. spratti* 4% and *C. acicula* 4% Decrease in the number of shells found; silty sediments are initially mixed with a lot of sand, but towards the top of the zone predominantly silty/clayey	Strong land-derived erosion at the base of the zone; persistence of freshwater bodies but at the top of the zone no more evidence for running freshwater stream, possibly as a result of aridification; increase in the percentage of leaf litter snails, possibly as a result of breakdown of dense vegetation; open country (*T. spratti*) and patches of grassland with light vegetation in the vicinity
E1	2335–2305	6187–6926 BC (8137–7876 BP)	Among a total of 4448 marine and brackish water aolluscs, 52 freshwater and land snails, of which *Vitrea* spp. 25%, *P. moussonii* 13%, *Lymnaea* sp. 13%, *O. hydatinus* 11%, *C. caruanae* 11% and *C. acicula* 10% Marked increase in the number of shells; sediments contained notably more sand than at the end of the previous zone	Severe soil erosion (*C. acicula*), resurgence of freshwater stream (*P. moussonii*) and continuation of vegetated slow-moving water/pond (*Lymnaea* sp. and *G. crista*); environment similar to the previous zone

Table 4.8 *(cont.).*

Zone	Depth (cm)	Date ranges cal. BC/AD (BP) for the start of each zone (2σ)	Molluscan assemblages	Environment
E2	2305–1955	6123–5891 BC (8073–7841 BP)	Among 2992 marine and brackish water molluscs, a total of 30 freshwater and land snails, of which *O. hydatinus* 20%, *C. caruanae* 14%, *C. acuta* 10%, *P. moussonii* 7% and *C. acicula* 7% Sharp decrease in the number of molluscs, with many samples containing no shells; sediments were very clayey with little fine sand	Massive land-derived erosion (*C. acicula*), liberating leaf litter taxa as well as open country and taxa associated with light vegetation; paucity of shells found is likely to be due to the very rapid sedimentation
F	1955–1925	5609–5142 BC (7559–7362 BP)	Among 162 marine and brackish water molluscs, a total of 22 freshwater and land snails, of which *O. hydatinus* 32%, *C. caruanae* 27%, *P. moussonii* 14%, *C. acicula* 14% and *Lymnaea* sp. 9% Short zone, where the land-derived inwash contained an increase in fine sand and shells	Highest proportion on non-marine shells possibly due to another severe land-derived erosion event (*C. acicula*), this time accompanied by an increase in fine sand after perhaps a brief respite which could have allowed the environment and snail populations to recover; environment appears to be similar to the previous zone, with a running freshwater stream (*P. moussonii*), a pond (*Lymnaea* sp.), some dense vegetation (*O. hydatinus*) and light vegetation (*C. caruanae*)
G	1925–1670	5583–5380 BC (7533–7330 BP)	Among 650 marine and brackish water molluscs, a total of 43 freshwater and land snails, of which *C. acicula* 28%, *P. moussonii* 25%, *O. hydatinus* 23%, *B.* cf. *truncatus* 7%, *T. spratti* 2% and *C. acuta* 2% Relatively fewer shells found, with some samples containing no non-marine shells at all; amount of fine sand varied, but sediments were predominantly very silty/clayey	Massive erosion (*C. acicula*), now possibly as a result of early agriculture, which would have led to a breakdown of the vegetation, allowing leaf litter and other taxa to be liberated and carried into the inlet; fewer taxa would have arrived once the stores in the soil had been exhausted; as in Zone E2, intermittent evidence of permanent freshwater bodies (*P. moussonii*, *G. crista*); appearance of *B.* cf. *truncatus*, indicative of transient, patchily distributed ponds, possibly as a result of the ongoing erosion
H	1670–1550	5256–4909 BC (7206–6859 BP)	Among 790 marine and brackish water molluscs, a total of 40 freshwater and land snails, of which *C. acicula* 33%, *C. caruanae* 23%, *P. moussonii* 7%, *Lymnaea* sp. 3% and *Vitrea* spp. 3% Short zone, with a general increase in the number of shells; predominantly silty/clayey sediments with an increase in sand compared with the previous zone	Even more massive erosion (*C. acicula*), possibly fluctuating hydrology levels (*P. moussoni* and *Lymnaea* sp. once replaced by *B.* cf. *truncatus*); more leaf litter species released, perhaps due to a renewed breakdown of the vegetation
I	1550–1330	4805–4306 BC (6755–6256 BP)	Among 20845 marine and brackish water molluscs, a total of 316 freshwater and land snails, of which *C. acicula* 19%, *C. caruanae* 19%, *C. acuta* 14%, *P. moussonii* 8% and *Lymnaea* sp. 8% Increase in the number of shells, possibly due to intermittent periods of stabilizing environmental/climatic conditions, although erosion still continued unabated; samples initially contained up to 50% of sand, fining upwards to around 25%	Continuous erosion with marine and terrestrial inwash events (*C. acicula*), increase in erosion of grassland (*C. acuta*), open country/karstland and areas with dense and light vegetation (*O. hydatinus* and *C. caruanae*); presence of fast running freshwater (*P. moussonii* and *A. fluviatis*), ponds rich in vegetation (*Lymnaea* sp. and *G. crista*) and reappearance of wetlands

Table 4.8 *(cont.).*

Zone	Depth (cm)	Date ranges cal. BC/AD (BP) for the start of each zone (2σ)	Molluscan assemblages	Environment
J	1330–1213	3866–3038 BC (5816–4988 BP)	Among 33124 marine and brackish water molluscs, a total of 443 freshwater and land snails, of which *C. acuta* 32%, *C. acicula* 14%, *P. moussonii* 10%, *Lymnaea* sp. 6% and *Vitrea* spp. 5% Increase in the amount of non-marine molluscs, reaching a maximum of 78 shells per sample; sediments are silty/clayey with a high sand content (up to 50%)	Evidence of massive erosion and terrestrial inwash throughout (*C. acicula*), mainly eroding areas of grassland (*C. acuta*) and very light vegetation (*C. caruanae*); continuous presence of freshwater bodies, as in the previous zone, but no wetland species were found; leaf litter shells were still washed in, as were open country/karstland species, with a notable increase of the garrigue species *T. spratti*
K	1213–1100	3198–2435 BC (5148–4385 BP)	Among 19107 marine and brackish water molluscs, a total of 277 freshwater and land snails, of which *C. acuta* 16%, *C. acicula* 14%, *P. moussonii* 14%, *T. spratti* 10%, *Lymnaea* sp. 7%, and *Vitrea* spp. 5% Number of shells found comparatively similar to the variations in the previous zone; the sediments also contained a similar amount of sand, first increasing (coarsening up) and then decreasing (fining up)	Continuous evidence of strong terrestrial inwash and erosion (*C. acicula*); running freshwater stream still present (*P. moussonii*), but may have been reduced in size and flow strength as *A. fluviatis* is no longer found; disappearance of *B.* cf. *truncatus, G. crista, P. moquini* and *Pisidium* sp. may point to severe aridification and an impoverished pond environment, in which only *Lymnaea* sp. survived; the land snails found are very similar to the previous zone and as such show little change

Table 4.9. *Molluscan zones for the Salina Deep Core (SDC).*

Zone	Depth (cm)	Date ranges cal. BC (BP) for the start of each zone (2σ)	Molluscan assemblages	Environment
A	2850–2805	unknown	2183 marine and brackish water molluscs; very small, sometimes mono-specific, assemblages; taxa include *Cerastoderma glaucum, Abra* sp., *Corbula gibba, Bittium reticulatum*	Basal part of core is terrestrial, possibly of Late Pleistocene age, including recycled marine taxa
B	2805–2700	unknown	Very small assemblages dominated by Cardiidae, *C. glaucum, Acanthocardia* sp., *C gibba, B. reticulatum*	Basal part of zone is terrestrial, possibly of Late Pleistocene age, including recycled marine taxa; highest part is base of Holocene marine sequence, with a low-diversity assemblage characteristic of rather confined, turbid, turbulent environments of possibly slightly abnormal salinity; *B. reticulatum* suggests presence of marine vegetation
C	2700–2565	7008–6533 BC (8958–8483 BP)	Larger, higher-diversity assemblages, dominated by *B. reticulatum, C gibba, Cerastoderma* spp. and with lesser *Abra* sp. *Nassarius* sp, *Acanthocardium* sp., *Rissoa* sp. *Ostrea edulis, Cerithium* sp. *Kellia* spp. and *Hydrobia* spp.	Assemblages are consistent with a mosaic of environments including fine sand, gravel, rock, marine vegetation and normal marine salinities, with an input from brackish waters; high *C. gibba* in the basal part of the zone may suggest modest eutrophication
D	2565–2375	6601–6211 BC (8551–8161 BP)	Assemblages dominated by *B. reticulatum, C. gibba, Cerastoderma* spp. and with lesser *Parvicardium exigens*, *Abra* sp., *Acanthocardia* sp., *Rissoa* sp. and *Kellia* sp.	Assemblages suggest marine waters with a mosaic of substrates, including fine sand, gravel, rock, marine vegetation
E	2375–2300	6263–5971 BC (8213–7921 BP)	Fairly sizeable assemblages of moderate diversity, dominated by *C. gibba, Abra* sp., *B. reticulatum*, with lesser *Parvicardium* sp, *Retusa truncatula, Acanthocardia* sp., *Kellia* sp. *Hydrobia* sp.	Assemblages suggest quite turbid, eutrophic marine waters with limited marine plants and a waning connection to brackish waters

Table 4.9 *(cont.).*

Zone	Depth (cm)	Date ranges cal. BC (BP) for the start of each zone (2σ)	Molluscan assemblages	Environment
F	2300–2208	6115–5883 BC (8065–7833 BP)	Small, relatively low-diversity assemblages dominated by *B. reticulatum*, with some *Rissoa* sp., *C. gibba* and *Hydrobia* sp.	Assemblages are suggestive of marine waters with abundant marine plants and rocky and gravelly bottoms, and a connection to brackish, perhaps lagoonal waters
G	2208–2190	5990–5716 BC (7940–7666 BP)	Small, low-diversity assemblages dominated by *B. reticulatum* and *C. gibba*, with some Cardiidae and *Abra* sp.	The assemblages are suggestive of fairly eutrophic marine waters with muddy and gravelly bottoms and abundant marine vegetation
H	2190–2110	5964–5684 BC (7914–7634 BP)	Small assemblages with low but rising diversity, dominated by *C. gibba*, with some *B. reticulatum*, *Hydrobia* spp., Cardiidae and *Acanthocardium* sp.	These assemblages are consistent with a rather eutrophic marine to brackish environment, with predominantly gravelly bottoms and some marine vegetation
I	2110–1915		Small assemblages with high diversity, dominated by *B. reticulatum*, with some *Cerastoderma* spp., *Loripes lacteum, Parvicardium exiguum, Abra* sp., *C. gibba, Rissoa* spp., *Cerithium* spp. and *Hydrobia* spp.	Assemblages are suggestive of normal marine waters with a slight connection to brackish waters; there was abundant marine vegetation and a mixture of muddy, gravelly and rocky bottoms
J	1915–1700		Small assemblages of moderate diversity, dominated by *B. reticulatum*, with significant 1700–1670 *Rissoa* sp., *C. gibba,* Abra sp., and some *Cerastoderma* spp., *L. lacteum, P. exiguum, Acanthocardia* sp. and *Turbonilla lactea*	Assemblages are suggestive of normal marine waters, possibly slightly eutrophic at the bottom and top of the zone where *C. gibba* peaks; there is evidence for muddy, gravelly and rocky bottoms and abundant marine vegetation
K	1700–1670		Small and rather variable assemblages of low diversity, with Cardiidae, *Cerastoderma* sp. Pectenidae, *Abra* sp., *Acanthocardia* sp. and *B. reticulatum*	Assemblages are consistent with normal marine waters, sandy and gravelly bottoms and some marine vegetation; Pectenidae might suggest relatively clear waters
L	1670–1330		Variably sized assemblages, large in the middle of the zone, of fairly high diversity, dominated by *B. reticulatum* and with significant *Cerastoderma* spp., *Abra* sp. and *Rissoa* spp. There are some *L. lacteum, P. exiguum, C. gibba, Kellia* spp., and *Hydrobia* spp.	Assemblages are consistent with normal to slightly eutrophic marine waters, with a minor connection to brackish environments; there is evidence for sandy, gravelly and rocky bottoms and abundant marine vegetation
M	1330–1210		Large assemblages of moderate diversity, heavily dominated by *B. reticulatum*, with some *Cerastoderma* spp., *L. lacteum, P. exiguum, Abra* sp., *Rissoa* spp., *Cerithium* spp., *T. lactea* and *Hydrobia* spp.	Assemblages are suggestive of marine waters of normal salinity, with a minor connection with brackish environments; there was very abundant marine vegetation and sandy and rocky bottoms
N	1210–1180		Small, low diversity, very variable assemblages with high *Cerastoderma* spp., *Abra* sp., *B. reticulatum* and *Rissoa* spp.	The low diversity and prevalence of *Cerastoderma*, which has oligohaline tolerances, may suggest marine waters of slightly abnormal salinity, perhaps consistent with development of a saline lagoon behind a bay-bar; taxa are consistent with sedimentary bottoms, with some rocky places and variable marine vegetation
O	1180–1100		Large assemblages of high diversity, with high *B. reticulatum* and *Hydrobia* spp. with some *L. loripes, P. exiguum, Abra* sp. and *Rissoa* spp.	The assemblages are suggestive of marine waters of normal salinity, with a strong connection to brackish waters; taxa are consistent with abundant marine vegetation and sandy and rocky bottoms

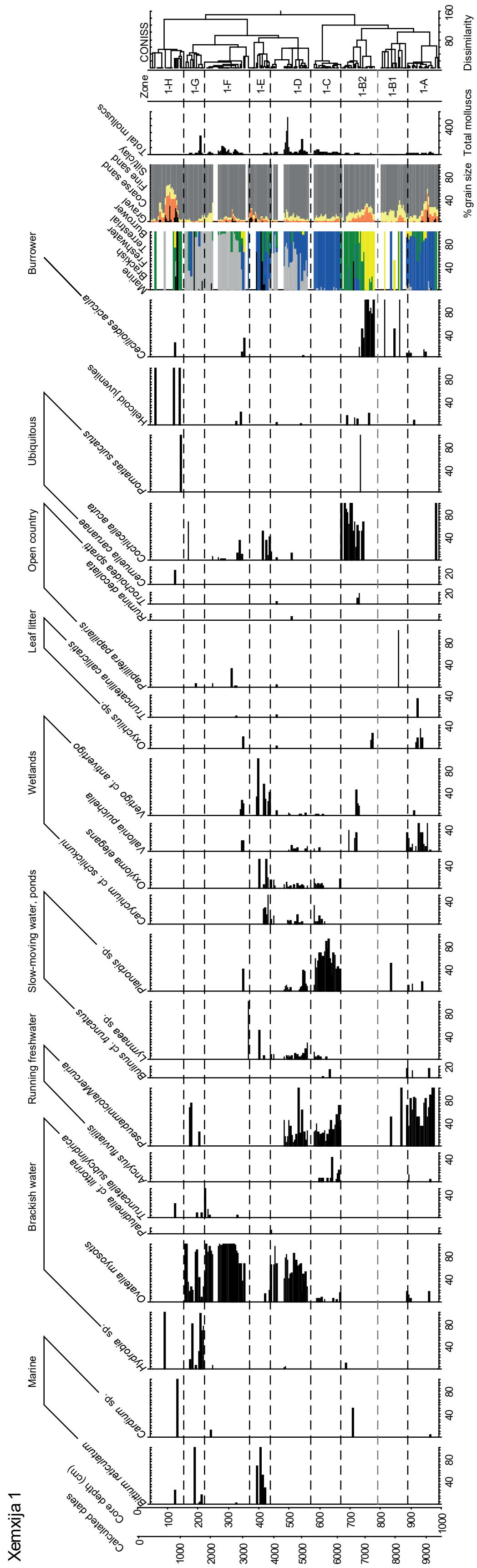

Figure 4.7. *Xemxija 1 molluscan histogram (C.O. Hunt & K. Fenech).*

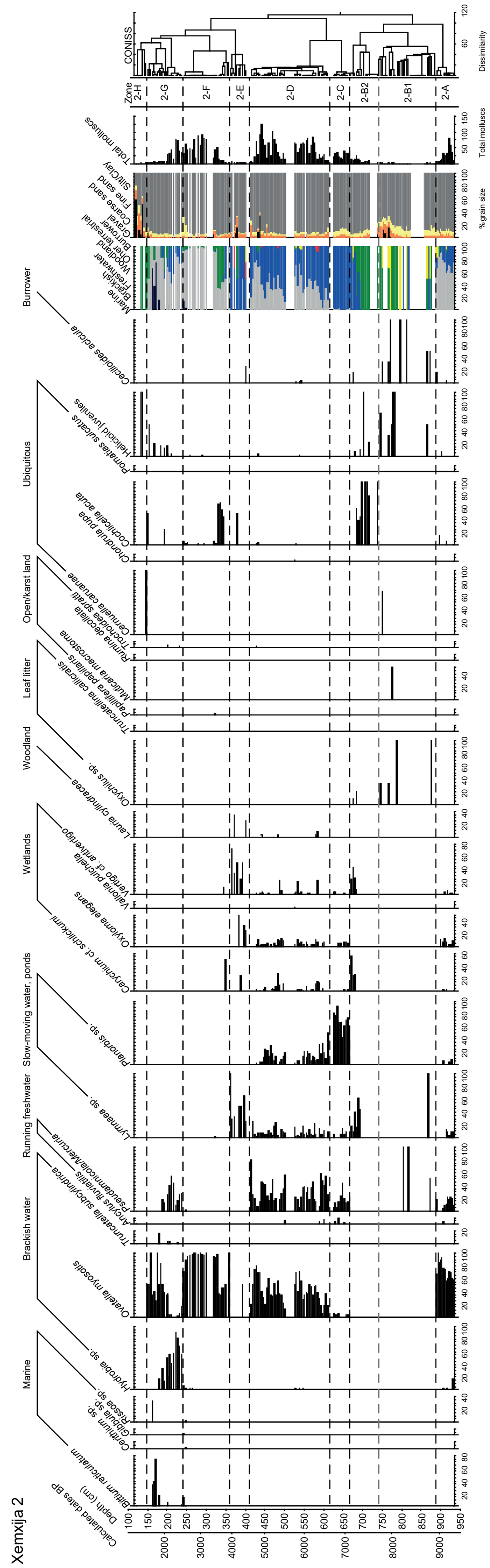

Figure 4.8. *Base of Xemxija 2 molluscan histogram (C.O. Hunt & K. Fenech).*

Table 4.10. *Molluscan zones for the Xemxija 1 core (XEM1).*

Zone	Depth cm	Date ranges cal. BC/AD (BP) for the start of each zone (2σ)	Molluscan assemblages	Environment
1-A	990–888	7568–6779 BC (9518–8729 BP)	Total of 168 molluscs, of which *P. moussonii* 80%, *V. pulchella* 11%, *C. acicula* 3%, *Oxychilus* sp. 2%, *Cardium* sp. 0.6% The lowermost sample was sterile, the maximum number of shells found in a sample was 27; assemblages consisted predominantly of freshwater species, with a few land snails periodically washed in; one marine shell fragment only; influx of stones and coarse sand in the lower half of the zone, which then fines up and becomes predominantly silty/clayey	It is likely that these sediments accumulated by colluviation and alluvial processes behind a coastal barrier; running freshwater (*P. moussonii*), slow moving waters or ponds (*Planorbis* sp.), damp grassy (*V. pulchella*) and dense vegetation (*Oxychilus* sp.) were present; soil erosion events in the catchment are indicated by *C. acicula* and the presence of stones and coarse sand; *O. myosotis* points to saltmarsh and *Cardium* sp. to marine waters nearby; these are rare enough to suggest emplacement on the deposition site by wave-action during storms
1-B1	888–790	6391–6014 BC (8341–7964 BP)	Total of 15 molluscs, of which *C. acicula* 47%, *P. moussonii* 33%, *P. papillaris* 7%, *Planorbis* sp. 7% Only very few molluscs were found in this zone, many samples were sterile; a few small mudballs were found at the base of this zone, indicating rapid sediment influx, the remainder was predominantly silt/clay with small amounts of fine sand	Dramatic environmental change, possibly due to intense aridification, perhaps as a result of the 8.2 ka BP event; the sediments are colluvial in origin, probably accumulating behind a coastal barrier; extreme reduction of the freshwater bodies is suggested by the reduction in aquatic taxa; open karstland is indicated by *P. papillaris*; severe erosion onto the site and hostile conditions may have led to the paucity of molluscan remains
1-B2	790–670	5720–5252 BC (7670–7202 BP)	Total of 105 molluscs, of which *C. acuta* 50%, *C. acicula* 25%, *V. pulchella* 8%, *Oxychilus* sp. 2%, *Cardium* sp. 1%, *Hydrobia* sp. 1% Predominantly land snail assemblages, no subaqueous freshwater species; inwash of one marine mollusc and one brackish water mollusc; after an initial increase, the presence of small mud balls decreases; the top part consists mainly of silt/clay with small amounts of fine sand	Erosion within the catchment seems to have diminished during this zone; in the lower part of the zone a few leaf litter snails (*Oxychilus* sp.) may indicate the former presence of scrub but these and overlying assemblages are rich in the erosion indicator *Ceciliodes acicula*, suggesting the breakdown of vegetation and a phase of soil erosion; higher in the zone the open country *T. spratti* peaks and *Cochlicella acuta* becomes important, perhaps consistent with some garrigue, light grassland or dunes; *Vallonia pulchella* and *Vertigo* cf. *antivertigo* are present in the upper part of the zone; they were which were probably associated with marsh and reeds; the occasional marine taxa were probably thrown into the site by wave action
1-C	670–570	4324–4062 BC (6274–6012 BP)	Total of 564 molluscs, of which *Planorbis* sp. 62%, *P. moussonii* 28%, *C.* cf. *schlickumi* 4%, *O. myosotis* 3%, *A. fluviatilis* (2%) The molluscan assemblages consisted exclusively of different freshwater associated or tolerant species; the sediments were predominantly silt/clay with little fine sand throughout and coarse sand only in the lower half of the zone	Dramatic environmental change and expansion of freshwater bodies, probably behind a coastal barrier and perhaps reflecting increased precipitation; moving water species *P. moussonii, A. fluviatilis*, suggest a rapid perennial freshwater stream; this fed a freshwater lagoon, indicated by *Planorbis* sp., *Bulinus* cf. *truncatus* and *Lymnaea* sp. Encroaching wetlands are suggested by rising *C.* cf. *schlickumi, O. elegans, V. pulchella* and *V. cf. antivertigo* Seaward, *O. myosotis* indicates upper saltmarsh, presumably part of the low coastal barrier

Table 4.10 *(cont.)*.

Zone	Depth cm	Date ranges cal. BC/AD (BP) for the start of each zone (2σ)	Molluscan assemblages	Environment
1-D	570–480	3512–3094 BC (5462–5044 BP)	Total of 1791 molluscs, of which *O. myosotis* 63%, *P. moussonii* 22%, *Planorbis* sp. 8%, *C.* cf. *schlickumi* 1% Molluscan assemblages consist of brackish water, freshwater and at times a few land snails; one sample contained solely freshwater shells; the number of shells found varied greatly, the highest number being 508 shells, and one sample containing no shells; variations in the particle size distribution were also noted, with the irregular increases in coarse sand and small stones	Rising *O. myosotis* points to encroaching saltmarsh; freshwater species decline in percentage and diversity, suggesting diminishing input from freshwater streams, declining water quality and the gradual disappearance of freshwater lagoons; the last freshwater species left is *Lymnaea* sp., which is tolerant of poor habitats; wetland taxa decline, then recover, suggesting that fringing reedbeds diminished, then expanded; the very few land snails indicate the presence of light grassland (*C. acuta, T. callicratis*) and scrub (*R. decollata*); leaf litter species were found only at the top of this zone, in association with *C. acicula,* possibly as a result of the breakdown of dense vegetation and soil erosion due to aridification or human activity
1-E	440–366	1953–1574 BC (3903–3524 BP)	Total of 87 molluscs, of which *O. myosotis* 23%, *V.* cf. *antivertigo* 23%, *C.* cf. *schlickumi* 17% *O. elegans* 13%, *C. acuta* 10%, *Bittium reticulatum* 9%, *Lymnaea* sp. 2% Dramatic decrease in the number of shells found, with several sterile samples; the assemblages were often mixed with marine species; freshwater snails were rare, but wetland and land snail species were frequent; the sediments reflect severe erosion in the catchment, with at least three events marked by an influx of stones and coarse sand	Swampy marshland is indicated by *V.* cf. *antivertigo* and *C.* cf. *schlickumi*, but the former freshwater bodies were reduced to shallow pools (*Lymnaea* sp.) and the freshwater stream appears to have vanished, possibly as a result of continued aridification; *C. acuta* denotes the presence of dry grassland or dunes; the saltmarsh (*O. myosotis*) was still present initially, but reduced or more distant; the small marine species *Bittium reticulatum* is usually associated with seaweed and may have been blown or washed into the site with aquatic vegetation by storm waves overtopping a coastal barrier; storms are also indicated by the increase in coarse sand and stones
1-F	366–220	1279–556 BC (3229–2506 BP)	Total of 842 molluscs, of which *O. myosotis* 95%, *C. acuta* 2%, *V.* cf. *antivertigo* 0.6%, *C. acicula* 0.2% Assemblages were strongly dominated by brackish water species, freshwater shells were found only at the base of this zone and again at the top; land snails occurred intermittently in low numbers; the distribution of coarse sediments indicates at least two inwash events	Soil erosion and inwash of eroded materials from nearby slopes is suggested by *C. acicula* at the beginning of this zone; this event may have led to the infilling of the previous shallow pools and marshland; this may have resulted in the extension of the saltmarsh, as indicated by the dramatic increase in *O. myosotis*; the few land snails suggest that a little dense vegetation, indicated by taxa indicative of leaf litter, may have been present at the base of the zone; but higher in the zone there is evidence only for grassland or dunes (*C. acuta*) and open karstland (*P. pappilaris*)

Table 4.10 *(cont.).*

Zone	Depth cm	Date ranges cal. BC/AD (BP) for the start of each zone (2σ)	Molluscan assemblages	Environment
1-G	218–155	AD 52–510 (1898–1440 BP)	Total of 375 molluscs, of which *Hydrobia* sp. 75%, *O. myosotis* 15%, *P. moussonii* 6%, *Bittium reticulatum* 2% Molluscs from all major habitat groups were found in this zone, of which land snails were the rarest; the number of shells per sample varied between 1 and 253 specimens	The sudden appearance of the brackish water/lagoonal *Hydrobia* sp. in large numbers may indicate the formation of a brackish lagoon behind the coastal barrier; the proximity of the coast is also suggested by *T. subcylindrica*, while saltmarsh (*O. myosotis*) persisted; running freshwater directly entering the lagoon is indicated by *P. moussonii*; again, open country/karstland and grassland was present
1-H	158–48	AD 737–830 (1213–1120 BP)	Total of 10 molluscs, of which *Hydrobia* sp. 10%, *T. subcylindrica* 10%, *Bittium reticulatum* 10%, *C. acicula* 10% Dramatic reduction in the number of molluscs found, with many sterile samples; shells from all major habitats were present; the sediments showed a dramatic increase in stones and coarse sand, first coarsening up and then fining up	The site had completely dried up; the freshwater stream was no longer detected; this is perhaps because of anthropogenic water management (the stream is today caught in a reservoir); as a result, wetland species were also absent and the saltmarsh disappeared; infrequent inwash events from the sea led to the deposition of a few marine/lagoonal shells; the very few land snails suggest light vegetation (*e.g. C. caruanae*), while the burrower *C. acicula* may either be intrusive or may have been part of soil erosion and inwash, as suggested by the deposition of coarse sand and stones

Table 4.11. *Molluscan zones for the Xemxija 2 core (XEM2).*

Zone	Depth cm	Date ranges cal. BC/AD (BP) for the start of each zone (2σ)	Molluscan assemblages	Environment
2-A	933–890	7526–7221 BC (9476–9171 BP)	Total of 353 molluscs, of which *O. myosotis* 71%, *P. moussonii* 14%, *Lymnaea* sp. 4%, *C. acuta* 0.5%, *C. acicula* 0.5% All samples contained shells, their numbers varied between five and 81; the assemblages consisted mainly of brackish water associated species, often mixed with freshwater/wetland snails; land snails periodically appeared in the upper half of the zone in low numbers; the sediments were silty/clayey with small amounts of fine and coarse sand throughout	Saltmarsh environment, as indicated by *O. myosotis*, probably behind a coastal barrier, with nearby running freshwater (*P. moussonii*), slow moving water/ponds (*Lymnea* sp. and *Planorbis* sp.) and vegetated wetlands (*O. elegans*); sparse land snails indicate grassland (*C. acuta*); the presence of the burrower *C. acicula* may be intrusive, as the particle size distribution would not necessarily point to input of sediment resulting from severe erosion
2-B1	890–740	7197–6787 BC (9147–8737 BP)	Total of 25 molluscs, of which *C. acicula* 28%, *Oxychilus* sp. 16%, *P. moussonii* 12%, *Muticaria* sp. 4% As in Xemxija 1, only a few molluscs were found, with many sterile samples, indicating rapid sedimentation; the sudden change in sediment colour from light grey to reddish brown suggests an event, but the calculated date for this event would be several hundred years before the similar change in Xem1; initially, the samples contained a relatively stable amount of fine sand	Dramatic change in the environment. The saltmarsh disappeared, but running freshwater (*P. moussonii*) and slow moving water/pond (*Lymnae* sp.) were still present, probably behind a coastal barrier, in the lower half of this zone; the upper half of the zone is characterized by an absence of freshwater-associated snails; in fact, the last occurrence of *P. moussoni* falls into the date range of the 8.2 ka BP event, suggesting that the freshwater species may have vanished as a result of the abrupt aridification that led to the

Table 4.11 *(cont.).*

Zone	Depth cm	Date ranges cal. BC/ AD (BP) for the start of each zone (2σ)	Molluscan assemblages	Environment
			(around 20%), but there was a sudden increase of coarse sand and stones at 765 cm, peaking at 750 cm and then gradually fining upwards	drying up of the water bodies; light vegetation suggested by *C. caruanae* and some leaf litter by *Oxychilus* sp.; the presence of the burrower *C. acicula* may perhaps be autochtonous and not necessarily the result of heavy erosion
2-B2	740–670	6054–5437 BC (8004–7437 BP)	Total of 120 molluscs, of which *C. acuta* 40%, *Lymnaea* sp. 22%, *C.* cf. *schlickumi* 13%, *Oxychilus* sp. 5%, *C. acicula* 2% Increase in the number of shells per sample, ranging between three and 26; assemblages contained mainly land snails, with freshwater snails re-appearing in the upper part of the zone; the amount of sand gradually decreased from 25% to 5%	A slow recovery of the freshwater bodies behind the coastal barrier is indicated by the reappearance of *Lymnaea* sp., a freshwater snail tolerant of poor conditions and thus a pioneer species; wetlands soon became re-established (*C.* cf. *schlickumi*), as did denser vegetation (*Oxychilus* sp.), while light grassland persisted, as suggested by common *C. acuta* and the Helicioid juveniles; with the slow re-establishing of a freshwater body, the number of shells also increased, indicating a slowing down of the previous rapid sedimentation
2-C	670–615	5500–4877 BC (7450–6827 BP)	Total of 307 molluscs, of which *Planorbis* sp. 39%, *P. moussonii* 15%, *C.* cf. *schlickumi* 4%, *O. myosotis* 3% Between 14 and 41 shells per sample; the assemblages consisted only of freshwater associated shells and intermittently a few brackish water molluscs; the sediments were silty/clay with sand, sand increasing from 5% to 15% and then fining up towards the end of the zone; tncrease in sand appears to be linked to increased running freshwater (*P. moussonii*)	Freshwater bodies were now fully re-established behind the coastal barrier; shallow standing or slowly moving water is suggested by *Planorbis* sp., fed by a steady running freshwater stream (*P. moussonii* and *A. fluviatilis*); expansion of the water body pushed back the wetland margins; *O. elegans* indicates plant growth in the pond or at the water edge; slow return of the saltmarsh (*O. myosotis*) in the vicinity
2-D	615–415	4974–4381 BC (6924–6331 BP)	Total of 1877 molluscs, of which *O. myosotis* 45%, *P. moussonii* 28%, *Planorbis* sp. 11%, *C.* cf. *schlickumi* 3%, *Lauria cylindracea* 0.2% Marked variations but general increase in the number of shells per sample; strong but fluctuating presence of brackish water species among freshwater associated snails; land snails were few and irregularly found, among which first appearance of the woodland indicator *L. cylindracea*; generally the sediments had a silt/clay content above 90% in all but four samples, indicating fairly stable conditions between periodical inwash events	Fluctuations in the freshwater bodies coupled with increases or decreases in the saltmarsh as evidenced by *O. myosotis*; presence of woodland is indicated by *L. cylindracea* shortly after 4400 BC, while the grassland is also found (*C. acuta*) intermittently; major rainstorms occurred around 4000 BC, which led to the inwash of the brackish water *Hydrobia* sp. from the nearby sea and *C. acicula* from the hinterland, after which the saltmarsh was again diminished through increased flowing freshwater (*P. moussonii*); this fluvial event also left its mark at the same depth in Xem1; there appear to have been strong weather induced fluctuations in the running freshwater flow, which often affected the population of *Planorbis* sp., which do not tolerate intensive water movements; this species disappears at the top of the zone after a major fluvial inwash

Table 4.11 *(cont.).*

Zone	Depth cm	Date ranges cal. BC/AD (BP) for the start of each zone (2σ)	Molluscan assemblages	Environment
2-E	410–360	2837–2470 BC (4787–4420 BP)	Total of 30 molluscs, of which *Lymnaea* sp. 33%, *V.* cf. *antivertigo* 33%, *O. elegans* 10, *C. acuta* 6%, *L. cylindracea* 6% Dramatic decrease in the number of shells found, one sample was sterile; assemblages consisted of mainly freshwater/wetland molluscs, with brackish water species occurring only once, and land snails only in two samples; the sediments had an increased content of coarse sand, stones occurred in the middle of the zone; together with the very low amount of molluscs found, his indicates very rapid sedimentation	The date suggests that this zone describes the beginning of the end of the Temple Period and it is marked by a dramatic change in the environment; there is no more evidence for running freshwater, indicating that stream either dried up or the water output was dramatically reduced, possibly due to severe aridification; the only freshwater snail found is *Lymnea* sp., indicative for poor conditions in the now very shallow freshwater pool, which, however, sustained some vegetation and the wetland surrounding it (*O. elegans*); severe erosion and subsequent inwash events of sediments is suggested by *C. acicula* in the beginning of the zone; inwash events occurred throughout and the continuous presence of coarse sand and at one point also stones may have contributed to the shallowing of the freshwater pond. Some woodland still existed (*L. cylindracea*) as did grassland (*C. acuta*); evidence for the previously extensive saltmarsh occurred only once (*O. myosotis*), possibly indicating that the inwash events were of terrestrial origin, as no marine or subaqueous brackish water species (*Hydrobia* sp.) were found
2-F	360–240	2231–1715 BC (4181–3665 BP)	Total of 870 molluscs, of which *O. myosotis* 93%, *C. acuta* 4%, *P. moussonii* 1%, *P. papillaris* 1%, *Hydrobia* sp. 0.6% The assemblages consisted predominantly of brackish water species, freshwater/wetland species were rare, land snails occurred in small numbers intermittently; marine shells were found at the top of the zone; the sediments were silty/clayey, sand generally occurred in lower amounts than in the previous zone; one event in the middle of the zone had small stones washed in, another at the top had a notable influx of fine sand	Dramatic change of the environment, the pond and wetlands silted up and got replaced with grassland a saltmarsh (*C. acuta* and *O. myosotis*), the latter expanding rapidly, though patches of grassland persisted throughout; the woodland indicator was no longer found, and apart from the grassland species *C. acuta*, the only other land snail identified was the open country species *P. papillaris*; while the pond resurfaced once briefly (*Lymnaea* sp.), the running freshwater stream remained elusive, indicating a continuation of the previous aridification; a strong sea storm at the top of the zone may have led to the breakdown of a bay-bar and led to an influx of a few marine shells, *Hydrobia* sp. and fine sand; this event was also found in Xemxija 1 at the same depth
2-G	240–147	873–245 BC (2823–2195 BP)	Total of 398 molluscs, of which *Hydrobia* sp. 59%, *P. moussonii* 22%, *O. myosotis* 12%, *Bittium reticulatum* 4%, *C. acuta* 0.7% The zone contained molluscs from all major habitat categories in differing mixes; brackish water associated species were the most common ones, *P. moussonii* was the only freshwater	Continuation of seaward inwash onto the site with a sharp increase in the brackish water mud snail *Hydrobia* sp., which replaced the saltmarsh indicator *O. myosotis*; the marine inwash events may have been in conjunction with strong rainfall, as the running freshwater species *P. moussonii* reappears, but it no longer formed ponds or wetlands; with the

Table 4.11 *(cont.).*

Zone	Depth cm	Date ranges cal. BC/AD (BP) for the start of each zone (2σ)	Molluscan assemblages	Environment
			associated snail found, wetland species were absent; land snails occurred intermittently, as did marine molluscs; the sediments were predominantly silty/clayey throughout without notable changes in the low sand content	waning and subsequent disappearance of the freshwater stream, the saltmarsh extended again (*O. myosotis*) and the brackish water body in the nearby sea vanished (*Hydrobia* sp.), leading to the inwash of marine species (*B. reticulatum*); the very few land snails found are indicative of grassland (*C. acuta*) with light vegetation and open country/garrigue (*T. spratti*)
2-H	147–103	AD 74–777 (1876–1173 BP)	Total of 5 molluscs of which *C. acuta* 40%, the remainder indeterminate Heliciid fragments Dramatic reduction in the number of molluscs found, with many sterile samples, particularly at the top of the zone; as in Xem1, the sediments received a strong increase in stones and coarse sand, coarsening up	The site had now completely dried up, there is no longer evidence for a saltmarsh, freshwater or marine influence; the very few land snails are indicative of grassland and light vegetation

Table 4.12. *Correlation and integration of molluscan data from Xemxija 1 (XEM1) and Xemxija 2 (XEM2).*

Date cal. BC/AD (BP) (2σ)	XEM1	XEM2
7550–6250 BC (9500–8200 BP) Pre-Neolithic Period	Zones 1-A, base of 1-B1 Key taxa: *P. moussonii*, *Planorbis* sp., *V. pulchella*, *O. hydatinus* Freshwater bodies and wetland, leaf litter	Zones 2-A, up to middle of 2-B1 Key taxa: *O. myosotis*, *P. moussonii*, *O. elegans*, *C. acuta* Saltmarsh with freshwater bodies and wetland, grassland
6250–4150 BC (8200–6100 BP) Early Neolithic Period	Zones part of 1-B1, 1-B2 Key taxa: *P. moussonii*, *Planorbis* sp., *P. papillaris*, *C. acuta*, *C. acicula* Aridification leading to drying up of freshwater bodies, establishment of grassland	Zones part of 2-A, 2-B2, 2-C Key taxa: *P. moussonii*, *Lymnaea* sp., *Planorbis* sp., *C. acuta* Aridification and disappearance of saltmarsh, followed by appearance of grassland, superseded by shallow freshwater pools fed by a stream and surrounding wetlands and reappearance of the saltmarsh
4050–2350 BC (6100–4400 BP) Temple Period	Zones 1-C and most of 1-D Key taxa: *P. moussonii*, *Planorbis* sp., *O. myosotis* Variety of freshwater bodies and associated wetlands; from *c.* 3250 BC onwards, strong fluctuations of precipitation led to decreases in the freshwater water bodies and extension of saltmarsh	Zone 2-D Key taxa: *O. myosotis*, *P. moussonii*, *Planorbis* sp., *L. cylindracea* Continuous fluctuations between saltmarsh and freshwater bodies, due to variations in precipitation; appearance of woodland *c.* 4050 BC
2350–1950 BC (4400–3900 BP) End of Temple Period, Early Bronze Age (Tarxien Cemetery Phase).	Zone top of 1-D Key taxa: *O. myosotis*, *Lymnaea* sp., *O. elegans* Disappearance of running freshwater stream, persistence of saltmarsh and poor quality shallow freshwater pool and vegetated wetland	Zone 2-E Key taxa: *Lymnaea* sp., *V.* cf. *antivertigo*, *L. cylindracea*, *C. acicula* Severe erosion events, and as in XEM1, disappearance of freshwater stream but persistence of poor quality shallow freshwater pool and vegetated wetland; saltmarsh diminished, but woodland still occurred

Table 4.12 *(cont.).*

Date cal. BC/AD (BP) (2σ)	XEM1	XEM2
1950–650 BC (3900–2600 BP) Bronze Age to Phoenician/early Punic	Zones 1-E and half of 1-F Key taxa: *B. reticulatum*, *O. myosotis*, *Lymnaea* sp., *C. acuta* Breaking down of bay-bar, sudden marine influence, presence of small shallow freshwater pool with associated vegetated wetlands, which disappear after 1150 BC; after that, extension of saltmarsh, surrounding landscape is open country and lightly vegetated grassland/steppe	Zone F Key taxa: *O. myosotis*, *C. acuta* Expansion of saltmarsh and disappearance of freshwater/wetlands after 1750 BC; no more evidence for woodland; presence of grassland and open country/garrigue
650 BC–AD 850 (2600–1100 BP) Early Punic to Arab Period	Zones: upper half of 1-F and 1-G Key taxa: *O. myosotis, P. moussonii, Hydrobia* sp., *C. acuta* At first strong presence of saltmarsh, but the eventual breaking down of bay-bar led to the inwash of sediments with *Hydrobia* sp. and *B. reticulatumi,* severely diminishing the saltmarsh; brief reappearance of freshwater stream around AD 650, without formation of pools or wetland; presence of grassland and open country/garrigue	Zones: 2-G and 2-H Key taxa: *O. myosotisi*, Hydrobia *sp., P. moussonii, B. reticulatum, C. acuta* As in XEM1, marine inwash of sediments with *Hydrobia* sp. and *B. reticulatumi,* severely diminishing the saltmarsh, but with a stronger signature than in XEM1; reappearance of running freshwater until around 150 BC, but no formation of wetland or pools; after 150 BC, reappearance of saltmarsh with marine influence; presence of grassland and light vegetation
AD 850–1450 (1100–500 BP) Arab Period to pre-Knights Period	Zone H Key taxa: *B. reticulatum, Hydrobia* sp., *C. caruanae* Occasional marine influence, fast sedimentation and disappearance of saltmarsh; presence of light vegetation	no data

in this case was caused by agricultural erosion of nutrient-rich topsoil and inwash into the Salina inlet. Further eutrophication events are suggested by high *C. gibba* at the base and top of zone I and in the middle of zone L. All of these coincide with a sudden significant expansion of *Plantago lanceolata* and expansion of some coprophilous fungal spores in the pollen diagram, interpreted as reflecting a major expansion of livestock grazing and disturbance through agricultural activities. The second event also coincides with a rise in cereal pollen, suggesting an intensification of arable activity. In all of these cases, it is plausible to regard the eutrophication of the Salina Inlet as reflecting rises in the input of nutrients resulting from agricultural activity.

4.5.6. *Xemxija 1 and 2*

The extraction site of these cores, taken less than 1 m apart, was situated at the end of Pwales Valley outside the Simar Nature Reserve and at a distance of less than 100 m from the sea at Xemxija Bay. Geographically, the area is a graben described as a low-lying, flat bottomed basin (Bowen-Jones *et al.* 1961, 34). The flattish floor of the graben is flanked by steep slopes, with substantial gravelly alluvial fans debouching from tributary valleys. The basin has a catchment of around 7 sq. km. Archaeological remains near the location include a number of Neolithic tombs and the remains of a temple (Evans 1971). The valley has been a prime area for agriculture to this day (National Statistics Office 2016).

A CONISS analysis was performed with both cores in the TILIA graphs, and both could thus be linked and sub-divided into seven different molluscan assemblage zones (MAZs), discussed below. The links, however, are at times only broadly linear with respect to the measured depth in both cores, which may be a result of the different energy environments of the water flow and cut-and-fill stratification (Figs. 4.7 & 4.8; Tables 4.10–4.12). Bayesian models provide the date frame for the cores, with WZ2 covering the last *c*. 7675 years (see Chapter 3, Table 3.6).

4.5.6.1. Conclusion: Xemxija

Of all the cores analysed, the two from Xemxija were the only ones which showed a semi-continuous sequence from the early Holocene. The cores revealed varied freshwater environments that were susceptible to prolonged droughts and increased rainfall periods during prehistory and beyond until the area was covered in made ground, probably fairly late during the British Period. The combination of a relatively small catchment area with a relatively low-energy environment provided a rare insight into the past environment and climates of the Maltese Islands. Prolonged droughts appear to have left their mark at around 6200 cal. BC and after 2500 cal. BC, shortly after which several freshwater species were no longer found and are now extinct. These may very well coincide with the droughts associated with the 8.2 ka and 4.2 ka BP events. Severe fire events were largely absent from these cores and human impact may be difficult to detect through the molluscan analysis. It is perhaps possible that the presence during the fifth millennium BC (between *c*. 6.15 and 3.6 m in the core) of *Lauria cylindracea,* for which there was no previous fossil record, may have been the result of importing soil around tree saplings for planting at Xemxija. It is perhaps more likely, however, that the species was able to flourish in the wetland vegetation surrounding the freshwater bodies in the valley floor.

4.6. Interpretative discussion

4.6.1. Erosion – evidence of major events from the cores

Erosion is fundamentally a natural process, though often driven and modulated by human activities. The majority of the studied sediments had accumulated following erosion of soils or exposed older deposits within the catchments, transported to the deposition sites by running water. In ephemerally active regimes, typical of semi-arid, seasonal environments such as those characterizing much of the Maltese Holocene, material may be repeatedly eroded and re-deposited as it moves through the catchment. This storage and re-mobilization of sediments and their contained biogenic materials led to some radiocarbon ages not being in stratigraphic order in the cores.[9] Major erosion events could be recognized in the cores through sudden changes in the sediment colour, coarsening of texture and the appearance of large clasts and in the composition of the mollusc assemblages. In particular, *Cecilioides acicula,* which buries itself in the soil at depths varying between 20 cm and 2 m, possibly provides some indication for erosion events (see Chapters 2 & 5), especially when it was found in waterlain sediments at the coring sites. This suggests that significant quantities of soil may have been displaced by erosion over the studied interval.

4.6.1.1. Mġarr ix-Xini

The sediments of the core retrieved from the alluvial plain in Mġarr ix-Xini reflected the high energy environment and interplay of the natural forces in several ways. Sudden soil colour changes in the sediments pointed to at least 15 major events and marine sediments alternated several times with terrestrial deposits. These were always accompanied by dramatic changes in the sediment textures. The particle size analysis (Appendix 4) showed that, on numerous occasions, stones were incorporated in the sediment suggesting highly energetic flows. The molluscan assemblages contained throughout an admixture of shells belonging to three major habitat groups: terrestrial, brackish water-associated and marine snails in widely varying amounts. The possible erosion indicator *C. acicula* occurred irregularly throughout, but only in the upper 60 cm of the core (depth from surface down to 1.2 m) was it likely to have been part of the natural assemblage and to have lived in the sediments.

The lowermost dated deposit may be attributed to the Punic period (510–360 cal. BC; UBA-33096). It is probable that earlier valley fill sediments had been removed, presumably by running water and it is probable that further erosion (by running water or the sea) affected the accumulating sediments on several occasions between that time and the present day.

4.6.1.2. Marsaxlokk

Although the core was only 3.86 m long, there were ten distinctive changes in the sediment colour during this interval, from at least cal. AD 435–670 (at 2.86 m; 1444 BP; UBA-29351). A terrestrial soil was overlain by marine sands, then alluvial/colluvial derived silts, followed by a distinctive layer of decomposed plant material that was overlain by coarse marine sand containing a piece of Punic pottery. Further marine silts passed into alternating terrigenous and marine silts, and terrestrial, possibly colluvial, silts. Most of the samples contained marine gastropods and bivalves, while brackish water shells were prominent and terrestrial species occurred throughout. The total number of molluscs varied greatly. The irregular presence of *C. acicula* may suggest that several severe erosion events occurred.

4.6.1.3. Wied Żembaq

In the Wied Żembaq 1 core over the last 3.5 millennia BC, changes in the soil colours were less marked than in the other cores. Nonetheless, the presence of horizons of limestone pebbles at *c*. 3.5–3.62 m and 2.17–3.15 m suggest an episodically very energetic depositional environment and erosion within the catchment. Most samples contained molluscs belonging to at least three major habitat groups, but several samples had only land snails, albeit in low numbers. There are several horizons marked by the erosion indicator *C. acicula* and molluscs from several habitat groups, notably near 4.44 m, and between 2.85 and 3.35 m. Marine influence increased considerably in the top metre of studied material.

4.6.1.4. The Marsa 2 core

Fifteen major changes in sediment colour could be observed in the Marsa 2 core, probably from the Neolithic Ġgantija phase onwards. Very strong marine influence could be detected from 9 m upwards in the molluscan assemblages. There is a sharp change from brownish oxidized sediments of largely terrestrial/eroded soil origin to dark grey reduced marine sediments. The lack of dateable material in the lower part of the core is an indication of very rapid deposition. The particle size distribution, characterized by coarse sands and gravel, suggests highly energetic depositional regimes. Major events deposited quantities of gravel on three occasions. Rapid deposition was also indicated by thick layers of hydro-collapsing fine sands that could not be retained by the corer, at 5.25–5.95 m, and towards the top of the core close to the groundwater table. The molluscan assemblages varied, but usually contained at least three major habitat categories (marine, brackish water and land snails), also often freshwater molluscs. The possible erosion indicator *C. acicula* was particularly frequent above 6.5 m. The extent of recycling in this energetic but episodically active environment is brought into sharp relief by the finding of two conjoining potsherds more than one metre apart in the core and by the stratigraphically disordered radiocarbon dates, with insecure dates evident until the Late Bronze Age, a feature remarked on also in the neighbouring Marsa 1 core by Carroll *et al.* (2012). Towards the top of the core, marine molluscs become rare. In the upper 50 cm of the core the presence of *C. acicula* may be autochthonous, given that this was now a terrestrial environment.

4.6.1.5. Salina Deep Core

The roughly 17 m of marine sediments from the Salina Deep Core displayed a large number of sedimentary events, probably from close to the beginning of the Holocene. The sediment colours were dark reddish brown in the basal terrestrial sediments, but the overlying marine sediments are light brown/grey to dark grey/brown, reflecting post-depositional sediment reduction in the presence of organic matter. The sediment textures range from clayey stony silt diamicts to sands, silts and clayey silts. It is likely that most of the sampled marine sequence resulted from the deposition of turbidites (sub-marine mass flows). Typically, this type of sedimentation in shallow waters is caused by very turbid or hypercritical fluvial flows entering a marine basin. Sedimentation was very rapid, in response to enormous sediment flux from the large, steep catchment, but also because accommodation space was created by the very rapid rate of sea level rise during the early Holocene. The relatively offshore nature of sedimentation was indicated by the generally low counts for terrestrial molluscs, particularly between 22.5 and 18.5 m. This interval contained very few marine molluscs, but the possible erosion indicator *C. acicula* was often present in the core. The sherds of Tarxien Phase pottery found near the top of the sampled sequence again point to the energetic nature of the environment and the likelihood of sediment storage and recycling within the catchment.

4.6.1.6. Xemxija

Owing to the basin structure of Pwales Valley, where the influence of the nearby sea was limited and the depositional environment was generally not very energetic, the vast majority of the sediments accumulated because of material arriving from the catchment during precipitation events sufficiently powerful to cause run-off. Both the Xemxija cores are thought to span much of the Holocene period, and certainly the last *c*. 7500 years.

That part of Xemxija 1 below 6.7 m is marked by rather mixed mollusc assemblages, including the possible erosion indicator *C. acicula* and the intermittent occurrence of freshwater snails. These are consistent with several severe events. The presence of small mud balls between 7.8 and 6.7 m indicates torrential rains and high stream flow velocities (Wigand & McCallum 2017). Quieter, more organic-rich sedimentation then occurred. Sedimentation became more energetic between 5.65 and 5.01 m and then intensified further. Some of these events saw a considerable influx of marine molluscs. Mud balls were prominent between 4.4 and 3.5 m, again indicating torrential rains and high stream flow velocities. The occurrence of wind-blown quartz sand in this part of the core suggests the proximity of a dune system.

Xemxija 2 closely mirrored the events found in Xemxija 1 and provided additional information. Often high *C. acicula* and frequent mud balls between 8.08 and 7.18 m indicate episodic torrential rainfall, high streamflow and strong soil erosion. This may possibly coincide with the 8.2 ka BP event.[10] Quieter sedimentation then occurred, but between 4.13 and 3.18 m the number of shells decreased dramatically. The possible erosion indicator *C. acicula* was found at 4.01 m, and again, the massive presence of gravel-sized mud balls up to 2.78 m indicated episodic torrential rainfalls with high stream flow velocities. Wind-blown very fine quartz was abundant throughout.

In both cores, from 1.5 m depth upwards, there was a notable influx of stones and coarse sand and the deposits were often devoid of any mollusc remains. The light brown colour of the sediments indicates severe terrestrial soil erosion.

4.7. Environmental reconstruction based on non-marine molluscs

The following reconstruction is based on the dated results from all the cores, depending on their date ranges and suitability. As the non-marine assemblages in the cores were predominantly death assemblages from within the catchment areas, the emerging picture is of a general nature.

4.7.1. Early Holocene (c. 8000–6000 cal. BC)

The base part of the cores from Xemxija and the Salina Deep Core contained material that was radiocarbon dated to *c*. 8000–6000 cal. BC (see Chapter 2). The molluscan assemblages suggest the presence of perennial streams, slow moving water bodies and ponds, which today no longer exist in these areas. Both sites also had areas of saline marshland as evidenced by the presence of *Ovatella myosotis*. The margins of the freshwater bodies, the extent of which are unknown, had relatively lush plant growth, which provided the leaf litter/damp habitat for different species. Open country/karstland was also in the vicinity. The prevalence of ubiquitous snail species points to a disturbed and, possibly at times, harsh environment. The molluscan evidence from Xemxija suggests a shallowing and subsequent drying up of the water bodies towards the end of the seventh millennium BC, which may very well have been associated with the global 8.2 ka BP event that led to severe aridification through prolonged droughts. This was followed by massive mud-flows containing barely any plant material, which may suggest that the local environment was quite barren at the end of the Early Holocene.

4.7.2. Mid-Holocene (c. 6000–3900 cal. BC)

The period appears to have continued to be marked by environmental instability and prolonged droughts, during which the freshwater bodies at Xemxija were still absent. The signature is different in the Salina Deep Core owing to different energy environments, where very high sedimentation rates could be observed at the coring site and non-marine molluscs, including freshwater/wetland associated species, occurred irregularly throughout. The saline marshland species *O. myosotis* was no longer found at Xemxija and Salina. Of the land snails, ubiquitous species prevailed in both sites, where Xemxija had a decrease in leaf litter snails but this was not mirrored at Salina. Open country/karstland snails were irregularly present in small numbers at both sites.

4.7.3. Temple Period (c. 3900–2400 cal. BC)

This period was marked by a decisive change in the environment at Xemxija, where there was now a full-blown freshwater environment that was host to a large variety of freshwater/wetland snail species and which indicated the presence of perennial running, slow-moving and ponded freshwaters. The presence of the marginal saline marshland species *O. myosotis* was occasionally found again until 3630–2930 cal. BC, increased substantially after this point in both cores, perhaps indicating an increase in the extent of the saline marshland habitat. The land snails found after this date showed the existence of woodland habitats at Xemxija.

From the Salina Deep Core, the upper part, from 14.74–11.4 m, has also been dated to the Temple Period. No clear picture or trend emerged. The molluscan assemblages contained predominantly ubiquitous snails, followed by open country/karstland species and leaf litter species. The freshwater/wetland-associated molluscs showed a wide diversity and abundance, indicating a continuous presence of perennial running freshwater, slow-moving water and ponds in the Burmarrad Plain. Despite this, the saline marshland species *O. myosotis* was not found in the samples.

The lowermost deposits of the Wied Żembaq cores can be attributed to the Temple Period, from around 3600 cal. BC onwards. The general picture from this site is that during the Temple Period, there was a perennial freshwater stream in the valley, as evidenced by the freshwater snails *Pseudamnicola moussonii*/*Mercuria similis*. This probably created a saline marshland at the mouth of the valley, which provided the habitat for *O. myosotis.* The land snails here were predominantly open country/karstland species, followed by ubiquitous species. Leaf litter-associated snails were generally in a minority, despite the presence of a freshwater stream.

4.7.4. Early to later Bronze Age (2400–c. 750 cal. BC)

The Bronze Age period saw a dramatic decrease in freshwater-associated snails at Xemxija, possibly associated with the 4.2 ka BP event.[11] Most notable was the sudden absence of the running freshwater species *P. moussonii*/*M. similis* in both cores. The absence or dramatic reduction of freshwater input may have led to a situation where several species vanished and possibly became locally extinct from several sites, particularly after *c*. 1500 cal. BC. Ubiquitous land snails dominated, most prominently the light grassland/dune species *Cochlicella acuta,* while leaf litter species and open country/karstland species occurred only occasionally.

The leaf litter woodland indicator *Lauria cylindracea* was no longer found from around 1800 cal. BC onwards.

Other cores with segments dated to the Bronze Age included Wied Żembaq and Mġarr ix-Xini and Marsa 2, all of which contained relatively high-energy sediments. At the former site, the snails associated with running freshwater vanished during this period. The stream may not have disappeared completely, as leaf litter species and the brackish water/saline marshland species *O. myosotis* occurred in good numbers, although the latter occurred rather irregularly. Open country/karstland species increased, as did the ubiquitous species. At Mġarr ix-Xini, leaf litter species were generally very sparse, the analyses were dominated by open country/karstland species and ubiquitous snails throughout. As deposits belonging to the Temple Period were not found, it is not possible to comment on any changes. In Marsa 2, the non-marine molluscan assemblages in the deposits that were dated to this period showed the presence of running freshwater, slow-moving/standing waters and wetlands. The land snails indicated habitats for leaf litter species. Open country/karstland species also occurred. Again, the most prominent snail group was the ubiquitous species.

4.7.5. Latest Bronze Age/early Phoenician period to Late Roman/Byzantine period (c. 750 cal. BC–cal. AD 650)

There are no radiocarbon dates for the sediments covering this section in the Xemxija cores, but the calculated ranges in Xemxija 2 at 2.57 m showed a decrease in the saline marshland, increasing influence from the nearby sea, and a reappearance of the perennial freshwater stream at about 750 cal. BC as indicated by *P. moussonii/M. similis*. The same signature was found in Xemxija 1 slightly further up at 2.1 m, but the calculated age range is several hundred years younger and there is no overlap. Nonetheless, the reappearance of this snail still fell into the period. *P. moussonii/M. similis* were the only freshwater snails found in this section. Land snails were generally very scarce in both cores from Xemxija, and among the few found, ubiquitous species dominated. No leaf litter species were recovered, whilst open country species were very scarce.

At Wied Żembaq, the brackish water saline marshland species *O. myosotis* was now very scarce, possibly indicating that the freshwater input into the valley was even more limited now than it was before. The amount of leaf litter species also decreased, while open country/karstland species and ubiquitous snails prevailed.

At Mġarr ix-Xini, the radiocarbon chronology is also insecure, but the picture is similar to that of the previous period. The presence of several grape pips of *Vitis vinifera*, dated to the Punic period, show that vines had meanwhile been imported and grew successfully on Gozo (see Chapters 3 & 7).

In the Marsa 2 core, initially deposits dated to the start of that period still contained quite abundant and diverse freshwater snails, but by the end of the period, only *P. moussonii/M. similis* indicated the presence of a freshwater stream. The rare occurrence of *Planorbis* sp. pointed to a slow-moving/stagnant water body in the plain. Ubiquitous snails were dominant, followed by open country/karstland species and a few leaf litter snails.

The situation at Marsaxlokk, a core with a less secure radiocarbon chronology but covering the period in question, revealed an absence of perennial freshwater at the coring site. Ubiquitous snails predominated in the assemblages, followed by open country/karstland species. Leaf litter species were only found on two occasions. The presence of the coastal marshland species *O. myosotis* would indicate that some seasonal freshwater influence occurred.

4.8. Concluding remarks

Full molluscan analyses of snails belonging to all major habitat groups rarely feature in the Mediterranean literature. The results obtained through the *FRAGSUS Project* provide valuable insights into the past environment, landscape and climate that the study of only one singular habitat group could not have achieved on its own. The numbers of snails found varied greatly in the cores, but while they may not have reached statistically viable numbers in many of the samples, the marked variations themselves tell a story of episodes of severe erosion and environmental recovery when placed in context with the sediments in which they were found. The presence of specific indicator species helped to provide insight as to what environments were present in the catchment at any given time.

Although the cores, widely distributed in the Maltese Islands, did not cover the same time intervals, together they covered the different periods of Malta's prehistory and history, allowing a more or less continuous picture to emerge. Few of the deposits dating to the early Holocene, prior to the arrival of the first settlers, contained leaf litter species that would support the notion of a previously forested or densely vegetated environment, at least within the catchments of the coring sites. When the first settlers arrived, possibly around 6000 cal. BC, the non-marine molluscs showed a predominantly open landscape and freshwater habitats in Salina and Xemxija, but the people probably faced an environment that had recently recovered from a prolonged drought, during which rare torrential rainfall caused severe erosion, possibly as a result of the 8.2 ka BP event.

The rise of the Neolithic and flowering of the Temple Culture occurred during a relatively humid climatic period: freshwater was abundant at Xemxija, Salina and, on a smaller scale, at Wied Żembaq and leaf-litter species which suggest dense vegetation in favoured sites, although much of the landscape was lightly vegetated. Once agriculture started, it is not clear whether the frequently occurring soil erosion episodes resulted from vegetation removal or modification by cultivation and landscape disturbance caused by people and their livestock, or from natural processes relating to the removal of vegetation by drought. It is likely that all these processes were involved, as they are today. Towards the end of the Temple Period, the species diversity and abundance of the non-marine molluscs became severely reduced, especially leaf litter and freshwater taxa. This is suggestive of desiccation and/or land degradation. Furthermore, the presence of marine molluscs at Xemxija indicated the breaching or overtopping of the bay-bar during storms.

The Bronze Age seems to have been initially characterized by rather dry climates and very little dense vegetation, for instance at Wied Żembaq. By about 2000 cal. BC increasing freshwater and leaf-litter taxa seem to indicate a rise in effective moisture, an environment which may have persisted with some fluctuations until the Roman Period, when the assemblages in the cores at Xemxija and Marsa are consistent with the drying of freshwater bodies and decreases in dense vegetation, most probably the result of increasing climatic aridity that seems to have persisted to the present day.

4.9. Notes on selected species

The analyses above were based on several indicator species, which have specific habitat requirements. Among these, some species are today extinct, whilst others had no previous palaeontological record in the Maltese Islands suggesting that some might be recent introductions (compare Table 4.1, after Giusti *et al.* 1995).

4.9.1. Extinct species:

Gyraulus (Armiger) crista (Linnaeus 1758)
This freshwater species occurs in perennial shallow waters of a wide variety of habitat types including ponds, lakes and coastal lagoons with abundant aquatic vegetation (Heino & Muotka 2005; Zettler & Daunys 2007; Zealand & Jeffries 2009). It tolerates freshwater to water with low salinity (Seddon *et al.* 2014) and can resist periods of partial drying (Giusti *et al.* 1995).

While only one juvenile specimen had been found by Giusti *et al.* (1995) in the Quaternary deposit of Wied tal-Baħrija, 36 specimens were found in the Salina Deep Core in association with other extinct species. As the samples in this core did not contain material post *c.* 2500 cal. BC, it is unknown when this species became extinct. Sub-fossils of this species have recently been found together with *Oxyloma elegans*, in an undated Holocene deposit at Salini (Cilia & Mifsud 2012).

Bulinus (Isidora) cf. *truncatus* (Audouin 1827) complex
Specimens of this freshwater species have been found in Xemxija 1, Marsa 2 and in the Salina Deep Core. This species is indicative of a variety of perennial flowing and standing water bodies, where it lives on the banks among vegetation and on stony beaches (Giusti *et al.* 1995; IUCN 2017). Extinct today from the Maltese Islands, it was found in deposits pre-dating the end of the Temple Period in Xemxija 1 and in the upper half of the Salina Deep Core. In the Marsa 2 core it was last found in deposits dated to the Late Bronze Age/Early Phoenician Period.

This species is an intermediate host for the schistosomiasis (bilharzia) parasite, and the disease has been traced back to Neolithic times in Chad and in Egypt, where it is likened with the Aaa disease (King & Bertsch 2015). It is possible that locally, *Bulinus truncatus* were also an intermediate host for the parasites causing the disease (trematode worms of the genus *Schistosoma*), which then could have negatively affected the local human and animal populations. Untreated, infection with the parasites is deadly in *c.* 60 per cent of cases.

Oxyloma elegans (Risso 1826)
A freshwater-wetland species associated with areas bordering a perennial stream, where it lives on permanently wet ground, but also on plants in the water (Giusti *et al*. 1995; IUCN 2017). Extinct today from the Maltese Islands, it was found in good numbers in Xemxija 2 from the lowermost deposits onwards (*c.* 7000 cal. BC) with interruptions up until shortly after the end of the Temple Period. In Xemxija 1 it was found between the early Temple Period (from *c.* 4000 cal. BC) and deposits dated to the Bronze Age at around 1500 cal. BC. In the Salina Deep Core and in Marsa 2, it only occurred once, in a storm deposit dated to the Tarxien (late Neolithic) phase, while in Marsa 2 the storm deposit cannot be dated more closely than before the end of the Late Bronze Age/early Phoenician period.

Vertigo cf. *antivertigo* (Draparnaud 1801)
This now locally extinct hygrophile species lives among decomposing plant material and under flood debris in swampy meadows, and river and lake margins that

may be flooded occasionally, but never seasonally dry up (Giusti *et al.* 1995; Welter-Schultes 2012). Although its presence in Malta was based on specimens from a Quaternary deposit at Wied il-Baħrija where it occurred in association with *Oxyloma elegans* (Giusti *et al.* 1995), its occurrence preceded and outlived the latter species in both Xemxija cores by several hundred years. In the Salina Deep Core it was found only once, in a deposit dated to *c.* 6000 cal. BC. In Marsa 2, one specimen was found in a Late Bronze Age/early Phoenician deposit.

4.9.2. Species with no previous fossil record:

Lauria cylindracea (Da Costa 1778)
This is the only woodland 'indicator species' in the Maltese Islands, where today it occurs in remnants of forest and in maquis communities under leaf litter. With no palaeontological record, its introduction date to the Maltese Islands was unknown (Giusti *et al.* 1995). *Lauria cylindracea* was found in small numbers in the Xemxija 2 core. The deposits are not closely dated, but it would appear that the species may have been introduced to the area around 4000 cal. BC, possibly in conjunction with olive tree saplings that were planted there, as indicated by the pollen from Xemxija 1 (see Chapter 3). As the olive is not native to Malta, it must have been imported, when the roots would have been covered with soil and leaf litter that could have contained this tiny snail species. The species occurred last in Xemxija 2 core deposits that were not closely dated, but may possibly be from around 2000 cal. BC, at a time when in the same core *Vertigo* cf. *antivertigo* became extinct and other freshwater/wetland snail species disappeared.

4.9.3. Other indicator species:

Truncatellina callicratis (Scacchi 1833)
The species is associated with very dry, calcareous grassy sites, open rocky hillsides, and above all, leaf litter, where, in the Maltese Islands the evidence suggests, it is mainly found (Giusti *et al.* 1995). It has not been reported from the Quaternary deposits of the Maltese Islands, but a few shells were found in the archaeological excavations at the Xagħra Brochtorff Circle in Gozo, dated to the Temple Period (Schembri *et al.* 2009). Its presence was noted in all coring sites except Marsaxlokk and its earliest occurrence could be noted in Xemxija 1 and the Salina Deep Core, in both instances in deposits dated to *c.* 5900 cal. BC.

Ferussacia (s.str.) *folliculus* (Gmelin 1791)
Another leaf litter species, characteristic of damp habitats. It withstands long periods of dryness dormant under stones, wood or litter (Giusti *et al.* 1995). Although today common and widespread in the Maltese Islands, it had no previous fossil record. Two sites revealed its occurrence since prehistory – Wied Żembaq (*c.* 800 cal. BC) and, much earlier, the Salina Deep Core (*c.* 5300 cal. BC).

Pseudamnicola (s.str.) *moussonii* (Calcara 1841) and *Mercuria* cf. *similis* (Draparnaud 1805)
These were the most widespread and commonly occurring freshwater species. They were present in all cores except in Mġarr ix-Xini (Gozo) and in Marsaxlokk. Unless they were the only freshwater species present (as in Wied Żembaq), they appeared as pioneer species before any other freshwater snails and persisted longer, even when others had long vanished (e.g. Xemxija and Marsa). Both species are indicative of a perennial running freshwater stream and their shells look very similar, a secure distinction cannot be made on the basis of the shell alone. *Mercuria* cf. *similis* (Draparnaud, 1805) has no secure fossil record and is thus believed to be a relatively recent introduction to the Maltese Islands (Giusti *et al.* 1995). Although they are placed in different genera, both belong to the same family (Hydrobidae), share the same habitat and were thus listed in the graphs as *Pseudamnicola/Mercuria*.

Ovatella (Myosotella) myosotis Draparnaud 1801
A more terrestrial than aquatic species, it is always found close to beaches without strong wave movement. This brackish water species tolerates environments with low salinities and lives on the shores of pools in saline marshlands and valley mouths that reach the coast, where it is found amongst algae, under stones or wood and on muddy substrata (Giusti *et al.* 1995; Welter-Schultes 2012). As such, it is a good indicator of an environment with a steady freshwater influence close to the sea.

Cecilioides acicula (Müller 1774)
This widespread subterranean species has been regularly found in archaeological deposits in the Maltese Islands, often in very high numbers (e.g. Fenech & Schembri 2015), where it may be intrusive. This burrowing species lives among plant roots and deeply embedded stones, usually at depths of 20 to 40 cm below the soil, but depending on the substrata, it has been found at depths of two metres and more (Giusti *et al.* 1995; Boddington *et al.* 1987). This species occurred prominently in all cores investigated, which had been taken in alluvial plains and where sediments accumulated only by erosion processes. The presence of this burrower among other surface-dwelling snails in the samples suggests a tolerance and association with

severe erosion events that de-stabilized substantial amounts of soils of which this species was part. Where material was available for dating, these invariably resulted in radiocarbon age inversions, underlining the massiveness of these events.

Notes

1 For example, *Oxyloma elegans*, *Bulinus truncatus*, etc.
2 Two cores were extracted from Marsa in June 2002. Of these, the Marsa 1 core formed part of separate PhD projects by Frank Carroll (Queen's University Belfast) and by Katrin Fenech (University of Malta). For the *FRAGSUS Project*, Fenech's half of the unprocessed Marsa 2 core was subjected to similar investigations to those made for the Marsa 1 core. The aim was to get fresh data from Malta's largest water catchment, to compare and contrast the findings with Core 1 and, through radiocarbon and other dating, to put the results in a chronological context.
3 The Marsa 2 core was extracted by A.N. Terracore Ltd., whereas Salina Deep Core was extracted by SolidBase Ltd.
4 All sub-samples and residues are being kept at the Department of Classics and Archaeology, University of Malta.
5 After Ridout-Sharpe 1998, 338.
6 Another core, MX2, was extracted at less than a metre distance from the coring site of MX1. It was one metre long and extended from 1–2 m in depth. The contents of MX2 were analysed, the molluscan assemblages resembled the ones of MX1 and reflected the energy-driven changes in the depositional environment. The molluscan spreadsheet for MX2 is provided in Appendix 5.
7 These are thought to be associated with the production of wine and work by the Superintendence of Cultural Heritage has shown that production could have started in Punic times (see also Jaccarini & Cauchi 1999 for the Mġarr ix-Xini Regional Park Project; Bonanno 2008; Pace & Azzopardi 2008).
8 The mechanical retrieval of the cores from Marsa was sponsored by Ms Linda Eneix through the OTS Foundation in 2002.
9 Radiocarbon age inversions have been detected in similar coring locations in other countries, where they were found to be a consequence of re-deposition of old sediments (see Stanley & Hait 2000; Angulo *et al*. 2008).
10 The 8.2 ka BP event denotes a global abrupt cold event that resulted in an aridity crisis, which interrupted the humid Early Holocene. Evidence of this event, which lasted several hundred years, was found in the Mediterranean in Spain (Gonzales-Samperiz *et al*. 2009), North Africa (Benito *et al*. 2015), Sicily (Tinner & Lotter 2001), France (Magny *et al*. 2009) and the eastern Mediterranean (Pross *et al*. 2009).
11 In Xemxija 1, the deposits attributed to the Bronze Age span from 465 to *c*. 326 cm, and in Xemxija 2 from *c*. 390 to *c*. 265 cm. The upper limits of these ranges were assigned according to the sedimentation rates calculated by Rowan McLaughlin.

Temple landscapes

The ERC-funded *FRAGSUS Project* (*Fragility and sustainability in small island environments: adaptation, cultural change and collapse in prehistory, 2013–18*), led by Caroline Malone (Queens University Belfast) has explored issues of environmental fragility and Neolithic social resilience and sustainability during the Holocene period in the Maltese Islands. This, the first volume of three, presents the palaeo-environmental story of early Maltese landscapes.

The project employed a programme of high-resolution chronological and stratigraphic investigations of the valley systems on Malta and Gozo. Buried deposits extracted through coring and geoarchaeological study yielded rich and chronologically controlled data that allow an important new understanding of environmental change in the islands. The study combined AMS radiocarbon and OSL chronologies with detailed palynological, molluscan and geoarchaeological analyses. These enable environmental reconstruction of prehistoric landscapes and the changing resources exploited by the islanders between the seventh and second millennia BC. The interdisciplinary studies combined with excavated economic and environmental materials from archaeological sites allows Temple landscapes to examine the dramatic and damaging impacts made by the first farming communities on the islands' soil and resources. The project reveals the remarkable resilience of the soil-vegetational system of the island landscapes, as well as the adaptations made by Neolithic communities to harness their productivity, in the face of climatic change and inexorable soil erosion. Neolithic people evidently understood how to maintain soil fertility and cope with the inherently unstable changing landscapes of Malta. In contrast, second millennium BC Bronze Age societies failed to adapt effectively to the long-term aridifying trend so clearly highlighted in the soil and vegetation record. This failure led to severe and irreversible erosion and very different and short-lived socio-economic systems across the Maltese islands.

Editors:
Charles French is Professor of Geoarchaeology in the Department of Archaeology, University of Cambridge.
Chris O. Hunt is a Professor in the School of Biological and Environmental Sciences, Liverpool John Moores University, Liverpool.
Reuben Grima is a Senior Lecturer in the Department of Conservation and Built Heritage, University of Malta.
Rowan McLaughlin is Senior Researcher in the Department of Scientific Research at the British Museum and honorary research scholar at Queen's University Belfast.
Caroline Malone is a Professor in the School of Natural and Built Environment, Queen's University Belfast.
Simon Stoddart is Reader in Prehistory in the Department of Archaeology, University of Cambridge.

Published by the McDonald Institute for Archaeological Research,
University of Cambridge, Downing Street, Cambridge, CB2 3ER, UK.

Cover design by Dora Kemp and Ben Plumridge.

ISBN: 978-1-902937-99-1

UNIVERSITY OF CAMBRIDGE

ISBN 978-1-902937-99-1
9 781902 937991