McDONALD INSTITUTE MONOGRAPHS

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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*

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FRAGSUS

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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).*

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Contents

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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 1

The geology, soils and present-day environment of Gozo and Malta

Petros Chatzimpaloglou, Patrick J. Schembri, Charles French, Alastair Ruffell & Simon Stoddart

This chapter sets the scene in terms of the geology and present-day climate, vegetation and soils of the Maltese Islands. Geology and faulting has had a huge influence on topography, soils and vegetation, and in turn on the nature of human use and exploitation of the islands. All of these themes are further developed below (and in *FRAGSUS* Volumes 2 and 3), giving time-depth to the sequences of climatic, environmental and landscape changes throughout the Holocene.

1.1. Previous work

The geological formations of Maltese Islands received little attention from scholars before the nineteenth century AD, in common with other parts of Europe. Nonetheless, ancient Greek authors made the first surviving references to fossils found elsewhere in the Mediterranean (e.g. Xenophanes of Colophon, born about 570 BC and Origen, AD 185–254). A number of early advances in the stratigraphic study of geology were made by British scholars such as Smith (1769–1839), following the incorporation of Malta into the British Empire in 1800, when the focus and expertise on geological stratification commenced. Commander Thomas Abel Brimage Spratt made the first comprehensive geological descriptions of the islands, including the identification of chert outcrops (Spratt 1843, 1854). He was followed by John Murray who produced a review of the geology of the islands in 1890 (Murray 1890). His work was focused on oceanic sedimentation, an expertise he gained on the Challenger Expedition (1872–6) and his interpretations demand respect, even if they are not entirely correct. Murray's work stimulated John Henry Cooke, an expatriate teacher of English, to produce a series of detailed and highly considered studies on individual geological features (Cooke 1891, 1893a–c, 1896a–c). They included the only accurate, comprehensive macroscopic investigation of the chert outcrops of the Maltese Islands (Cooke 1983b), which was considered very high-quality research at the time. They presented a high level of detail and largely accurate interpretation in contrast to more generic geological work of the time (Zammit Maempel 1977; Gatt 2006a & b, and references therein).

Research on the geology of the Maltese Islands continued during the twentieth century, when researchers focused on a range of features. A typical example was Hobbs (1914), who interpreted and described many of the faults and structures of the islands. In addition, substantial detailed information on the structure of the islands is contained in the study of water resources by Morris (1952) and Newbery (1968). The recent long-term research of Martyn Pedley is of particular significance as he has observed and published on the full spectrum of Maltese geology (Pedley 1974, 1975, 1978, 1993, 2011; Pedley *et al*. 1976, 1978, 2002). This includes a modern geological map of the Maltese Islands (Pedley 1993) which is still the basis of the present official geological maps published by the Maltese Government (https://continentalshelf.gov.mt/en/Pages/Geological-Map-of-the-Maltese-Islands.aspx). Pedley's work and that of other contemporary workers, laid the foundations for the modern study of the geology, geomorphology and palaeoenvironment of the islands (Pedley & Bennett 1985; Pedley *et al*. 2002; John *et al*. 2003; Magri 2006; Föllmi *et al*. 2008; Gruszczynsk *et al*. 2008; Baldassini & Di Stefano 2015; Galea 2019; Scerri 2019; and references therein). More recently there has been a focus on the now submerged continental shelf around the Maltese Islands associated with pre-Holocene archaeological and palaeoenvironmental investigations around the coasts (Hunt 1997; Micallef *et al*. 2013; Foglini *et al.* 2016; Harff *et al.* 2016; Prampolini *et al*. 2017).

1.2. Geography

Malta is made up of a small group of three principal islands – Malta, Gozo, Comino, and a number of minor islets and rocks (Fig. 1.1), with a total land surface of 316.75 sq. km. It is characterized by high hills or plateaux (Ta' Dmejrek on Malta is 253 masl and Ta' Dbieġi on Gozo is 187 masl) separated by deeply incised valleys which are characteristically orientated southwest–northeast. Much of the remaining non-urban landscape is dominated by agricultural land with terraced fields on hilly ground to the north of Malta and on Gozo. Although past water bodies have been reported on the surface of the islands, there are today no lakes, rivers or permanent streams, and only some springs and coastal wetland areas.

Malta and Gozo are the largest islands (respectively 245.86 sq. km and 67.1 sq. km), while Comino and Cominotto, which are found in the narrow channel between the main islands, are smaller at 2.8 sq. km and 0.1 sq. km (9.9 ha), respectively. The Maltese Islands lie at the centre of the Mediterranean Sea, with a southeast–northwest orientation, between Sicily and the North African coast (Fig. 1.1). They are far from any mainland, located *c*. 96 km south of Sicily, about 300 km east of Tunis and 290 km north of the Libyan coast (Cassar *et al*. 2008; Schembri, P.J. 2019). In spite of their small size, these islands occupy a very

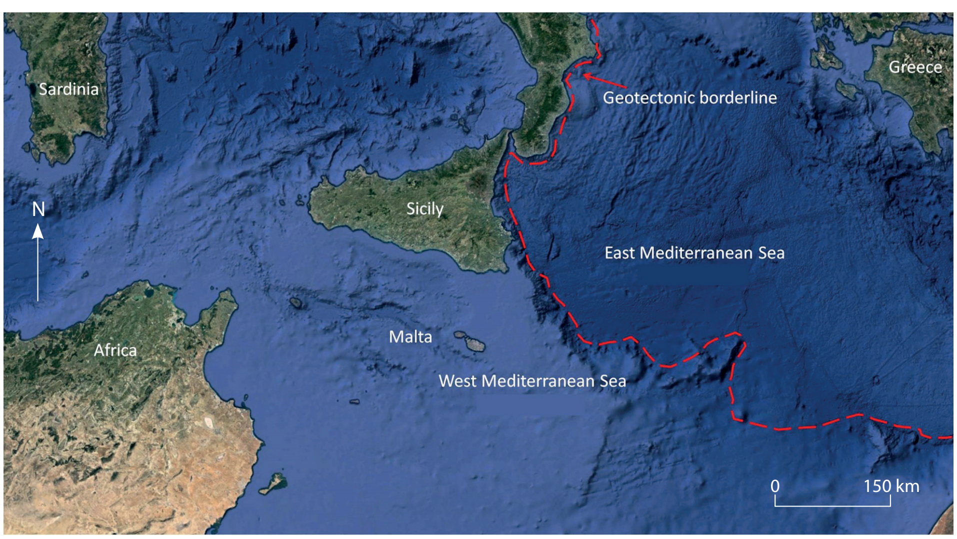

Figure 1.1. *The location of the Maltese Islands in the southern Mediterranean Sea with respect to Sicily and North Africa (P. Chatzimpaloglou).*

significant location within the broader Mediterranean region (Stoddart 1999). Their location in the Sicilian Channel, the main navigational seaway connection between the eastern and western Mediterranean, with the presence of exceptional natural harbours, gave the Maltese Islands an indisputable strategic importance (Blouet 1984; Pedley *et al*. 2002).

1.3. Geology

It is difficult to distinguish when exactly the basin which contains the Maltese Islands began to form. Some authors place this at 150 million years (when Pangea began to break into continents), whilst others suggest 100 million years ago (when Europe split from North America and started moving towards North Africa) (Pedley 1974; Puglisi 2014). Regardless of exactly when this occurred, the progressive approach of the European and African continents transformed the intermediate zone (Tethys seaway) between them, the forerunner of the present day Mediterranean Sea, and created the foundations of the central Mediterranean where the Maltese Islands are located. This, however, was not a simple process, but included a variety of complex movements and caused many stresses to the continents' margins. Moreover, the oceanic crust at the margin of the African continental plate that has subducted beneath the Eurasian plate brought up ocean sediments and slivers of ocean crust to form mountainous coasts or islands, with associated volcanism and orogeny (Pedley 1974; Galea 2007; Puglisi 2014). The African plate is still moving towards the Eurasian plate today. The Maltese Islands have a key position in this environment as they lie in what was originally a shallow sea (depth below 200 m) at the junction of the western and eastern Mediterranean basins (Fig. 1.1). This area called the 'Sicilian-Tunisian Platform,' and also known as the 'Pelagian Block,' represents the foreland margin of the African continental plate and consists of massive marine carbonate deposits (Pedley 1974). Extensional tectonics and the associated uplifting in the central parts of the Pelagian Block as a result of the development of the Pantelleria Rift System in the Late Miocene gave rise to what today are the Maltese Islands to the northeast and the island of Lampedusa to the southwest of the rift (Reuther & Eisbacher 1985; Dart *et al*. 1993; Galea 2007, 2019). This rifting also resulted in deep trenches (grabens) between the Maltese and Lampedusa islands, accounting for the deep water to the east and southeast of Malta in an otherwise shallow sea.

Inevitably, the location of the Maltese Islands in this broader geological environment has shaped the type of rock formations found on them. Maltese rocks are composed almost entirely of shallow to medium-depth marine sedimentary formations, mainly of the Oligo-Miocene age (*c*. 30–5 ma BP) with a variety of scattered freshwater and terrestrial deposits of limited extent and rare brackish and marine deposits of Quaternary age. The Oligo-Miocene marine sediments are most comparable with the mid-Tertiary carbonate limestones occurring in the Ragusa region of Sicily to the north, in the Pelagian Islands and in the Sirte Basin of Libya to the south (Pedley *et al*. 1978; Schembri 1994). There are five main rock formations, which are present in a simple succession with a number of hiatuses (Oil Exploration Directorate 1993; Pedley *et al.* 1976, 2002; Zammit Maempel 1977; Galea 2019; Scerri 2019). These, starting from the bottom, are: a) the Lower Coralline Limestone, b) the Globigerina Limestone, c) the Blue Clay, d) Greensand and e) the Upper Coralline Limestone (Figs. 1.2 & 1.3; Table 1.1). The Lower Coralline Limestone, Globigerina Limestone, and Upper Coralline Limestone are in turn composed of a number of members.

Table 1.1. *Description of the geological formations found on the Maltese Islands.*

Geological time (youngest to oldest)	Formation	Description	Thickness
Miocene	Upper Coralline Limestone	Shallow marine limestone with abundant coral-algal mounds and reefs, commonly altered to micrite and sparite	0.70–175 m; moderate to very high permeability (especially where karstified)
	Greensand	Friable, glauconitic argillaceous sandstone, moderate permeability	0.5–15 m
	Blue Clay	Massive to bedded grey/blue shallow marine/offshore calcareous claystones with occasional to abundant marine fossils. Impermeable or an aquiclude	50–75 m
	Globigerina Limestone	Shallow marine, calcareous mudrocks with abundant fossils, poor permeability, phosphatized hardgrounds	20–227 m
Oligocene	Lower Coralline Limestone	Shallow marine limestones with spheroidal algal structures, abundant echinoid fossils. Well-cemented and permeable	100–140 m

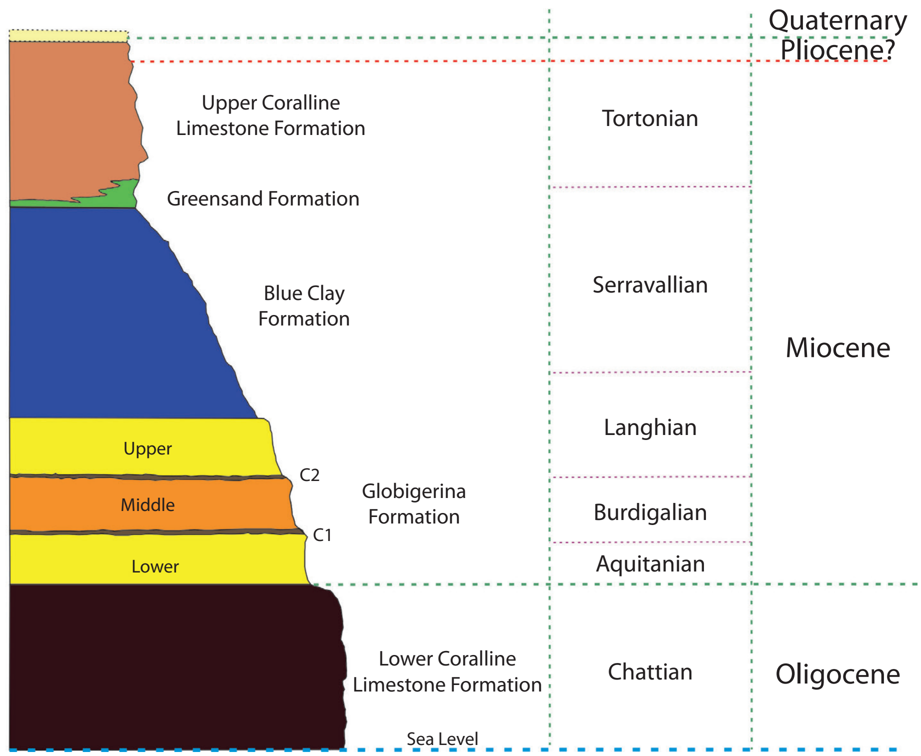

Figure 1.2. *Stratigraphic column of the geological formations reported for the Maltese Islands (P. Chatzimpaloglou).*

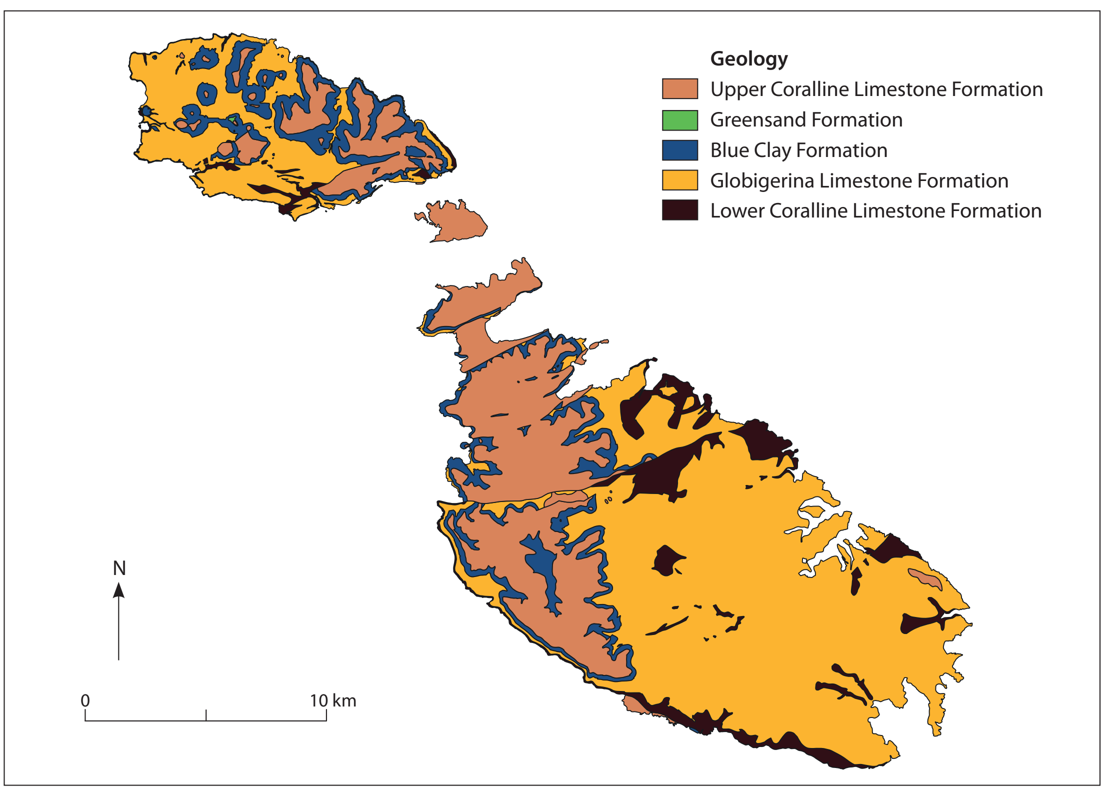

Figure 1.3. *Geological map of the Maltese Islands (P. Chatzimpaloglou, adapted from Pedley 1993).*

Although the geology of the islands appears rather simple with a similar stratigraphy, each formation, and, where present, its members, present different characteristics reflecting their depositional settings (Fig. 1.3). The stratigraphy of Malta is juxtaposed by normal faults, arranged as graben and half-graben. Gozo is structurally less complex with a 'layer-cake' stratigraphy, but has a more varied geology than Malta. The centre of Gozo is dominated by the Upper Coralline Limestone, resting on Blue Clay, where the Globigerina Limestone and Lower Coralline Limestone outcrops in coastal locations and the base of some valleys. Here erosion has occurred low enough in the succession to expose these formations and table-top plateaux or mesas of weathered and eroded Upper Coralline Limestone. Finally, Comino and its satellite islands are composed of only the highest layers of the Upper Coralline Limestone Formation.

1.4. Stratigraphy of the Maltese Islands

1.4.1. Lower Coralline Limestone Formation

The Lower Coralline Limestone is the oldest exposed rock formation on the Maltese Islands. It is a hard, pale grey limestone and contains beds with fossils such as corals and marine calcareous algae. Outcrops of this limestone are mainly restricted to coastal sections along the western coasts of Malta and Gozo (Fig. 1.4). It can be up to 140 m thick, forms sheer cliffs particularly on the southwest coasts of the islands because of the islands' tilt and its base cannot be seen above sea level. When found inland, this formation forms barren grey limestone-platform plateaux on which karstland develops (Schembri 1997), as for example those found in the west of Gozo (Fig. 1.5). The rocks comprising this formation are all indicative of having been laid down in a shallow sea and can be sub-divided into five different facies[1] of limestones (Pedley *et al*. 2002). These facies are: a) the Reef Limestone (Wied Magħlaq), b) the fine-grained Shallow Lime Muds (Attard), c) the cross-bedded Lime Sands (Xlendi), d) the Foraminiferal Limestones and e) the 'Scutella Bed' (Il-Mara) (see Gauci 2019 for detail). Felix (1973) suggested that the deposition of the Lower Coralline Limestone had initially been in a shallow gulf-type environment. In addition, succeeding beds provided evidence of increasingly open marine conditions during which algal rhodolites developed. Finally, a shallow marine shoal environment followed and was the dominant environment in all areas except southeastern Malta. In this area, calmer conditions prevailed in a protected deeper water environment (Pedley *et al*. 1976).

1.4.2. Globigerina Limestone Formation

The Globigerina Limestone Formation is a softer, yellowish fine-grained limestone that forms irregular slopes (Fig. 1.6) and is the most extensively exposed formation on these islands (Schembri 1997). It is named after *Globigerina*, a microscopic planktonic foraminifera, which is abundant in this formation. The Globigerina Limestone varies in thickness from some 20 to *c*. 227 m (Fig. 1.2), a characteristic which possibly signifies the onset of the warping of the sea bed and possibly the formation of depressions because of the collapse of the sea bed above underlying caverns (Pedley *et al.* 2002). The lithology and fossils in the rock show that this formation was originally deposited in deeper water between 40 and 150 m below the influence of

Figure 1.4. *Typical coastal outcrops of Lower Coralline Limestone, forming sheer cliffs (P. Chatzimpaloglou).*

Figure 1.5. *Characteristic geomorphological features developed on the Lower Coralline Limestone in western Gozo (Dwerja Point). The picture shows different sub-circular collapsed karstic features (a & b), while the green arrow points to the location of the chert outcrops (image © 2017 Google).*

wave action (Felix 1973). The unexpected occurrence of the planktonic foraminiferans, such as *Globigerina*, in this shallow-water depositional environment may be explained by a drift that brought these organisms into this shallower basin from the surrounding deeper water seas.

The Globigerina Limestone is divided into three members (Upper, Middle and Lower Globigerina Limestone) separated by two main phosphatic conglomerate beds (referred as the Lower Phosphorite Conglomerate Bed C1 and the Upper Phosphorite Conglomerate Bed C2), which do not exceed one metre in thickness (Fig.

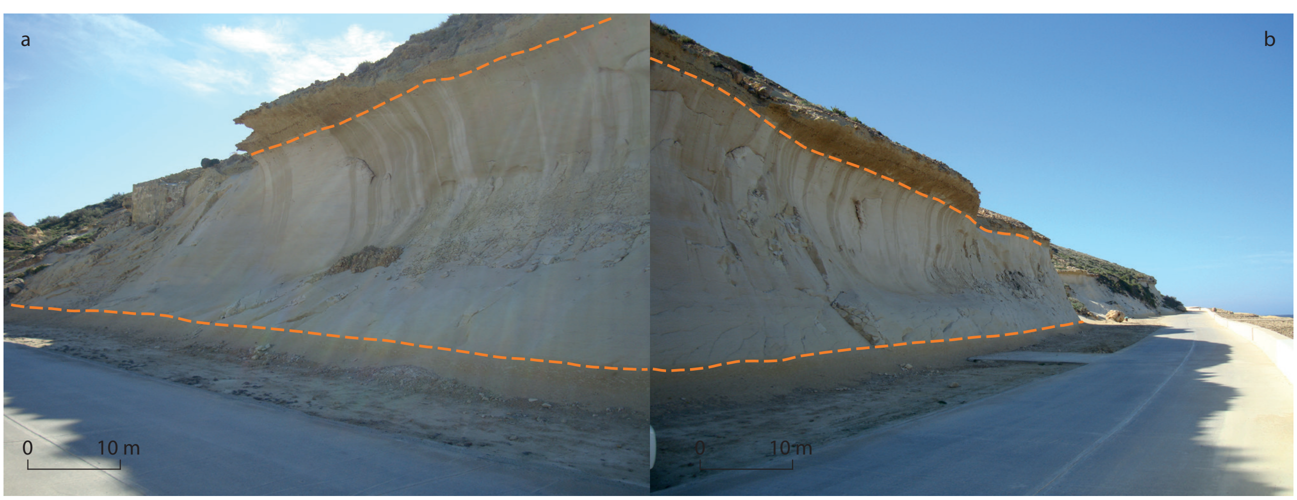

Figure 1.6. *The Middle Globigerina Limestone at the Xwejni coastline. It is one of the biggest outcrops of this unit and the orange lines highlight the two conglomerate layers, which are clearly presented in this location, and signify the transition to the Upper and Lower Globigerina units (P. Chatzimpaloglou).*

1.2); other minor phosphatic layers also occur (Baldassini & Di Stefano 2015). The upper and lower members have a pale yellow colour, while the middle member is pale grey (Fig. 1.6). The latter unit is considered to have been deposited during the time that the central Mediterranean Sea basin reached its deepest level. This could also explain the presence of chert outcrops, which have been found intercalating with the Middle Globigerina Limestone (Fig. 1.7).

The two conglomerate layers show evidence of erosion phases through the incorporation of many pebbles of brown-coloured limestones (Pedley *et al*. 2002). In addition, their presence indicates that the sea basin was influenced by water agitation and that the sea levels had probably fallen during their deposition. The colour of these layers is attributed to the high concentration of francolite (a phosphatic mineral) in the cements. The significant presence of this mineral suggests that the water streaming over the shallow sea bed at the time of deposition was rising from greater depths as an 'up-welling' current which was coming from the depths of the western Mediterranean basin and passing eastwards (Pedley *et al*. 2002). These inputs may also have been supplying material during the deposition of the Middle Globigerina Limestone that contributed to the formation of the chert outcrops.

The fine-grained particles comprising the Upper and Lower Globigerina Limestone members are only lightly cemented and therefore are easily worked as building stone. Indeed, the Lower Globigerina Limestone member, called '*franka*' in Maltese, has proven to be the most suitable building stone available on the islands. This is related to its uniform texture and explains why most of the buildings of the Maltese Islands, until recently, were built from this unit. Its texture, in addition to its extensive exposure on Malta and Gozo, has contributed to the smoothing of the topography of the islands. The thin fine sandy/silt loam soils developed on this formation are intensively cultivated and terraced.

1.4.3. Chert outcrops

The existence of chert outcrops has been long reported (Cooke 1893a), but little is known about their characteristics and the conditions under which they formed. Archaeological research has revealed that these chert

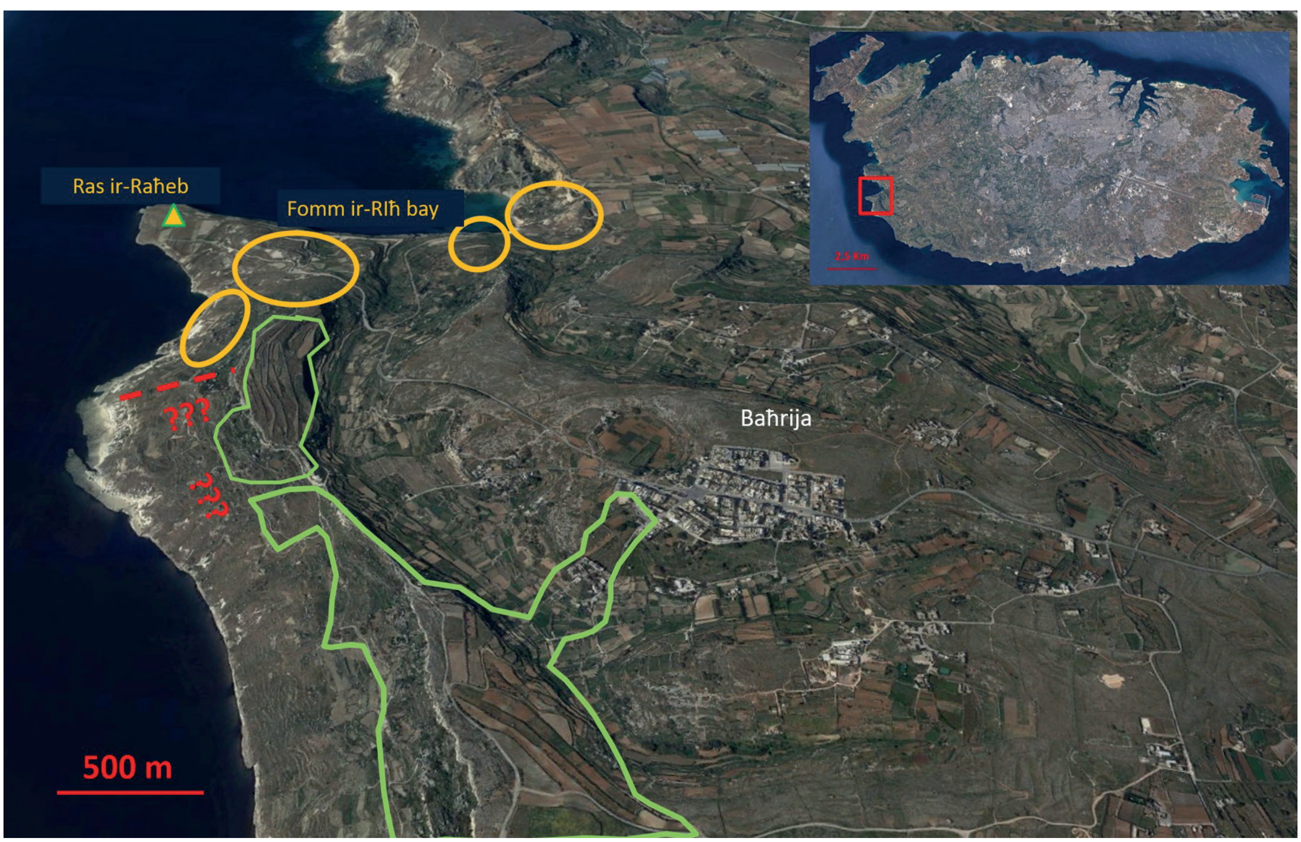

Figure 1.7. *An overview of the area investigated in western Malta. It presents the locations of chert outcrops (yellow lines) and the areas investigated during fieldwork (green lines) (image © 2017 Google).*

Figure 1.8. *The end of the major fault system of Malta (Victoria Lines) at Fomm Ir-Riħ, with chert outcrops to either side (P. Chatzimpaloglou).*

rocks were used by the prehistoric inhabitants (Malone *et al.* 2009a; Vella 2009). The Middle Globigerina Limestone member has extensive exposures in both islands of Malta and Gozo, but not all of them present chert outcrops. Recent fieldwork has revealed that chert outcrops were present only on the western parts of both islands in bedded form (Chatzimpaloglou 2019; Chatzimpaloglou *et al*. 2020).

The main chert outcrops on Malta were located in the Fomm ir-Riħ Bay area at the end of the Great Fault (Fig. 1.8), which is a major tectonic feature of Malta, and are considered more extensive than those on Gozo. The chert outcrops on Gozo were found at Dwejra Point, close to Fungus Rock (Fig. 1.9). The area is characterized by massive karstic features which could have been enhanced by past tectonic activity. The investigation of both exposures showed that nodular chert was present at the top and bottom of the unit, while bedded chert and/or silicified limestone were found in the middle part of the unit (Fig. 1.10). Generally, the outcrops present similar macroscopic characteristics with the bedded outcrops and have a higher concentration of carbonate material than the nodules.

1.4.4. Blue Clay Formation

The Blue Clay Formation is a very soft formation which generally forms either as low or rounded slopes when exposed on the surface or as very steep slopes where it cascades over the underlying Globigerina Limestone (Pedley *et al*. 1976, 2002). The thickness of the formation ranges from 50 to 70 m (at Fomm ir-Riħ Bay) (Fig. 1.11). Although the Blue Clay has macroscopic differences from the Globigerina Limestone, they have very similar characteristics at least to the Upper Globigerina member. The Blue Clay is composed of very fine-grained sediments, with a large proportion of them of foraminiferal origin. This suggests that this formation was deposited in a similar deep-sea depositional setting to the Globigerina Limestone (Pedley *et al*. 2002) and it can be regarded as a continuation of the Upper Globigerina Limestone member sedimentation in which clay material of terrigenous origin became progressively incorporated (Scerri 2019).

Basically, the main factor that distinguishes the Blue Clay Formation from most of the Globigerina Limestone is the presence of clay minerals. This clay content can only have come from a land source, although the possibility that part of the clay fraction originates from volcanic ash of an active volcano should not be excluded (Pedley *et al*. 2002). The quality of clay material mixed with the plankton-derived calcium carbonate detritus prevented the formation from reaching the same level of hardness as the limestones. The Blue Clay is the softest rock formation of the Maltese Islands and produces most of the fertile and water retentive soils found across Gozo and Malta, provided there is the level of plough technology to work these heavier soils. This would have been more

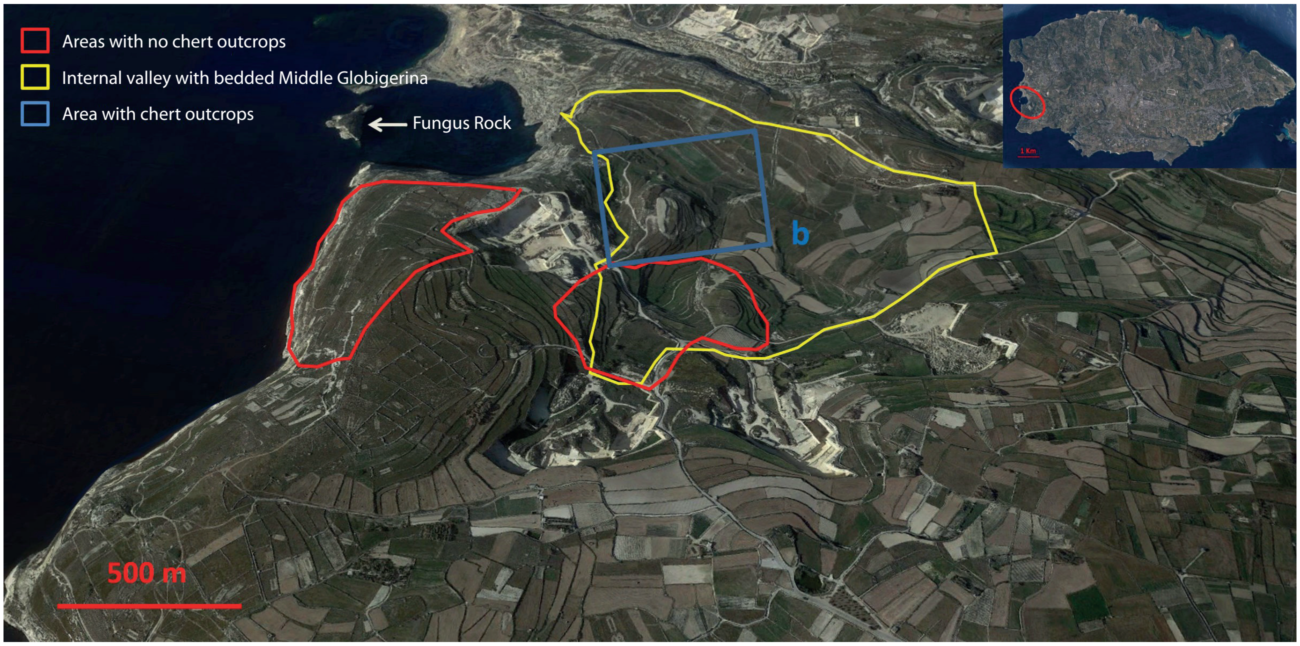

Figure 1.9. *An overview of the western part of Gozo where the chert outcrops are located. The yellow line orientates the internal valley, closer to Fungus Rock, the location of the chert outcrops (blue rectangle), and the areas investigated during fieldwork (red lines) (image © 2017 Google).*

Figure 1.10. *Chert outcrops: bedded chert (a & c), and nodular chert (b & d) (P. Chatzimpaloglou).*

Figure 1.11. *Four characteristic exposures of the Blue Clay formation on Gozo and Malta (P. Chatzimpaloglou).*

likely in Roman and later historical times (Margaritis & Jones 2008). It is also the basis of the perched aquifer as it forms an aquiclude to the porous rocks above. This perched aquifer was practically the only source of freshwater, apart from surface run-off, on the islands up to the British Period because of the springs that originated from it at the level of the Blue Clay-Greensand/Upper Coralline Limestone interface (Cassar *et al.* 2008). The upper parts of the formation show an increase in brown phosphatic sand grains and green grains of the complex mineral glauconite.

1.4.5. Greensand Formation

The Blue Clay transitions into the Greensand Formation with the Upper Coralline Limestone above (Pedley *et al.* 2002). The outcrops of this formation, when they are present, are very thin and only in Gozo do they exceed 11 m (i.e. 11 m at Il-Gelmus). The freshly exposed outcrops, mainly in man-made deep cuts, have a characteristic greenish colour influenced by the presence of glauconite (a complex, silicate based mineral). In contrast, the weathered exposures have an orange-brown colour formed by the oxidation products of this mineral. These Greensand outcrops represent the residue of a long period of submarine erosion and winnowing of sediments, probably related to the uplift of the Maltese area on the north flank of the Pantelleria Rift. Where present, the top part of the formation passes transitionally into the overlying Upper Coralline Limestone Formation. This same upper part of the formation, lying above the Blue Clay, acts as an important point of water seepage and springs in the stratigraphy of the Maltese Islands.

1.4.6. Upper Coralline Limestone Formation

The Upper Coralline Limestone Formation is situated at the top of the stratigraphic sequence of the Maltese Islands. It is a hard, pale grey limestone, similar to the Lower Coralline Limestone Formation. This limestone forms sheer cliffs of varying height and includes a similar content of fossils such as corals and coralline alga. It can be up to *c*. 170 m thick (Fig. 1.4), although it also forms thin hill cappings and limestone platforms (Schembri 1997). Karstic geomorphological features have been reported on this formation (Fig. 1.4), but not at the same scale as for the Lower Coralline Limestone. The Upper Coralline Limestone is mostly comprised of shallow marine sediments deposited in different marine or intertidal environments and it generally comprises four members (oldest first): Ghajn Melel, Mtarfa, Tal-Pitkal and Ġebel Imbark (Pedley 1978). The Upper Coralline Limestone is the only formation exposed on Comino and Cominoto, while it is fully developed in western Malta and eastern Gozo (Pedley *et al*. 2002).

1.4.7. Quaternary deposits

Although the main marine sedimentation processes ended between the Miocene and Pliocene, there are a variety of post-Miocene Quaternary deposits of limited areal extent scattered throughout the islands (Trechmann 1938; Pedley *et al*. 1976; Hunt 1997; Hunt & Schembri 1999). The best studied of these are the cave and fissure infilling sediments because of their at times abundant fossil vertebrate remains, which provide insights into the climatic conditions and palaeoenvironment at the time of deposition (see Hunt & Schembri 1999 and references therein). Other types of Quaternary deposits include marine highstand deposits, freshwater lake deposits, fluvial conglomerates and alluvial fan deposits, slope deposits, breccias and blown sand (aeolian) deposits.

Initial colonization of the islands by terrestrial biota is thought to have taken place during the Messinian Salinity Crisis when the central Mediterranean was mostly dry land connecting North Africa to Sicily and Europe (Hunt & Schembri 1999; Schembri 2003; Cassar *et al*. 2008). Following the refilling of the Mediterranean during the Zanclean, the Maltese Islands were isolated until the Pleistocene glaciations when they may have become connected to Sicily (but not to North Africa) during lowstands or, if not connected, to have been separated by a channel much narrower than at present because of low sea levels. This facilitated further waves of colonization of the islands by biota able to disperse over the land bridge or across the narrowed channel (Thake 1985a; Hunt & Schembri 1999; Schembri 2003; Cassar *et al.* 2008).

Based on a comparative study of the Maltese fossil Pleistocene fauna recovered from Quaternary deposits with that of the Sicily and the Italian mainland, Hunt and Schembri (1999) have postulated three main waves of colonization of the Maltese Islands by biota: an early influx during a marine regression in the Lower Pleistocene–early Middle Pleistocene (Oxygen Isotope Stage 16: 690,000 years BP), a series of influxes during the marine regressions of the late Middle Pleistocene (between Oxygen Isotope Stage 12: 490,000 years BP and Stage 8: 300,000 years BP), and a final influx during the sea level low-stand of the Last Glacial Maximum (Oxygen Isotope Stage 2: 22,000–17,000 years BP) when sea level fell by 120–130 m and probably connected the Maltese Islands with Sicily via a land bridge. After this the Maltese Islands gradually attained more or less their present configuration and coastline as sea levels rose (Furlani *et al.* 2013).

1.5. Structural and tectonic geology of the Maltese Islands

Tectonics have affected the geography and geomorphology of the Maltese Islands (Galea 2019). The main geological formations essentially lie horizontally, but are displaced at intervals by faults belonging to two main families: a) a series of east–northeast to west–southwest trending faults, and b) the Magħlaq and associated faults which trend northwest to southeast. The first family has been active since the Early Miocene and has resulted in the horst and graben systems most evident north of the Great Fault up to the South Gozo Fault. The second became active in the Late Miocene as a result of development of the Pantelleria Rift System. These faults were responsible for making the western side of Malta higher than the east, forming dramatic seacliffs of the western/northwestern shores (Alexander 1988; Bonson *et al.* 2007; Ruffell *et al*. 2018; Galea 2019). According to Lambeck *et al*. (2011) and Furlani *et al*. (2013, 2018), Malta appears to have remained tectonically stable throughout the Holocene.

The continental shelf around the Maltese Islands was progressively drowned by sea level rise since the Last Glacial Maximum (Furlani *et al.* 2013), such that there are well preserved terrestrial palaeo-landforms present on the present sea floor at depths shallower than *c*. -130 m (Foglini *et al.* 2016; Micallef *et al.* 2013; Prampolini *et al.* 2017). The post-Quaternary tectonics are restricted mainly to regional movements which have resulted in the submergence of archaeological features such as the 'cart-ruts' which enter the sea at St. George's Bay, St. Paul's Bay and Birżebbuġa (Hyde 1955; Furlani *et al.* 2013), and the presence of speleothems (cave mineral deposits, including stalagmites) in marine caves (Rizzo 1932; Furlani *et al.* 2018).

1.6. Geomorphology

The geomorphology of the Maltese Islands has been thoroughly described and discussed by a number

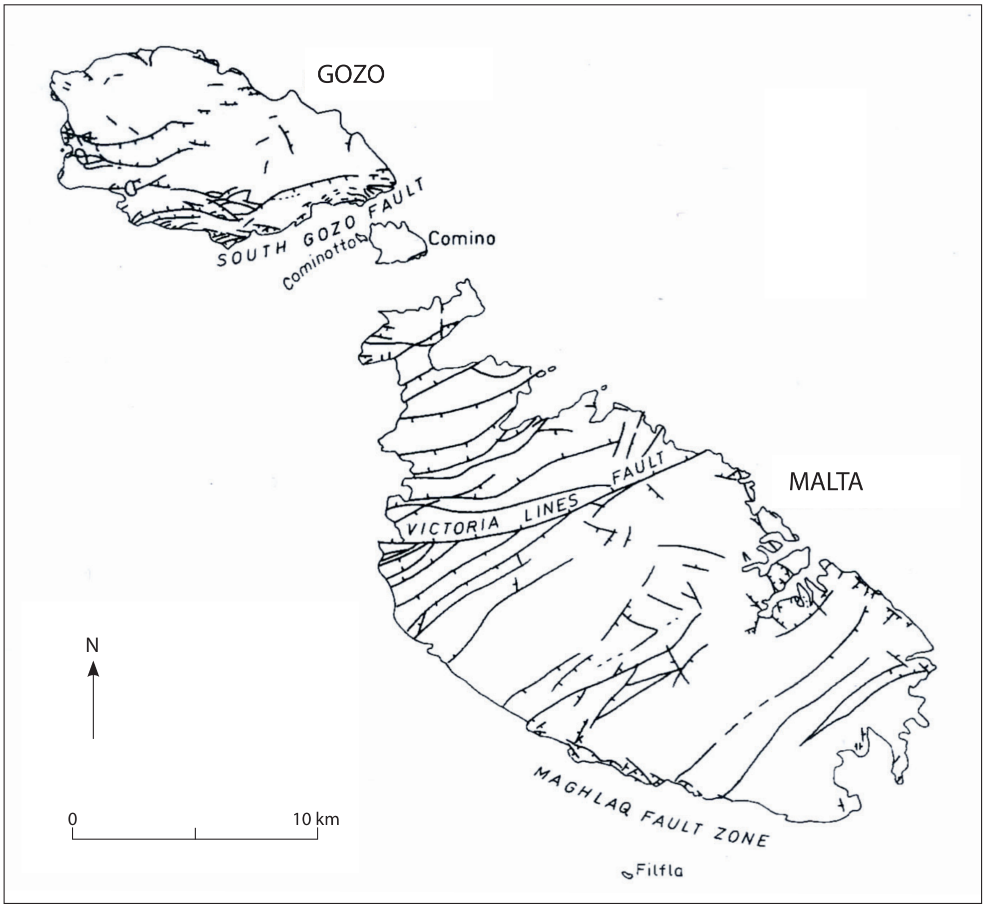

Figure 1.12. *Map of the fault systems, arranged often as northwest–southeast oriented graben, and strike-slip structures (after Gardiner* et al. *1995; Prampolini* et al. *2017) (P. Chatzimpaloglou).*

of scholars, including House *et al.* (1961), Vossmerbäumer (1972), Guilcher and Paskoff, (1975), Paskoff and Sanlaville (1978), Ellenberg (1983), Reuther (1984), Alexander (1988), Anderson (1997), Schembri (1993, 1994 & 1997) and Prampolini *et al.* (2017), and, most recently, in a multi-authored volume on the landscapes and landforms of the islands (Gauci & Schembri, 2019). The present account is based on these sources.

As already stressed above, the current geomorphological features of the Maltese Islands have been strongly influenced by the geological and tectonic status of the islands. Both Malta and Gozo are tilted towards the northeast which resulted the Lower Coralline Limestone along the west, southwest and southern coasts of the islands, and formed very steep to vertical cliff faces in most places rising straight from the sea. Along the east and southeast coast of both islands, but especially Malta, the tilt gives generally gently sloping shores, and where valleys open on the coast, drowned valleys form a ria and bay coastline. The Marsamxett and Grand Harbours are the prime examples of this.

On Malta, all five rock formations are only present north of the Great Fault and on the Rabat-Dingli uplands south of it. Elsewhere there are vast exposures of Globigerina Limestone which generally present a large-scale gentle folding which is responsible for the characteristic topography of plains, shallow depressions and low hills; in fact the only high ground in this part of the island is the Naxxar-Għargħur upland. Where the entire geological sequence is present, the Upper Coralline Limestone forms flat limestone-pavement karstic plateaux with steep cliff-like sides bordered by boulder screes at their base (Maltese: *rdum*) made by the slumping of blocks of rock from the cliff edge because of erosion of the underlying soft rock – the Greensand and/or Blue Clay. The eroded Blue Clay cascades down-slope to form taluses that cover the rock underneath (Globigerina Limestone). The Upper Coralline Limestone boulders also travel down-slope riding on the Blue Clay and where this happens on the coast, the result is a boulder-strewn shoreline.

Important and characteristic topographic features of the Maltese Islands are the *rdum* and *widien* (Schembri 1994, 1997). *Rdum* are important since they provide a very rough and dynamic terrain and as such have rarely been cultivated, thus providing refuges for many species of Maltese flora and fauna, which would have otherwise been extirpated from the heavily anthropogenically modified landscape. *Widien* are natural drainage channels formed either by stream erosion during a previous (post-Miocene) much wetter climatic regime, or by tectonism, such as the grabens of northern Malta and southern Gozo, or by a combination of the two processes. Most *widien* are now dry valleys and only carry water along their watercourses during the wet season. A few *widien* drain perennial springs arising from the perched aquifer at the Upper Coralline Limestone–Greensand/Blue Clay interface and have some water flowing in them throughout the year, attaining the character of miniature river valleys. By virtue of the shelter they provide and their water supply, *widien* are one of the richest habitats on the islands and are also extensively cultivated. The submergence of the mouths of some *widien* mainly caused by the tilt of the islands, has led in turn to the formation of wetlands of various types, providing yet another localized, semi-aquatic habitat type in an otherwise arid landscape.

1.7. Soils and landscape

It has reasonably been assumed that the seasonally dry and hot Mediterranean climate made the Maltese landscapes quite marginal for agricultural production especially since there were few natural springs originating from the perched aquifer, and what rain and surface run-off could be collected and stored was slim (Haslam 1969; Schembri 1997; Cassar *et al.* 2008). As a consequence, terracing was adopted extensively in Malta and Gozo to conserve soils and moisture and at the same time to create a more amenable landscape for subsistence based agriculture, although exactly when is a subject of debate (Fenech 2007; Grima 2004, 2008b; Micallef 2019) (see Chapters 5, 8 & 11). Like many other parts of the Mediterranean region, this landscape must have been prone to deforestation, drought and erosion, combined with intensive human activity (Bevan & Conolly 2013; Brandt & Thornes 1996; Hughes 2011; Grove & Rackham 2003), and these factors are the subject of much of this volume to follow. Today, the islands are characterized by highly terraced valleys between flat-topped limestone mesas, generally with substantial towns sprawling across these plateaux. The whole of the southeastern part of Malta, previously mainly agricultural with small scattered villages except for the harbour regions, is now being swallowed up by extensive urban development.

Maltese soils are relatively young and relate directly to the rock formations of islands. Previous studies have highlighted the low contribution of the climate to soil development and the great impact of human activities in their modification, particularly where there is cultivation, as being a valuable and practically non-renewable resource, natural soils have been translocated and mixed together and with various materials since the earliest of times (Lang 1960; Bowen Jones *et al.* 1961; Svarajasingham 1971; Farres, 2019). Possible trajectories of past soil development and change are further discussed in Chapter 5.

Lang's (1960) comprehensive study has laid the foundation for the understanding of Maltese soils and their development. This study identified three main types of soil: Carbonate Raw, Xerorendzinas and Terra soils. Of the four Carbonate Raw series soils, two are formed from Blue Clay parent material (Fiddien and San Lawrenz series), one from weathered Upper Coralline Limestone (Nadur) and one from dune sand (Ramla). These highly calcitic soils conform to an A/C profile, where the upper horizon directly overlies the parent material, and contain a very low level of organic content. The Xerorendizinas, which were divided into three series (San Biaġio, Alcol and Tal-Barrani), are largely formed from Globigerina Limestone parent material and also present an A/C profile. Normally grey, loose and powdery when dry, these soils have a high chalk and gypsum content with limited organic content (yet distinguishably more than the carbonate soils). Lastly, the Terra soils are found as *terra fusca* and *terra rossa*. Both are derived from Upper and Lower Coralline Limestone parent material and present an A/Bw/C profile. The Terra soils are well developed with little organic content (although more than the previous soils) and the notable presence of ferric hydroxide.

Maltese soils have most recently been studied as part of the MALSIS project, a Malta–EU co-funded programme with the objective of setting up a modern Maltese soil information system that includes a soils geo-database (Vella 2000, 2001, 2003). The MALSIS inventory recognizes seven soil groups of the World Reference Base for Soil Resources soil classification system (WRB 2014) that are present in the Maltese Islands. These are:

a) Calcisols (37 per cent), which are soils with a high proportion of translocated calcium carbonate and the most commonly occurring in the islands.
b) Leptosols (15 per cent), which are very shallow calcareous soils with a high gravel content that locally are found on exposed karstic plateaux

and *rdum*, usually associated with low steppic and low garrigue vegetation.

c) Cambisols (7 per cent), which are similar to Leptosols but deeper (>25 cm) and show some horizon development in the form of a subsoil layer (or B horizon), although this is very limited in Maltese cambisols.

d) Vertisols (7 per cent), which are soils with a high content of clay and characterized by deep cracks when dry and occur on the Blue Clay.

e) Luvisols (15 per cent), which are relict soils that formed under a previous wetter climatic regime, most likely during wet periods in the Pleistocene (see Chapter 5). The present climate does not form such soils, but it does modify them through the deposition of secondary calcium carbonate. Locally these soils have a reddish colour because of the presence of iron minerals and when undisturbed develop a surface layer of humus, a thin leached topsoil horizon, and a clayey and mineral rich subsoil. Such soils are found on flat or gently sloping karstland under high garrigue and maquis vegetation.

f) Arenosols, which are porous sandy soils with no or almost no clay content and are usually deep. Locally they develop in a limited number of areas were blown beach sand accumulated inland from the adjacent coast.

g) Regosols (19 per cent), which have been used as a 'bin-group' for soils that do not fit in any of the other local soil types. Such soils consist of broken down but otherwise practically unaltered parent material with no horizon development. Soils formed by mixing other soil types with powdered rock and anthropogenic waste are also classified as regosols.

1.8. Climate and vegetation

The present climate of the Maltese Islands is typically Mediterranean with characteristic mild, wet winters and hot, dry summers with ample sunshine (Chetcuti *et al.* 1992; Schembri 1993, 1994, 1997; Schembri *et al*. 2009; Galdies 2011). The climate is strongly bi-seasonal, particularly in terms of precipitation. Despite an average rainfall of 530 mm, most of it (*c*. 85 per cent) falls during the period from October to March. Precipitation is highly variable from year to year with some years having almost twice the mean annual rainfall and others half. The latter are known as drought years and a continuous run of such (Murray 1890; Blouet 1984) may have caused at least partial abandonment of the islands in the past. There may also have been the abandonment of marginal agricultural land because of a lack of irrigation water and crop failure, since local water resources were, directly or indirectly, entirely dependent on rainfall and the perched aquifer until the British period (Schembri 2003).

The mean monthly air temperature varies from 12 to 26° C, and rarely falls to zero for sufficiently long periods to affect plant growth (Haslam 1969; Chetcuti *et al.* 1992). The arid period extends from approximately the last third of March to the first third of September, with peak aridity reached between June and August and maximum temperatures of up to 43° C (Chetcuti *et al.* 1992). Ground (grass) temperatures may be much higher that the air temperature and values up to 49° C have been measured. Relative humidity is generally high, from 65–80 per cent, with wind prevalent throughout most of the year. This is important as it exposes dry un-vegetated soil to wind-winnowing, rendering already low-quality agricultural soils even more depleted.

The natural vegetation of the islands must be adapted to excess water during the wet season and to drought and heat in the dry season. Plant growth is thus restricted during the dry and hot summers with the main growing seasons being spring and, to a lesser extent, autumn (Haslam 1969; Haslam *et al.* 1977). This is reflected in the landscape which is generally green throughout the wet period, but appears mostly parched and bare of vegetation during the dry period given that many non-phanerophytes (phanerophytes = trees and shrubs) survive the dry season in the form of seeds (annuals) or some form of subterranean perennating organ (Haslam 1969; Schembri 1997).

The terrestrial vegetational assemblages of the Maltese Islands may be grouped into three categories, as follows: a) major communities that are part of the successional sequence towards the climatic climax, b) minor communities which are either specialized to occupy particular habitats or occupy habitats that are rare on the islands, or are relics from a previous ecological regime, now surviving in a few refugia, and c) vegetational assemblages of disturbed habitats, which are those occupying land subject to periodic disturbance, usually as a result of human activities, but also natural disturbances, such as the flooding of dry-valley (*wied*) watercourses following heavy rain (Schembri 1997). The present day vegetational assemblages of the Maltese Islands have been described by Haslam (1969), Lanfranco (1984, 1995), Lanfranco and Schembri (1986), Anderson and Schembri (1989), Schembri (1993, 1997) and Cassar *et al.* (2008).

These combined themes of chronology, climate, soils and vegetation will be developed further by the palaeoenvironmental data presented below in Chapters 2–5.

Notes

1 'Facies' is a term that provides a specific characterization of a group of rocks with distinct similar features. In sedimentary rocks, it embraces major features such as the main composition (e.g. quartz sand, clay or limestone facies), the sedimentary layering (e.g. cross bedded facies, etc.) or the main fossils. These are then related to an interpreted environment in which the sediments were deposited. Consequently, the rock can be referred to as beach-facies, lagoon facies, reef facies, and so on.

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.

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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