World Geomorphological Landscapes

Ritienne Gauci
John A. Schembri *Editors*

# Landscapes and Landforms of the Maltese Islands

Springer

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**Series Editor**

Piotr Migoń, Department of Geography, Faculty of Law, University of Wrocław, Wrocław, Poland

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*Editors*
Ritienne Gauci
Department of Geography
Faculty of Arts
University of Malta
Msida, Malta

John A. Schembri
Department of Geography
Faculty of Arts
University of Malta
Msida, Malta

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*This volume is dedicated to all those esteemed individuals who over the years have contributed to the success of the Department of Geography at the University of Malta.*

*A special mention goes to late Mrs. Marlene Schembri and late Mrs. Mary Abela.*

# Foreword

With a population of over 470,000 people in 2017 and an area of 316 $km^2$, Malta is the most densely populated country in the European Union and yet has a wide variety of landscapes, which makes the country a fascinating natural laboratory for the geographer and environment specialist. Indeed, one of the strong themes in both the landscape history of the islands and the contemporary study of its landforms is the impact people have made over millennia and are making on the natural environment some, but by no means all of it, being deleterious. Human impact is heightened by seasonal flows of tourists, with the islands hosting 2.3 million in 2017, a number which has doubled since 2009.

Malta is an archipelago of three main islands and a number of islets located in the central Mediterranean. Formed predominantly of limestone, it has been worked into its distinctive landscapes by a combination of physical processes. These include tectonic, karstic, marine and subaerial processes, with the latter influenced by high summer temperatures with pronounced drought conditions, cooler climatic episodes punctuated by periods of intense rainfall and flooding. As a result, coastal features of the islands include a number of landforms, with landslides and other erosional systems being conspicuous. Often generated under conditions of intense rainfall and exploiting underlying features of the sedimentary geology, landslides create distinctive landscapes and present a hazard threat to people and their activities. As far as marine environments are concerned, the Maltese Islands have a rich variety of coastal landscapes which include *inter alia*: high cliffs; rias; boulder beaches; coastal wetlands; coastal karst; sandy beaches and shore platforms, landscapes that have been shaped by a variety of marine processes and which include storms and possible tsunamis generated by distant earthquakes. Contemporary processes of economic development, many of which relate both to marine servicing industries in the harbours and to tourism in all areas, are also concentrated at the coast and are major forcing factors of human-induced landscape change.

This volume represents a considerable academic achievement on the part of its editors, and they are fully justified in taking considerable pride in the achievements of their writing team in producing a valuable addition to the international series on *World Geomorphological Landscapes*. As external reviewer of this volume, I have read and commented on every chapter and have been impressed, not just by how many individual scholars have been involved in producing high-level contributions, but also by the quality of the research upon which the chapters are based. Much of the writing and all of the editing has been expertly handled by the academic staff of the Department of Geography at the University of Malta. Alumni from this department, many of whom have been awarded Masters and Ph.D. degrees by research, have also contributed chapters. In contrast to many other volumes in the series, the *Landscapes and Landforms of the Maltese Islands* has its origin within a department of just four full-time academic staff, but which has clearly established itself a leading centre for the study of Mediterranean geomorphology.

Maltese landscapes and landforms are explored in twenty-nine chapters divided into three parts. The first part, entitled Background, deals with: the geographical context; central Mediterranean tectonics; the evolution of the sedimentary geology and key geomorphological features. The bulk of the volume comprises twenty-two local case studies, which explore and

critically review a wide array of detailed investigations encompassing: ria coastal landforms and their fortified imprints; landforms of the Neolithic; Malta's submerged landscapes; cave dwellers and their impacts; rural terraced terrains; sinkholes and solutions subsidence; palaeosoils; landslides; freshwater rock pools; the sandy cove of Xatt l-Aħmar; an intriguing study of Filfla islet and the impact of aerial bombing and naval bombardment on its morphology; a detailed study of an extreme wave-generated boulder beach at Xgħajra coast; the Il-Majjistral Nature Park and saline marshlands and coastal wetlands. An interesting discussion on the collapse of the world-famous sea arch, the Azure Window, on Gozo and its effect on health and well-being is followed by chapters on: sea caves and coastal karst; shingle beaches; threats to beach environments; shore platforms; tsunamigenic landscapes and the geomorphological impacts of ancient cart-ruts. The book concludes with a comprehensive review of landscape diversity and protection polices and a fine conclusion on the important theme of sustainability.

It is a pleasure to have been invited to write this foreword, and I have no hesitation in commending *Landscapes and Landforms of the Maltese Islands* without reservation to a wide audience. This should not only include academic readers, but also others who like me have been awestruck by the beauty and uniqueness of Maltese landscapes.

Liverpool, UK Prof. David K. Chester

# Series Editor's Preface

Landforms and landscapes vary enormously across the Earth, from high mountains to endless plains. At a smaller scale, nature often surprises us creating shapes which look improbable. Many physical landscapes are so immensely beautiful that they received the highest possible recognition—they hold the status of World Heritage Sites. Apart from often being immensely scenic, landscapes tell stories which not uncommonly can be traced back in time for tens of millions of years and include unique geological events such as meteorite impacts. In addition, many landscapes owe their appearance and harmony not solely to the natural forces. For centuries, and even millennia, they have been shaped by humans who have modified hillslopes, river courses, and coastlines, and erected structures which often blend with the natural landforms to form inseparable entities.

These landscapes are studied by Geomorphology—'the Science of Scenery'—a part of Earth Sciences that focuses on landforms, their assemblages, surface and subsurface processes that moulded them in the past and that change them today. Shapes of landforms and regularities of their spatial distribution, their origin, evolution and ages are the subject of research. Geomorphology is also a science of considerable practical importance since many geomorphic processes occur so suddenly and unexpectedly, and with such a force, that they pose significant hazards to human populations and not uncommonly result in considerable damage or even casualties.

To show the importance of geomorphology in understanding the landscape, and to present the beauty and diversity of the geomorphological sceneries across the world, we have launched a book series *World Geomorphological Landscapes*. It aims to be a scientific library of monographs that present and explain physical landscapes, focusing on both representative and uniquely spectacular examples. Each book will contain details on geomorphology of a particular country or a geographically coherent region. This volume presents the geomorphology of Malta—a European country in the heart of the Mediterranean realm. Malta, comprising an archipelago of 316 $km^2$ in total, may seem too small to afford a separate volume in the series. The authors of the book show us, however, that such a view would not do justice to the geomorphic landscape of Malta which represents striking diversity, especially along the coastline. Malta is a textbook of rock coast geomorphology and structural relief of limestone plateaus, but many other facets of the islands are revealed here, including spectacular geoarchaeology associated with megalithic temples. In fact, the multiple interrelationships between geomorphology and humans can be hardly better displayed than in Malta.

*The World Geomorphological Landscapes* series is produced under the scientific patronage of the International Association of Geomorphologists (IAG)—a society that brings together geomorphologists from all around the world. The IAG was established in 1989 and is an independent scientific association affiliated with the International Geographical Union (IGU) and the International Union of Geological Sciences (IUGS). Among its main aims are to promote geomorphology and to foster dissemination of geomorphological knowledge. I believe that this lavishly illustrated series, which keeps to the scientific rigour, is the most appropriate means to fulfil these aims and to serve the geoscientific community. To this end, my great thanks go to Dr. Ritienne Gauci and Prof. John A. Schembri for adding this book to

their busy agendas, successfully coordinating the large, multinational team of authors, and delivering such an exciting illustrated story to read and enjoy. I also acknowledge the excellent work of all individual authors who share their expert knowledge of Malta with the global geomorphological community. Finally, I thank Prof. David K. Chester for accepting the role of an external reviewer and ensuring that the final product is of the highest quality. On a more personal note, I had twice the privilege to visit Malta, to enjoy its natural scenery and to admire its cultural landscapes. The Maltese landslides, visited in the company of Prof. Mauro Soldati and his research group, are an unforgettable experience. I am sure that this book, through accessible storytelling and great images, will provide a stimulus to many geoscientists, who have not yet seen Malta, to add the islands to their planned geomorphological itineraries.

Piotr Migoń
Series Editor

# Contents

# Editors and Contributors

## About the Editors

**Ritienne Gauci** is a Lecturer in Physical Geography at the Department of Geography of the University of Malta. Her research interests are mainly in coastal geomorphic processes and resultant landforms, rocky coasts, geoheritage and melitensia cartography. She holds a B.A. (Hons) and M.A. in Geography from the University of Malta and a Ph.D. from the Department of Geography of the University of Portsmouth, UK. Ritienne is currently the national scientific representative for the International Association of Geomorphology (IAG), member of the British Society of Geomorphology (BSG) and the Royal Geographical Society (RGS-IBG). She is also on the committee board of the Malta Map Society and acts as consultant editor for the Malta Map Society Journal. She has authored and co-authored a number of papers, also in collaboration with European universities such as the University of Portsmouth, Liverpool Hope University, University of Trieste and University of Modena and Reggio Emilia.

**John A. Schembri** is a Professor at the Department of Geography of the University of Malta. He read Contemporary Mediterranean Studies and History as an undergraduate at the University of Malta. This was followed by post-graduate studies at Durham University from where he obtained an M.A. in the Geography of the Middle East and the Mediterranean and later a Ph.D. through the Department of Geography at Durham. In 2016 he was conferred D. Educ. (Honoris Causa) by Liverpool Hope University, UK, for his contribution to Geography. John lectures in Geography at the University of Malta and his publications range from coastal land use, historical geography to cartography. John is a Chartered Geographer and a Fellow of The Royal Geographical Society (with IGB). He contributes regularly to lectures at the International Ocean Institute.

## Contributors

**Maria Attard** is an Associate Professor, Head of Geography and Director of the Institute for Climate Change and Sustainable Development at the University of Malta. She studied at the University of Malta and completed her Ph.D. in 2006 at UCL (London). Maria is active in NECTAR and Steering Committee Member of the World Conference on Transport Research. She is Co-editor of the journal *Research in Transportation Business and Management*, Associate Editor of the journal *Case Studies in Transport Policy* and Co-editor of the Emerald Book Series on *Transport and Sustainability*.

**Brian Baily** is a Senior Lecturer in environmental geography and GIS within the Geography Department at the University of Portsmouth, UK. His research interests are coastal change, GIS for monitoring change, environment foot printing and land utilization mapping.

**Sara Biolchi** is research fellow at the University of Trieste (Italy), where she works as geologist and geomorphologist in coastal and karst areas. She collaborates in several international projects, co-funded by the European Union, which deal with water management and natural heritage of the karst environment. She obtained her Ph.D. in Geomorphology at the University of Modena and Reggio Emilia (Italy). She is author or co-author of more than 20 international and national papers and of about 40 contributions in national and international congresses.

**Malcolm Bray** is a Visiting Research Fellow in the Department of Geography at the University of Portsmouth, UK. He gained a Ph.D. in coastal geomorphology from the London School of Economics in 1996. His research interests include coastal sediment budgets, gravel beaches and reconstruction studies of high energy wave impacts. He has provided guidance to local and national authorities on sediment transport, beach erosion problems, shoreline management and coastal conservation.

**Kelly Briffa** was born in Ta' l-Ibraġ, Malta, in 1992. She holds a Bachelor of Science (Hons) degree in Biology and Chemistry from the University of Malta, and is currently studying Medical and Pharmaceutical Biotechnology at the IMC University of Applied Sciences, Krems, Austria. She has carried out extensive research on the effect of rockpool morphometry on the species richness of aquatic plants, and has recently co-authored papers and posters at the International Congress of the European Pond Conservation Network (EPCN).

**Keith Buhagiar** is a Ph.D. graduate in archaeology from the University of Malta specialising in Maltese Medieval and Early Modern cave-settlements, rural landscape development and related water management systems. Dr. Buhagiar is a visiting lecturer in Palaeochristian, Byzantine and Medieval archaeology with the Department of Classics and Archaeology and the Faculty of Theology, both at the University of Malta. Research interests include central Mediterranean, North African and Near Eastern water management systems, troglodytism and Mediterranean settlement location and distribution as well as scientific rural landscape investigation.

**Ivan Calleja** is a geographer and holds a B.A. (Hons) (Melit.) and an M.A. (Melit.) from the Geography Department of the University of Malta. He currently teaches Geography at secondary and tertiary levels. He is also Visiting Lecturer at the Department of Geography of the University of Malta. His research interests are in karstic processes and landforms, geosites and geotourism, soil erosion and land degradation processes in Mediterranean environments.

**Joanna Causon Deguara** is a geographer, with a B.A. (Hons) (Melit.) and an M.A. (Melit.) from the Geography Department of the University of Malta. Her research interests are in coastal processes, geomorphology of bouldered beaches and geomorphological mapping. In collaboration with the Geography Department of the University of Malta, she has published on coastal boulder geomorphology of the Maltese Islands, and was involved in similar research with other European universities such as the University of Portsmouth, UK and the University of Trieste, Italy. Presently, Joanna lectures and carries out fieldwork sessions in physical geography for the Department of Geography at the University of Malta.

**David K. Chester** is a graduate of the Universities of Durham (1973) and Aberdeen (1978) and has been involved in research on natural hazards (especially volcanic eruptions and earthquakes), landscape change in the Holocene and geomorphology, for over forty years. Employed for most of his career at the University of Liverpool, where he still holds an honorary fellowship, he is currently Professor of Environmental Science at Liverpool Hope University. Professor Chester is a priest in the Church of England.

**Adrian Ciantar** is a geographer and holds a B.A. (Hons) (Melit.) from the Department of Geography of the University of Malta. He is Gozitan and has researched extensively on Xatt l-Aħmar for his undergraduate thesis, under the supervision of Dr. Saviour Scerri. He presently lives in Canada.

**Alan Deidun** is an Associate Professor within the Department of Geosciences at the University of Malta. He is currently involved in several areas of coastal and marine biology, oceanographic research and is Project Manager on a number of EU-funded projects, including: PANACEA (www.panaceaproject.net); BIODIVALUE (www.biodivalue.com); PERSEUS (www.perseus-net.eu), MED-JELLYRISK (www.jellyrisk.eu) and SeaofSkills (http://www.seaofskills.eu). Through the PANACEA project, the first ever marine environmental education centre in the Maltese Islands was opened at Dwejra (Gozo) in March 2013. He has authored over 100 peer-reviewed papers published on various thematics relating to coastal and marine biology, although he still retains an interest in sandy beach ecology, which he first addressed during his Ph.D. studies. Professor Deidun is also deeply involved in environmental advocacy, having penned a newspaper column for the past 15 years which has received journalism awards on three occasions. In total, he has written over 450 popular science and environmental advocacy articles in local newspapers and magazines.

**Stefano Devoto** obtained his Ph.D. in Geomorphology at the University of Modena and Reggio Emilia (Italy). His Ph.D. research was focused on the study of coastal landslides of NW Malta. He currently works at the University of Trieste (Italy) with a research grant. He has published more than 40 contributions in international journals and congresses and has been involved in national and international projects.

**Paul Farres** is currently a Visiting Research Fellow in the Department of Geography at the University of Portsmouth, having previously taught and researched in the Department from 1974 to 2014. Major activities focused on earth surface materials and processes and main publications concern soil erosion, specifically rainsplash mechanisms and soil crusting.

**Simon Farrugia** is a geography graduate from the University of Malta who completed a dissertation project on aeolian geomorphological processes at Ħaġar Qim. He also holds an M.Sc. in Environmental Monitoring and Assessment from the University of Southampton, UK. His research interests include aeolian processes, geographic information systems and quantitative tools for environmental monitoring. Simon's contributions include several peer-reviewed publications, local radio productions and public lectures on environmental monitoring and aeolian processes.

**Federica Foglini** is a researcher at the Institute of Marine Sciences—CNR in Bologna, Italy, and her main interests are focused in seafloor geomorphological mapping, design and management of Marine Geodatabase, development and implementation of WebGIS systems and digital cartography in the framework of European and National projects. She is involved in seafloor habitat mapping, high-resolution reflection seismic and stratigraphic interpretation, multibeam swath bathymetry acquisition and processing. She is co-author of international scientific papers and wrote several technical reports about implementation and design of Marine Geodatabase and GIS mapping. She often boards oceanographic expeditions as party chief, to supervise data collection and processing.

**Stefano Furlani** is an Associate Professor at the Department of Mathematics and Geosciences of the University of Trieste, Italy. His research deals with coastal geomorphology and sea level change with special emphasis on coastal karst and climatic change. He leads the Geoswim project for the snorkel surveying of the Mediterranean coasts. He is assistant editor of the Editorial Board of *Alpine and Mediterranean Quaternary*. He is author or co-author of about 100 papers.

**Lara Galea** was born in Żurrieq, Malta, in 1993 and holds a B.Sc. in Biology and Chemistry and an M.Sc. in Biology. She has co-authored papers and posters in refereed journals and conferences. She has also pursued further research on wetland biota at the Catholic University of Leuven, in Belgium.

**Pauline Galea** graduated with a B.Sc. in Mathematics and Physics from the University of Malta in 1977 and M.Sc. in Physics in 1979. She obtained her Ph.D. in Geophysics from the University of Wellington, New Zealand in 1994, after which she took responsibility of seismic recording and monitoring at the University of Malta. She is now Head of the Department of Geosciences and coordinates the Seismic Monitoring and Research Group, which manages the Malta Seismic Network and several geophysical applications. Her research interests are mainly the seismicity, tectonics and seismic hazard in the Central Mediterranean, and geophysical studies of the shallow subsurface.

**Andy Gibson** is Principal Lecturer and Leader of the Centre for Applied Geosciences within the Faculty of Science of the University of Portsmouth, UK. He is an engineering geomorphologist involved in the investigation and management of geological hazards and adaptation to the impacts of climate change. Andy is involved in numerous research projects including landslides in China, the geotechnical properties of the Hampshire Basin, and the impacts of geohazards on the UK economy and tourism industry. He is currently collaborating with the Department of Geography of the University of Malta on the geo-material properties of shore platforms.

**Reuben Grima** is a Senior Lecturer in cultural heritage management in the Department of Conservation and Built Heritage at the University of Malta. He studied archaeology at the Universities of Malta and Reading, and read for his Ph.D. at the Institute of Archaeology, University College London. From 2003 to 2011 he served with Heritage Malta as Senior Curator responsible for prehistoric World Heritage Sites. His research interests include archaeology of landscapes, cultural landscapes, and engagement of the public with the past.

**Robert Inkpen** is a Reader in Physical Geography at the University of Portsmouth, UK. He has published on a diverse range of research including the erosion of shore platforms, the decay and conservation of heritage materials, bacterial decay of stone and the philosophy of physical geography. He views academic research as having a key role to play in the practical conservation of environments as well as in the informing decision makers and the public of the social and cultural value of these underrated assets.

**Sandro Lanfranco** was born in Sliema, Malta, in 1966, and holds a Ph.D. in vegetation ecology. He lectures in Biology at the Department of Biology of the University of Malta. His main research interests are the ecology and systematics of plants. He has carried out or directed several studies, including long-term ones, on freshwater pools and their biota. He has authored or co-authored several scientific studies, technical reports, book chapters and books.

**Jessica Jade Lewis** is a Geotechnical Engineer for Fugro, UK. She previously completed her B.Sc. Geology at the University of Leicester, before going on to study M.Sc. Geological and Environmental Hazards at the University of Portsmouth. Her M.Sc. thesis was part of the Erasmus programme with the Geography Department of the University of Malta concerning landslide hazards in Xemxija.

**Aaron Micallef** is a Marie Curie Fellow and an Associate Professor at the Department of Geosciences, University of Malta. His expertise is in marine geology and geomorphology, in particular submarine canyons and landslides, fluid flow processes, and geomorphometry. He has co-published 27 papers and book sections, and contributed to 30 international conference communications, on these research topics. Aaron is also chairman of the International Association of Geomorphologists' Submarine Geomorphology working group.

**Stephan Micallef** is a geographer, and holds a B.A. (Hons) from the Department of Geography at the University of Malta. During his undergraduate studies, he researched on the perspectives of agritourism development on the Maltese Islands. In 2015, he was awarded an M.A. (Summa cum Laude) for his research on the effectiveness of rubble walls in retaining soil particles and water. His research interests are vested in the relationships of anthropogenic processes with the environment, with focus on sustainable development, agriculture, soil resources, water processes, culture, ecology and human adaptations to changing land-uses.

**Derek Mottershead** is currently Visiting Research Fellow in the Department of Geography, University of Portsmouth, UK. He gained a Ph.D. in geomorphology from University of London King's College in 1972 and has studied landforms in varied environments in Norway, Spain, Malta, Mallorca, New Zealand, Canada and USA, in addition to his long-term association with Southwest England. He has published a significant number of geomorphic studies in coastal geomorphology and is also a co-author of a systems-based undergraduate text on physical geography. He has been a longstanding executive committee member of the British Geomorphological Research Group (now British Society for Geomorphology).

**Alessandro Pasuto** is Research Director at the Research Institute for Geo-Hydrological Protection of National Research Council in Padova, Italy. His expertise mainly deals with applied geomorphology and engineering geology with special reference to landslide hazard assessment and monitoring. He is founder and director of GRJL, Italy–Japan joint laboratory on Hydro-Geological risks, foundation member of TellNet, International Disasters Transfer Live Lesson Network. He is also member of the Executive Committee of the CERG, European Centre on Geomorphological Hazard of the European Council. He is author or co-author of more than 170 scientific papers and has been guest-editor of two special issues of *Geomorphology*.

**Alastair Pearson** graduated from the University of Leeds in 1982 in Geography/History and completed a postgraduate Diploma in Cartography at University College of Swansea in 1983. He then joined the staff at Portsmouth as Map Librarian and became Head of the Geographical Information Services Unit in 1987 before appointment as lecturer in 1991. He was awarded a Ph.D. in 1996 and promoted to Principal Lecturer in 1997. He teaches GIS at undergraduate and postgraduate levels and leads field courses to Malta and Sicily. His other recent publications have concentrated on the history of cartography in the twentieth century.

**Jonathan Potts** is a Principal Lecturer in coastal management in the Department of Geography at the University of Portsmouth, UK. He leads its long established M.Sc. course in Coastal and Marine Resource Management. His research interests within coastal management include institutional and policy frameworks, spatial planning, public participation, education and interpretation.

**Mariacristina Prampolini** is a post-doctoral grant holder at CNR-ISMAR of Bologna and at the University of Modena and Reggio Emilia (Italy) carrying out research on the geomorphological evolution of the Maltese coasts since the Last Glacial Maximum to better understand the kinematics of active processes along the shorelines and on the seafloors. She is also expert in benthic habitat mapping. She is Member of the Associazione Italiana di Geografia Fisica e Geomorfologia (AIGeo).

**Avertano Rolé** lectures in Physical Geography at the University of Malta within the Geography Department. His main interests are geomorphology, soil erosion, and land degradation, and he has published several papers and official reports related to these fields. Other main academic interests include integrated coastal zone management. He participated, and led a number of EU and UNEP projects which addressed environmental issues related to this field. Mr. Rolé is very active in the field of environmental and geographic education and often leads groups of students, teachers, and other interested persons in guided field trips around various places within the Maltese Islands and abroad.

**Sephora Sammut** holds a B.A. (Hons) (Melit.) and an M.A. (Melit.) from the Department of Geography at the University of Malta and is a visiting lecturer within the same department. Her main area of interest is coastal geomorphology, in particular the morpho-sedimentary dynamics of shingle beaches. She has participated in conferences in both the local and foreign scenes, and published her research in international journals.

**Bernadine Satariano** is a Lecturer in Geography, with a B.A. (Hons) (Melit.), P.G.C.E. (Melit.), M.A. (Melit.) from the University of Malta and a Ph.D. (Dunelm). Her main area of interest explores how important place is for human health and wellbeing. She focuses on the socio-geographical processes related to inequalities in health and wellbeing within a Maltese context. Her recently published work explores: the social determinants of health within Maltese neighbourhood communities; the intergenerational processes and their impact on the health and wellbeing of adults and children; and the impact of neighbourhood social and cultural norms on child wellbeing. She is also involved in a research project focusing on children's geographies. She presented some of her research studies at the University of Portsmouth, Durham University, Paris Nanterre University, University of San Francisco, University of Angers and Cardiff University. She is a Fellow of the Royal Geographical Society (F.R.G.S.).

**Saviour Scerri** studied at the University of Malta and graduated as B.Sc. in Physics and Chemistry in 1972. He furthered his studies at the University of Milan where he graduated in Geology in 1976. He started his career as a ground engineer with Soil Mechanics. After four years he joined the Oil Exploration Department of the Government of Malta as a petroleum geologist where he specialised in seismic data interpretation and prospect generation. Presently he is working as a Consulting Geologist. His work includes mineral resource assessments, geo-environmental impact assessment and subsurface ground investigations. He is also engaged as a part time visiting senior lecturer (Geology) at the University of Malta.

**Martin Schaefer** graduated in Geography from Sheffield University. He obtained an M.Sc. in GIS (2001) and a PGC in Learning and Teaching in Higher Education (2006), both from University of Portsmouth. His current role is GIS Manager in the Department of Geography at Portsmouth, and he also teaches on undergraduate and postgraduate programmes as a part-time lecturer. He contributes to research projects in Spatial Data Management, Surveying and Data Capture, Arctic & Alpine Climate and Historical GIS & Cartography and has co-authored several publications in these fields.

**Arnold Sciberras** is an active Maltese naturalist and has contributed to the description of numerous novel faunal species in the Maltese Islands, especially of insect, arachnid and reptile taxa. Observation of animal behaviour is one of his key specialisations, especially that of lizards, and he was a founder member in 2012 of the Malta Herpetological Society. He sat for a number of years on the editorial board of The *Central Mediterranean Naturalist*, a Maltese peer-reviewed journal, and has participated in numerous sampling expeditions on small islands and islets, having documented for the first time the fauna and flora colonising all the islets which are to be found around the coastline of the Maltese Islands.

**Mauro Soldati** is Full Professor of Geomorphology at the Department of Chemical and Geological Sciences of the University of Modena and Reggio Emilia, Italy. His research deals with geomorphology and slope instability, with special emphasis on landslides and climatic change. He is President of the International Association of Geomorphologists (IAG) for the period 2017–2021. He is a member of the Editorial Board of the *Geomorphology*, as well as of other international journals, and has been guest-editor of special issues of the journal dealing with landslides. He is author or co-author of about 150 papers.

**Louise Spiteri** is a lawyer by profession, and currently she is the Chief Executive Officer of the Environment and Resource Authority of Malta. She obtained a LL.D. at the University of Malta in 1999 and a Magister Juris Degree in Public International Law in 2001. Dr. Spiteri has extensive working experience in the legal arm of environmental regulations, and in international and EU legal negotiations. She was also a lawyer linguist at the European Court of Justice and dealt with EU infringement cases, on behalf of Malta in front of European Court of Justice. She currently lectures on environmental and resource law at the University of Malta, and is working on a Ph.D. research on climate change law and the insurance market, at Imperial College London, UK. She has published articles mainly on environmental legislation and Malta's international environmental obligations, and a monograph on environmental law in Malta with Kluwer publishers.

**Stephen C. Spiteri** was born in Malta, 15 September 1963 and holds a Dipl. (Int. Des.) RI, B.A. (Hons) and Ph.D. Educated at St Aloysius College, B'Kara and later at the University of Malta, Dr. Spiteri specializes in the military architecture of the Hospitaller Knights of St John and the fortifications of the Maltese Islands. He is the author of a number of books and studies on the military history and fortifications of Malta, the Knights of St John, and British Colonial defences. He is a founding member of the *Sacra Militia Foundation for the Study of Hospitaller Military and Naval History*. Dr. Spiteri is also a part-time Senior Lecturer at the International Institute of Baroque Studies at the University of Malta, where he lectures and undertakes research on the history and development of military architecture, and on the art and science of fortification.

**Darrin T. Stevens** is currently occupying the post of Deputy Director Environment and Resources within the Environment and Resources Authority (ERA), where he is handling various issues related to Strategic International and National Affairs, Information Resources Management, Biodiversity and Nature Protection, Water (including Marine issues), Desertification and Land Degradation, and issues linked with Genetically-Modified Organisms and the environment, with particular reference to the implementation and coordination of the National Biodiversity Strategy and Action Plan, the development of the State of the Environment Report, as well coordination on various international commitments, including the EU Habitats Directive and Natura 2000, the EU Marine Framework Directive and selected aspects within the EU Water Framework Directive, the EU Biodiversity Strategy to 2020, the EU Regulation on Invasive Alien Species and the UN Convention on Biological Diversity. He is

also the Maltese national focal point for a number of international multilateral biodiversity treaties under the European Union, Council of Europe and United Nations, and is also author of a number of peer-reviewed scientific and popular articles and other publications, and was actively involved with various environmental NGOs.

**Marco Taviani** is a marine geologist and paleobiologist at the Institute of Marine Sciences—CNR in Bologna as Research Director, and has worked on many projects in the Mediterranean basin, Red Sea, Atlantic Ocean, Indian Ocean and Antarctica. His main research interests focus on biogenic carbonate factories, hydrocarbon-imprinted carbonates, deep water coral ecosystems, habitat mapping and paleoceanography. Has carried out over 40 oceanographic missions on board Italian, German, French and US research vessels; his expertise includes ROV operations, manned submersibles, drill coring, and SCUBA diving. He is active in popularizing Science in scientific documentaries, TV and radio.

**Chiara Tonelli** is a natural scientist and has a Ph.D. in earth system sciences. Her field of research is in geomorphology and her research interests are karst processes and landforms and their relationships to gravity and sea-level change.

**Talitha Van Colen** was born in Malta in 1995 and holds a B.Sc. (Hons) (Melit.) in Biology from the University of Malta, where she carried out research on the flora of saline marshlands of the Maltese Islands.

**Marie Louise Zammit Pace** is a geography graduate of the University of Malta and currently a part-time Ph.D. student in the Department of Geography at the University of Portsmouth, UK. Her research concerns beach management in both urban and rural environments, in small islands and with particular reference to the Maltese Islands. She is also an Assistant Environment Protection Officer at the Environment and Resources Authority (ERA), Malta. Her research interests are beach management, marine spatial planning, and public participation.

# Abbreviations

| | |
|---|---|
| ACM | Archivum Cathedralis Melitae |
| AEI | Area of ecological importance |
| AHLS | Area of high landscape sensitivity |
| AHLV | Area of high landscape value |
| asl | Above sea level |
| BC | Blue Clay |
| BCE | Before Common Era |
| BP | Before Present |
| C1 | Lower Phosphorite Conglomerate Bed |
| C2 | Upper Phosphorite Conglomerate Bed |
| ca. | Circa |
| COE | Council of Europe |
| EAFRD | European Agricultural Fund for Rural Development |
| EC | European Commission |
| eNGO | Environmental Non-governmental Organisation |
| EPD | Environment Protection Department |
| ERA | Environment and Resource Authority |
| FFNHPR | Flora, Fauna and Natural Habitats Protection Regulations |
| GL | Globigerina Limestone |
| GN | Government notice |
| GPS | Global positioning system |
| LCL | Lower Coralline Limestone |
| LGLM | Lower Globigerina Limestone Member |
| LGM | Last glacial maxima |
| MCA | Malta Communications Authority |
| MEPA | Malta Environment and Planning Authority |
| MGLM | Middle Globigerina Limestone Member |
| MRRA | Malta Resources and Rural Authority |
| MTA | Malta Tourism Authority |
| NBSAP | National Biodiversity Strategy and Action Plan |
| NEN | National Ecological Network |
| ODZ | Outside development zone |
| SAC | Special Area of Conservation |
| SCI | Site of Community Importance |
| SCRZ | Sicily Channel Rift Zone |
| SDS | Sustainable development strategy |
| SL | Subsidiary legislation |
| SPA | Special protected area |
| SPED | Strategic Plan for the Environment and Development |
| SSI | Site of Scientific Importance |
| TLGLHg | Terminal lower Globigerina Limestone hardground |

| | |
|---|---|
| TPA | Tree protection areas |
| UCL | Upper Coralline Limestone |
| UGLM | Upper Globigerina Limestone Member |
| VO | Voluntary organisation |
| WFD | Water Framework Directive |

# Units of Measurement

| | |
|---|---|
| cm | centimetres |
| g | grams |
| ha | hectares |
| ka | kilo-annum (i.e. one thousand years) |
| kg | kilograms |
| km | kilometres |
| $km^2$ | kilometres squared |
| km $h^{-1}$ | kilometres per hour |
| m | metres |
| $m^2$ | metres squared |
| $m^3$ | metres cube |
| m/s | metres per second |
| µS $cm^{-1}$ | microsiemens per centimetre |
| mi | miles |
| mm | millimetres |
| mS $cm^{-1}$ | millisiemens per centimetre |
| mya | million years ago |
| nmi | nautical miles |
| s | seconds |

# Introduction to Landscapes and Landforms of the Maltese Islands

1

Ritienne Gauci and John A. Schembri

*Lil din l-art ħelwa, l-Omm li tatna isimha,*
*Ħares, Mulej, kif dejjem Int ħarist:*
*Ftakar li lilha bil-oħla dawl libbist.*

*To this sweet land, the Mother whose name we bear,*
*Look after it, O Lord, as Thou hast always done:*
*Remember Thou hast dressed her with the brightest light.*

Dun Karm Psaila - Malta's National Poet, 1922.
*Innu Malti* (National Anthem of Malta) Verses 1–3.

**Abstract**

The Maltese Islands consist of an archipelago of three main islands—Malta, Gozo and Comino—and a group of islets. Centrally located in the Mediterranean Sea over a surface area of 316 km$^2$, they have long represented a landscape reality which trascends their size and encompass the evolving dynamics of the Mediterranean region in terms of its geology, geomorphology and long history of human interactions with the physical environment. The small geographical setting of the Maltese Islands helped to closely connect these landscapes with Maltese society and, as exemplified in the islands' literary and cartographic heritage, landforms acted as important backdrops of Maltese cultural identity. The chapter highlights how this volume is the result of a strong collaborative spirit between local and foreign researchers, nurtured for decades within the Department of Geography of the Faculty of Arts at the University of Malta.

**Keyword**

Island Geomorphology • Islandscape • Geography • Maltese Islands • Mediterranean

## 1.1 Introduction

The study of geomorphology, geography and islands enjoy, on their own terms, a wide fora of international recognition. This volume represents a unifying account of these three fields of study, weaved together in what we trust is a coherent compilation of scholarly contributions about the geomorphological landscapes of the Maltese Islands.[1]

Island geomorphology is best understood when the study of landscape realities which govern such small territories extends beyond their land borders and geographic size. The conventional notion of islands being remote and isolated cannot be further away from the truth for the Maltese Islands. These islands have nurtured their own insular identity, expressed in their cultural milieu, ecological refugia and linguistic characteristics; but the evolution of both their landforms and the long history of human interactions with the physical landscape bears witness to a wide and deeply connected journey, carried out in tandem with the story of the Mediterranean region.

R. Gauci (✉) · J. A. Schembri
Department of Geography, University of Malta, Tal-Qroqq, Msida, MSD 2080, Malta
e-mail: ritienne.gauci@um.edu.mt

J. A. Schembri
e-mail: john.a.schembri@um.edu.mt


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[1]The Maltese Islands is an archipelago of three main islands, MALTA, GOZO and COMINO, and a number of islets. The name of the country is MALTA. In this volume, in order to maintain a clear distinction, the terms 'Maltese Islands' and 'Malta' are used, respectively, to refer to the archipelago and its largest island.

The structure of the islands is the result of active tectonic processes that shaped the central Mediterranean over 23 million years ago. The lithostratigraphy originates from the marine sedimentary processes that operated in the pre-Pleistocene waters of the Mediterranean, whereas many of their palaeosoils were formed by highly dynamic fluvial deposits during the Quaternary period.

## 1.2 Island Geomorphology, Meaningful Landscapes

The relationship between early island settlers and their landscapes, which dates back to early Eneolithic Age (i.e. fourth millennium BC), was also the direct result of a complex network of communications between the Maltese Islands and the Mediterranean basin: mainly from Sicily and South Italy, to the south-western Balkans, the Ionian Islands and the Levant (Cultraro 2008). The influence of geology and geomorphology shaped the ways in which the Neolithic islanders inhabited the landscape and transformed their temple culture into a meaningful space which today is recognized as being of UNESCO World Heritage status.

In many ways, an island can be considered both paradise and prison, both heaven and hell (Baldacchino 2006). The geomorphological landscapes of the Maltese Islands represent a similar paradox for their inhabitants: a paradox which sways from one extreme to another as geopolitical and socio-economic events unfold on the islands, in the Mediterranean region and beyond. The coast with its accessible harbours, bays and shore platforms was very much feared due to piracy before the arrival of the Knights of St John in 1530 and in the decades thereafter. With the arrival of the Knights and the subsequent strengthening of coastal military defence, the coast was transformed into a place of growing socio-economic opportunities. This led to the gradual abandonment of cavernous landscapes from the islands' interior, which for millenia had ensured shelter and survival to troglodytic communities.

Beaches and shore platforms, once considered as dangerous access points for invaders, are today highly sought-after meccas for tourists. Landslides not only display a spectacular manifestation of geomorphological processes but also represent a geo-hazard requiring monitoring, technical scrutiny and preventive care. Deep faults running through the islands have created contrasting topographies of horsts, grabens and rias with breathtaking views, deep harbours and fertile valleys. And yet, they are also a sharp reminder of the powerful presence of active tectonism in central Mediterranean.

The geomophological story of the Maltese Islands is therefore a story of many bridges, which span multiple spatio-temporal dimensions. What started as an editorial endeavour aimed to illustrate the geomorphological qualities of the Maltese Islands soon grew into a showcase of the meaningful connections between the islandscape, its landforms and society through the centuries.

The blending of these themes has been resonating for centuries in traditional Maltese texts, including the first literary text ever written in the Maltese language: *Il-Kantilena* by Pietru Caxaro (pre-1485).[2] In his twenty-verse poem, Caxaro fused the islands' semitic-based linguistic culture with the Latin script, to create the Maltese script. The poem is the sad lament of a houseowner who witnessed his property collapse by land subsidence due to unstable geological foundations made of weak clays. The poem closes with a reflective tone on the variety of landforms, their colourful attributes and fruit-bearing blessings:

*Huakit by mirammiti Nizlit hi li sisen*
*Mectatilix li mihallimin ma kitatili li gebel*
*fen tumayt insib il gebel sib tafal morchi*
*Huakit thi mirammiti lili zimen nibni*
*Huec ucakit hi mirammiti vargia ibnie*
*biddilihe inte il miken illi yeutihe*
*Min ibidill il miken ibidil i vintura*
*haliex liradi 'al col xibir sura*
*hemme ard bayad v hemme ard seude et hamyra*
*Hactar min hedann heme tred mine tamara.*

*It (she) fell, my building, its foundations collapsed*
*It was not the builders' fault, but the rock gave way*
*Where I had hoped to find rock, I found loose clay*
*It (she) fell, my edifice, (that) which I had been building for so long,*
*And so, my edifice subsided, and I shall have to build it up again,*
*change the site that caused its downfall*
*Who changes his place, changes his luck!*
*for each (piece of land) has its own shape (features)*
*there is white land and there is black land, and red*
*But above all, (what) you want from it is [to bear] fruit.*

*Il-Kantilena*, Pietru Caxaro, pre-1485, Verses 11-20.

## 1.3 An Overview of this Volume

Following an introduction, *Landscapes and Landforms of the Maltese Islands* is divided into three main parts. *Part I* provides the background to the main geomorphological aspects responsible for the physical and geographic development of the Maltese Islands. *Part II* presents a selection of 22 contributions which describe the diverse geomorphological landscape of the islands. The location of the themes discussed in each contribution is illustrated in Fig. 1.1. It is worth noting how the small size of the islands

[2]The poem was discovered by Prof. Godfrey Wettinger and Patri Mikiel Fsadni in 1966. The original document can be viewed at the Notarial Archives in Valletta.

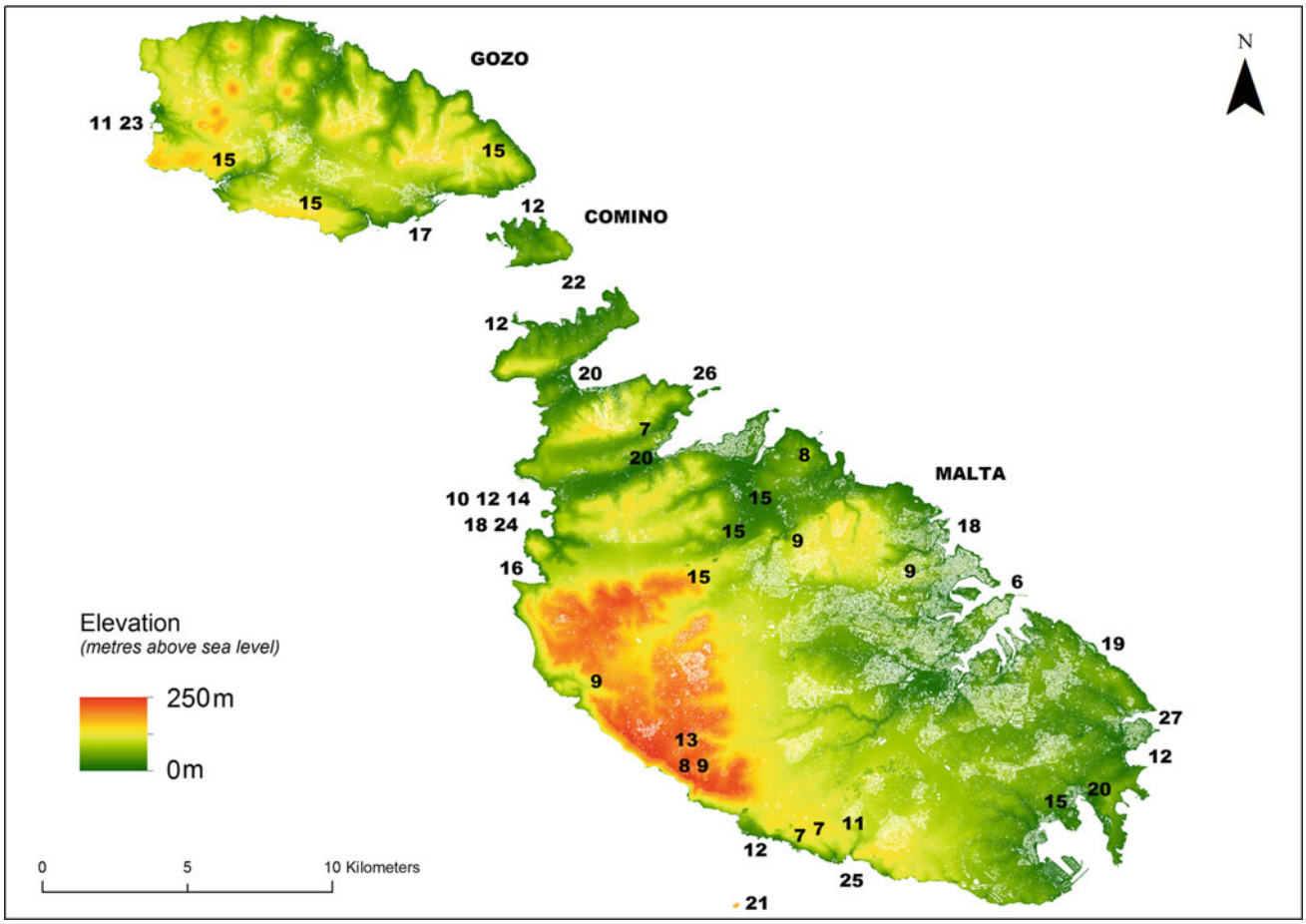


**Fig. 1.1** Location of selected geomorphological landscapes, indicated by volume chapter number. *Source* DEM map from ERDF LIDAR data (2012)

favoured the exploration of specific themes in more than one site across the archipelago. Such themes included palaeosoils, sinkholes, cart ruts, saline marshlands, freshwater rock pools and archaeological landscapes. This explains why some chapter numbers appear repetitively across the Maltese Islands in Fig. 1.1. *Part III* closes the volume with two important (and inter-linked) themes which determine the future of our landscapes and landforms: the regulatory framework and the concept of sustainability.

Some of the themes penned in this volume have never been researched before and reflect a dynamic and emerging community of researchers who are responding to new opportunities in island geomorphology research. In March 2017, research resilience for this volume was further put to test when the Maltese Islands experienced the sudden loss of one of their most iconic landforms: the Azure Window in Gozo. The intense societal response to such a loss reaffirmed the strong significance that landforms continue to project on to Maltese society. It encouraged our resolve to build further on this theme, with an additional contribution about the loss of the Azure Window which is to be found in this volume.

The volume was produced through an international collaborative set-up of 46 contributors, led by the Department of Geography of the Faculty of Arts at the University of Malta. The Department owes its origins to a multidisciplinary programme entitled Contemporary Mediterranean Studies, in which geography was introduced within the Mediterranean Institute and subsequently within the Faculty of Arts. The study of geography evolved into a fully fledged undergraduate and postgraduate degree programme which maintained contacts with foreign departments through research and publications, the Erasmus Student and Staff Exchange programme, and cooperation in joint field studies. To date, about 500 geography graduates are contributing to the environmental, socio-economic and cultural development of Malta, a number of whom continued their postgraduate studies in British and other European universities.

The Department of Geography has also been actively contributing in the International Association of Geomorphologists (IAG) as national scientific representative for the Maltese Islands. This editorial initiative, published under the

patronage of the IAG, aimed to bring together numerous local and foreign specialists, which included 22 geographers (many with field expertise in geomorphology) but also geologists, GIS specialists, biologists, geoscientists, archaeologists and environmental lawyers. Academic staff members from another four departments and two institutes within the University of Malta have contributed to this volume, mainly from the Department of Classics and Archaeology, the Department of Geosciences, the Department of Conservation and Built Heritage, the Department of Biology, the International Institute of Baroque Studies and the Institute of Climate Change and Sustainable Development. We are extremely grateful to have received the most helpful joint contribution of the Chief Executive Officer of Environmental Resource Authority (ERA) and the Deputy Director for Environment and Resources within the same national agency.

Out of 46 contributors, 19 contributors hailed from four foreign universities and two research institutes in Europe: University of Portsmouth (UK), Liverpool Hope University (UK), University of Modena and Reggio Emilia (Italy), University of Trieste (Italy), the Institute of Marine Science-CNR (Bologna) and the Research Institute for the Geo-Hydrological Protection of National Research Council (Padova). This multinational venture draws on the collaborative efforts sustained by the Department of Geography over many years, in order to establish an international presence in the geographical and geomorphological research community.

Each chapter has undergone a rigorous process of peer review made up of experts who acted as external or independent reviewers. Central in this review process has been the precious contribution of David K. Chester (Liverpool Hope University) whose experience and thorough external review of all chapters guided the authors and substantially enhanced the quality of the manuscripts. Thanks are also due to internal reviewers Reuben Grima (University of Malta) and Angus Duncan (University of Liverpool) for generously providing their specific expertise.

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Our gratitude goes also to Candida Gerada, for her unfailing patience shown towards us in the administration work for our department.

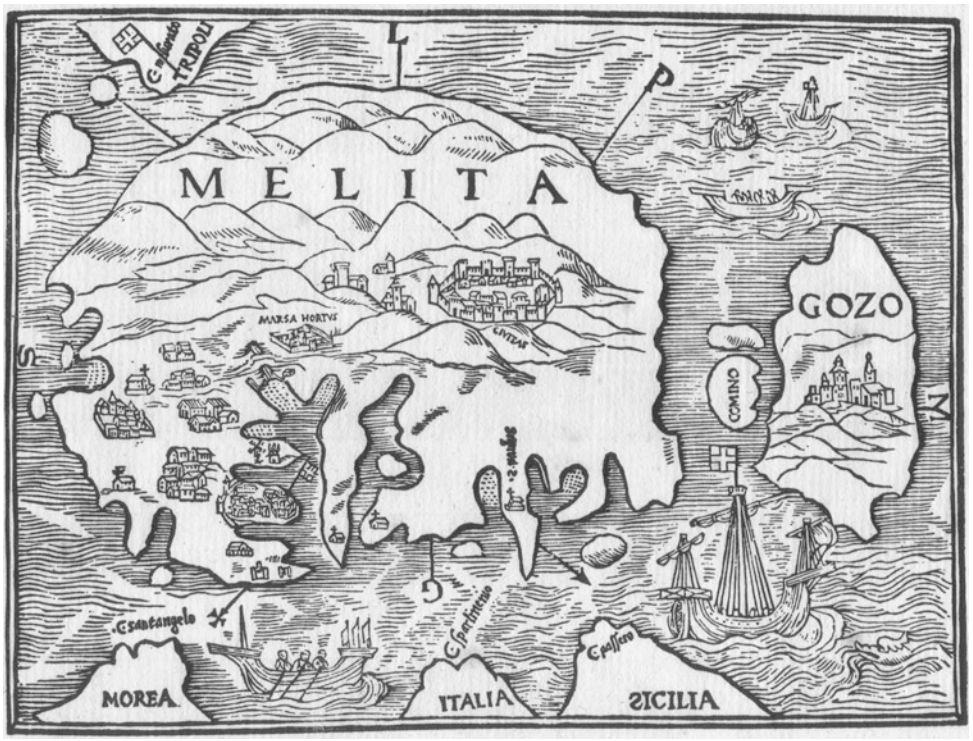


**Fig. 1.2** The first printed separate map of the Maltese Islands, produced by Jean Quintin d'Autun. This wood-cut map was drawn in 1533 and printed in Lyons in 1536. *Source* The National Library of Malta

We would also like to acknowledge the kind availability of Robert K. Doe, Springer Senior Publisher, in the early stages of this volume preparation and the assistance provided by Springer Book Project Coordinator, Manjula Saravanan and Springer Book Project Manager, Madanagopal Deenadayalan, in the final production stages.

The final and most important merit goes to all contributors who with patient dedication and rigorous commitment to research have made possible the production of this edited volume. We feel truly honoured to have received the collaboration of such a comprehensive community of esteemed scholars, especially on the occasion of the 250th anniversary of the founding of the University of Malta.

## 1.4 Conclusion

As geographers, we wish to conclude this chapter with a short anecdote. The earliest geographical treatise on the Maltese Islands is credited to Jean Quintin d'Autun in 1536. His *Insulae Melitae Descriptio Ex Commentariis Rerum Quotidianarum* is the earliest surviving printed description of the islands, which he wrote during his stay from 1530 to 1536 (Vella 1991). Well versed in cosmography and prolific in writing, Quintin is also credited with having been the first to draw a separate printed map of the Maltese Islands (Fig. 1.2).

His description of the islands left a lasting influence on writers with numerous re-editions and translations. Across a time span of almost five centuries, we hope that this volume will become another addition which honours the pioneering work of Jean Quintin d'Autun.

**Acknowledgements** The editors would like to thank Sephora Sammut for her help with a DEM image to complete Fig. 1.1. and the National Library of Malta for permission of reproduction of the Jean Quintin d'Autun map (1536) as Fig. 1.2.

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# Part I
# Background