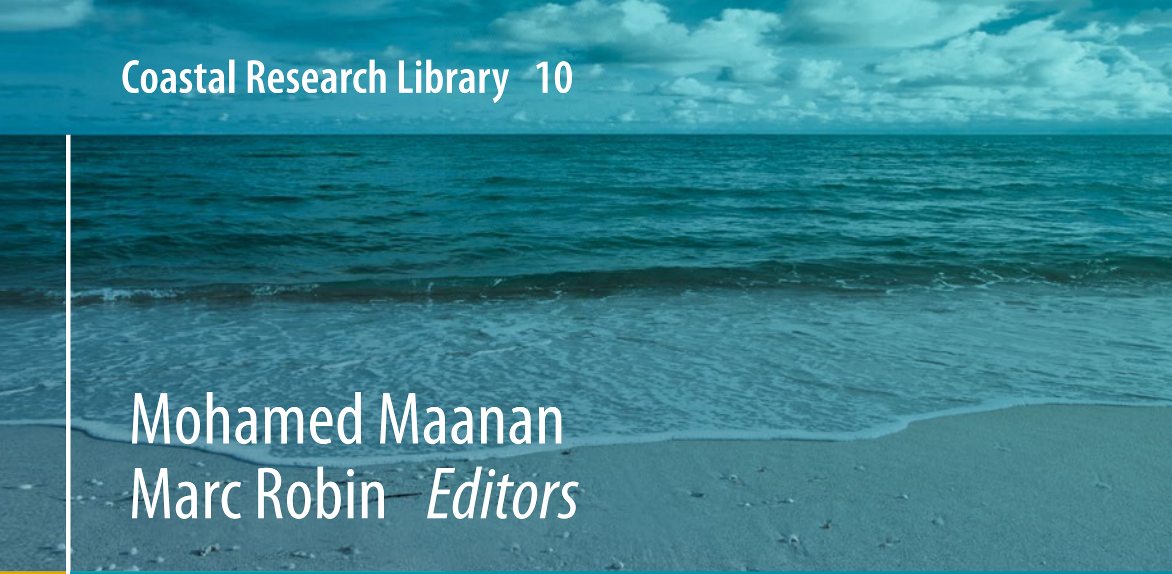

Coastal Research Library 10

Mohamed Maanan
Marc Robin *Editors*

Sediment Fluxes in Coastal Areas

Springer

Coastal Research Library

Volume 10

Series Editor

Charles W. Finkl
Department of Geosciences
Florida Atlantic University
Boca Raton, FL 33431, USA

The aim of this book series is to disseminate information to the coastal research community. The Series covers all aspects of coastal research including but not limited to relevant aspects of geological sciences, biology (incl. ecology and coastal marine ecosystems), geomorphology (physical geography), climate, littoral oceanography, coastal hydraulics, environmental (resource) management, engineering, and remote sensing. Policy, coastal law, and relevant issues such as conflict resolution and risk management would also be covered by the Series. The scope of the Series is broad and with a unique crossdisciplinary nature. The Series would tend to focus on topics that are of current interest and which carry some import as opposed to traditional titles that are esoteric and non-controversial. Monographs as well as contributed volumes are welcomed.

More information about this series at http://www.springer.com/series/8795

Mohamed Maanan • Marc Robin
Editors

Sediment Fluxes in Coastal Areas

Springer

Editors
Mohamed Maanan
Institut de Géographie et
d'Aménagement Régional
de l'Université de Nantes
Géolittomer, LETG UMR 6554-CNRS
Nantes Cedex 3, France

Marc Robin
Institut de Géographie et
d'Aménagement Régional
de l'Université de Nantes
Géolittomer, LETG UMR 6554-CNRS
Nantes Cedex 3, France

ISSN 2211-0577 ISSN 2211-0585 (electronic)
ISBN 978-94-017-9259-2 ISBN 978-94-017-9260-8 (eBook)
DOI 10.1007/978-94-017-9260-8
Springer Dordrecht Heidelberg New York London

Library of Congress Control Number: 2014952721

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

Sediment Fluxes: Natural and Anthropogenic Changes in Coastal Areas at Various Spatial and Temporal Scales

The world's coastal area is a long narrowed feature of mainland, island and adjacent seas denoting a zone of transition between land and ocean. If we consider a world coastal band 20 km wide, we can compute that this area represents nearly 4 % of total Earth surface. Nearly 30 % of people in the world live in this relatively small but highly valued and highly dynamic area. Humans have lived in the coastal area for millennia utilising its many and rich resources for their survival and socio-economic benefit.

Sedimentary processes occurring along coastal areas are a very complex issue and result from the interaction between deep processes (tectonics with subsidence/uplift) and superficial processes (climate, sea level change and hydrodynamic) (Cloetingh 2007). The pattern and distribution of sedimentary facies in depositional basins are under sediment fluxes control (Jones and Frostick 2002).

Coastal processes and natural ecosystems are subject to changes that vary greatly in geographic scales, timing and duration, combining to create dynamic and biologically productive coastal systems vulnerable to additional pressures resulting from human activities (Dean 2004). In turn, the sustainability of human economic and social hazards can be seen as a result of our poor understanding of the dynamics of land-ocean interactions, coastal processes and influence of poorly planned and managed human interventions (Crossland et al. 2007). Indeed a major problem for coastal studies is the constant changing coastal systems, from both natural and human causes (Maanan & Robin 2010). Changing wave and current regimes, climate, morphological processes and fluxes of materials from land, atmosphere and oceans are causes of high natural variabilities, which are still imperfectly understood. Moreover, major questions remain unanswered such as sedimentary fluxes quantification and precise models of both solid matter transport from source-to-sink areas and their consequences on building sedimentary architecture of continental shelf at various spatial scales (Milliman and Farnsworth 2011).

Conditions of erosion, timing and processes of sedimentary deposition and preservation as a function of environmental, climatic conditions and with human interplay are still a challenge in science (Anthony 2009).

Land-ocean sediment fluxes are one of the most important components in the sediment cycle of the Earth system and are also a major influencing factor in the processes of land-ocean interactions in coastal zones (Einsele 1992). The fluxes of continental water and sediment to a continental shelf largely depend on a region's climate and local drainage-basin characteristics, which together affect the hydrology of contributing rivers (Jones and Frostick 2002; Burt and Allison 2010). There are certainly other local factors that impact sediment delivery, including the anthropic influence.

Sediment is an integral part of coastal system. The term "sediment" refers mainly to sand, silt, clay, gravel, and bioclastic material that are transported by waves and currents along or near the coast but also by wind, along desert or arid coastline or between beach and dune.

The sources of beach material are the landmasses bordering the sea and the rivers, supplying the coastal area with cohesive and non-cohesive materials. In order to fully understand the coastal morphology in a specific area, it is necessary to have some knowledge of the geology of the area and of the sediment supply from the rivers. Other more special factors may influence the characteristics of the coastal area, such as the local flora and fauna as in the cases of coral coastlines and mangrove coastal areas. However, coasts defined by biological systems will receive little attention here.

Figure 1 gathers the main elements of the sediment cycle seen on a short time scale on coastal areas. It is inspired by a concept of sediment budget which is an

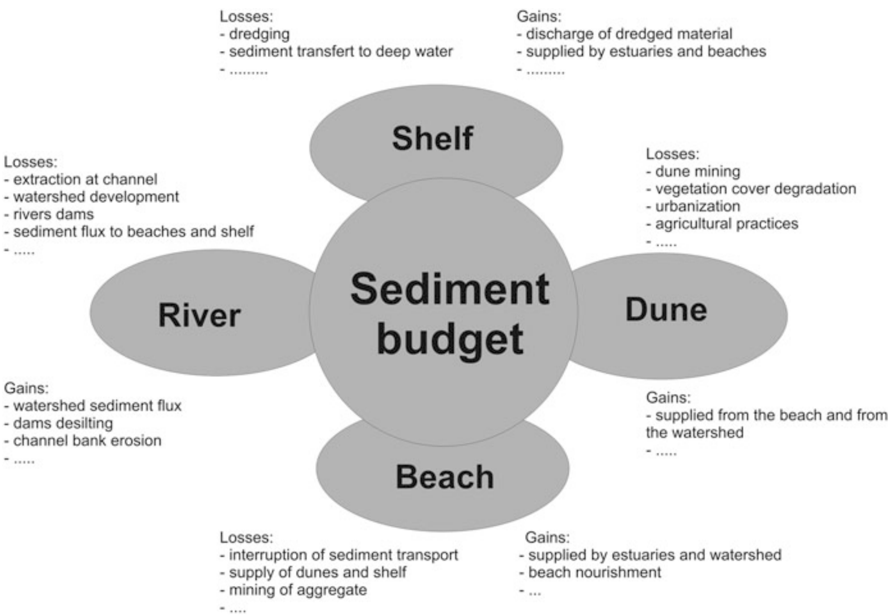

Fig. 1 Sediment budget principle on a coastal zone

accounting of the sources and disposition of sediment as it travels from its point of origin to its eventual outlet from a defined landscape unit like a drainage basin (Reid and Dunne 1996). We are concerned by sediment budget from land to see through four main coastal compartments which are trapping sediments over a given period or are providing sediments at other coastal compartments (shore, coastal dunes and cliffs, costal hinterland watersheds and rivers, nearshore zone and beyond offshore zone forming a sink on a short period beyond the depth of closure – nevertheless the sediments of offshore compartments can be mobilized in case of severe climatic changes involving the decrease of sea level).

Sediment fluxes are driven by different factors, such as proximal (climate/glaciation, land cover, topography), distal (base level) and local controls (human activity). The principal influences on sediment flux during the Holocene are driven primarily by geography (temperature, runoff, biogeography and pedology), geomorphology (basin area and relief), geology (tectonic, lithology) and climate change (sea level change, flooding, storms, length of the season and El Niño events or Asian monsoon) (Jones and Frostick 2002).

Sediment fluxes to the ocean during the period from the late Jurassic to the Pliocene ranged between 2.7 and 5.2 Gt·year^{-1}, but increased up to 9.6–15.5 Gt·year^{-1} in Pliocene-Holocene (Panin 2004). The contemporary sediment flux is 2, higher due to human disturbance of the coast and the land (Milliman and Syvitsky 1992). Over the Anthropocene which spreads over the last three centuries, however, large-scale human activities like dam, jetty and seawall construction challenge natural processes like changing sea level and major storms have influences on the shoreline position (Pilkey and Dixon 1996). Quick land cover changes over wide areas into watershed also impact water and sediment fluxes. From a quantitative point of view, the impact of watershed management by humans has first led to an increase in natural sediment supply to the ocean due to soil erosion (+2.3 +/−0.6 billion tonnes/year) and now leads to a decrease (1.4 +/−0.3) due to sediment trapping in dams (about 30 % of the sediment flux coming from inland) (Syvitski et al. 2005; Vorosmarty et al. 2003). At this decrease overlap subsidence processes in the majority of large muddy deltas (Syvistki et al. 2009) because of a large pumping water, oil and gas in coastal sedimentary layers. Finally, on an annual-decadal time scale, human activities, such as dredging, spoil disposals and beach replenishment, along with storm-generated waves, are probably the most important factors in shaping the coast (Hill et al. 2004). Quantitative assessment of the relative importance of these processes and prediction of future beach behaviour remain important problems for coastal geologists and engineers (Thieler et al. 2000).

Today, the coastal erosion which is felt in a generalized way is thus the result of a well-known convergence of the following factors: (a) climatic changes: increase of the marine level, modification of the modes weather-sailors (winds, swell); (b) reduction in the sedimentary contributions of the rivers because of the extractions of sands and gravels or the stopping, and the progressive unpacking, of the basins slopes; (c) reduction in sand stocks available on the spot because of urbanization; and (d) disturbances of the sedimentary transit by harbour works or protections which can defer the problem on the close sectors (Fig. 2). Hence coastal and marine sediments are limited in quantity and should be managed sustainably.

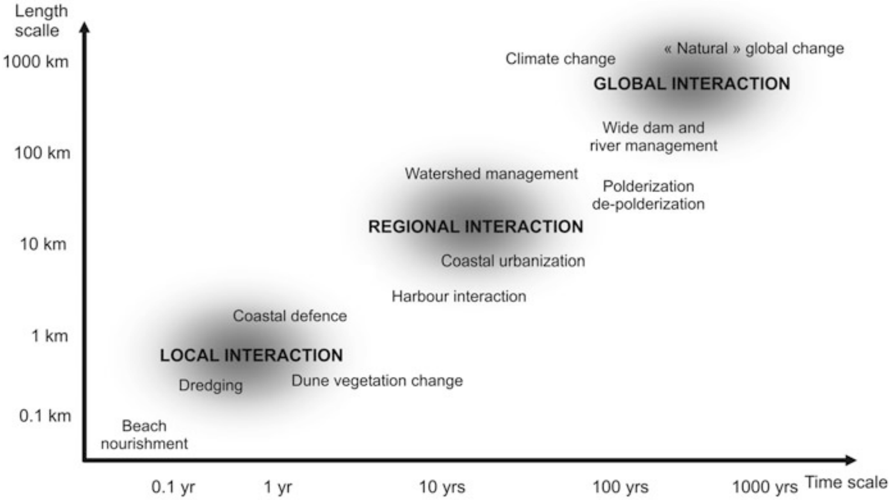

Fig. 2 Examples of human interaction with sediment fluxes in coastal area at various spatial and temporal scales

Moreover large amounts of sediment have been consumed on Earth for beach nourishment, land reclamation and construction.

Several studies gathering a wide and synthesized knowledge have been published concerning sedimentary fluxes at different spatial and temporal levels and different scientific issues. Jones and Frostick (2002) present a current perspective on controls and constraints on sediment supply, a model and empirically based driven understanding of sediment fluxes and the interaction of geomorphology, landscape evolution and sedimentary geology to provide a more complete picture of the Earth system. Crossland et al. (2007) addressed key elements of material flux between land, sea and atmosphere through the coastal zone and indications of: (i) change in land use, climate, sea level and human activities alter the fluxes in the coastal zone, and affect coastal quality and morphodynamic; and (ii) change in coastal systems, including responses to varying terrestrial and oceanic inputs, will affect the global carbon cycle and the trace gas composition of the atmosphere with an assessment of the influence of human society, before looking at future needs for targeted research and management actions in the coastal zone. More recently Burt and Allison (2010) published a volume entitled *Sediment Cascades: An Integrated Approach*. The aim of the book is to deal with sediment transport through the fluvial landscape with implications for catchment management, and consideration of larger-scale landform evolution. No single text integrates the landscape components we decided to include in the present book, covering the transfer of sediments from watershed environments, through transport pathways to the coastal zone under natural control (climatic and tectonic) at different time scales from the Holocene to the Anthropocene.

The book is a collection of many case studies carried out by researchers from several countries. These studies are provided by a large international spectrum of researchers and presented in a uniform structure, focussing particularly on sediment fluxes in different coastal regions and at various spatial and temporal scales.

The aim of the first part is to show the impact of the climatic change on sediment fluxes over a long period (Holocene) through the study of three cases. The first case concerns drastic Holocene environmental change on the north-east Atlantic coast (Baltzer et al.), the second case concerns impact of deglaciation during Holocene upon sediment flux in a polar coastal zone (Strzelecki et al.). The last one is a case-study along the coast of Rhone Delta over a shorter period during the little ice age which ends at the beginning of Anthropocene period (Provansal et al.).

The aim of the second part is to focus on processes and resulting landforms over the Antropocene period which is ongoing since the development of the industrial time. Three studies have been chosen in three different climatic areas: the first takes place in the tropical area of the French Guiana coast and is related to mud sediments (Anthony et al.). The second case studies a semi-arid country along the northwest coast of Morocco (El Mrini et al.). The last case takes place along the Channel Coast of France in Normandy characterized by high chalk cliffs, in a temperate climate (Costa et al.).

The third part of the book points out the use of modelling approaches of sediment fluxes at a higher spatial and temporal scale. In order to discuss the use of such modelling approach, we have chosen three cases: the first case addresses sediment exchange through the inlets of the Venice Lagoon in Italia (Umgiesser et al.). The second case highlights tidal inlet dynamics and relocation in response to artificial breaching on the west coast of Morocco (Zourarah et al.). The third case is focusing upon sediment transport formulae for coastal morphodynamic simulation, comparing calculated sediment flux against in situ data (Larroudé et al.).

We propose a fourth party concerning extreme events such as tsunamis and associated sediment fluxes (Regnauld and Mastronuzzi). Tsunamis are not linked to climate changes nor to climate but must be taken into account because of their major and instantaneous impacts on sediment fluxes and sediment cells.

This book is an essential reading for academics, students and professionals belonging to a wide range of disciplines like geography, biology, modelling, environmental sciences, land planning and marine policy.

Nantes, France

Mohamed Maanan
Marc Robin

References

Anthony EJ (2009) Shore processes and their palaeoenvironmental applications. Elsevier, Amsterdam/Boston, 519 p

Burt T, Allison R (2010) Sediment cascades: an integrated approach. Wiley-Blackwell, Chichester, West Sussex/Hoboken, 482 pp

Cloetingh S et al (2007) Topo-europe: the geoscience of coupled deep earth-surface processes. Glob Planet Change 58(1–4):1–118

Crossland CJ, Kremer HH, Lindeboom HJ, Marshall Crossland JI, Le Tissier MDA (2007) Coastal fluxes in the anthropocene. Springer, Berlin, 231 p

Dean RG, Dalrymple RA (2004) Coastal processes with engineering applications. Cambridge University Press, Cambridge/New York, 488 p

Einsele G (1992) Sedimentary basins. Evolution, facies, and sediment budget. Springer, Berlin/New York, 628 p

Hill HH, Kelley JT, Belknap DF, Dickson SM (2004) The effects of storms and storm-generated currents on the sand beaches in southern Maine. Mar Geol 210:149–168

Jones SJ, Frostick LE (eds) (2002) Sediment flux to basins: causes, controls and consequences. Geological Society, London, Special Publications, vol 191, 284 pages

Maanan M, Robin M (2010) Geomatic solution for coastal environments. Nova Science Publishers, New York, 371 pages

Milliman JD, Farnsworth KL (2011) River discharge to the coastal ocean: a global synthesis. Cambridge University Press, Cambridge/New York, 392 p

Milliman JD, Syvitsky JPM (1992) Geomorphic/tectonic control of sediment discharge to the ocean: the importance of small mountainous rivers. J Geol 100:525–544

Panin A (2004) Land-ocean sediment transfer in palaetimes, and implications for present-day natural fluvial fluxes. Sediment Transfer through the Fluvial System, pp 115–124

Pilkey OP, Dixon K (1996) The shore and the corps. Island Press, Washington, DC, 272 pp

Reid, Leslie M, Thomas Dunne (1996) Rapid evaluation of sediment budgets. Catena Verlag (GeoEcology paperback), Reiskirchen, 164 p

Schwab WC, Thieler ER, Allen JR, Foster DS, Swift BA, Denny JF (2000) Influence of inner continental shelf framework on the evolution and behavior of the barrier island system between Fire Island Inlet and Shinnecock Inlet, Long Island, New York. J Coast Res 16:396–407

Syvitski JPM, Vorosmarty CJ, Kettner AJ, Green P (2005) Impact of humans on the flux of terrestrial sediment to the global coastal ocean. Science 308:376–380

Syvitski JPM, Kettner AJ, Overeem I, Hutton EWH, Hannon MT, Brakendridge HGR, Day J, Vorosmarty CJ, Saito Y, Giosan L, Nicholls RJ (2009) Sinking deltas due to human activities. Nat Geosci 2:681

Thieler ER, Pilkey Jr. OH, Young RS, Bush DM, Chai F (2000) The use of mathematical models to predict beach behaviour for U.S. coastal engineering: a critical review. J Coast Res 16:48–70

Vörösmarty JV, Meybeck M, Fekete B, Sharma K, Green P, Syvitski JPM (2003) Anthropogenic sediment retention: major global impact from registered river impoundments. Glob Planet Change, n° 39(1–2):169–190

Contents

Contributors

Carl L. Amos School of Ocean and Earth Science, National Oceanography Centre, Southampton, Hampshire, UK

César Andrade Centro e Departamento de Geologia, Faculdade de Ciências, Universidade de Lisboa, Lisboa, Portugal

Giorgio Anfuso Dpto. de Ciencias de la Tierra, Facultad de Ciencias del Mar y Ambientales, Universidad de Cádiz, Cádiz, Spain

Edward J. Anthony Aix Marseille Université, Institut Universitaire de France, CEREGE, UM 34, Europôle Méditerranéen de l'Arbois, Aix en Provence Cedex, France

Agnès Baltzer CNRS – UMR 6554, Laboratoire Géolittomer/IGARUN, Université de Nantes – Campus du Tertre, Nantes Cédex 3, France

Jean-François Bourillet IFREMER Brest, REM, Plouzané, France

Guillaume Brunier CEREGE, Université Aix Marseille, UMR 34, Europôle Méditerranéen de l'Arbois, Aix en Provence Cedex, France

Adrien Cartier Laboratoire D'Océanologie et des Géosciences, UMR 8187 LOG, Université du Littoral Côte d'Opale, Wimeureux, France

Stéphane Costa Lab. Géophen., UMR CNRS-LETG Caen Géophen 6554, University of Caen Basse-Normandie, Caen, Cedex, France

Giuseppe Cultrone Departamento de Mineralogía y Petrología, Universidad de Granada, Granada, Spain

Mehdi Daou UMR 5519, LEGI, Université de Grenoble, Saint-Martin-d'Hères, France

Franck Dolique Univ. Antilles-Guyane, Martinique, Schoelcher, France

Abdelmounim El Mrini Département de Géologie, Faculté des Sciences, Université Abdelmalek Essaâdi, Tétouan, Morocco

Christian Ferrarin Institute of Marine Sciences, ISMAR-CNR, Venezia, Italy

Jérôme Fournier Muséum National d'Histoire Naturelle, Station Marine, Dinard, France

CNRS – UMR 7208 BOREA, Muséum National d'Histoire Naturelle, Paris cedex 05, France

Maria da Conceição Freitas Centro e Departamento de Geologia, Faculdade de Ciências, Universidade de Lisboa, Lisboa, Portugal

Antoine Gardel Université du Littoral Côte d'Opale, Laboratoire d'Océanologie et de Géosciences, CNRS UMR 8187 LOG, Wimereux, France

CNRS Guyane, USR3456, Immeuble Le Relais, Cayenne, France

Evelyne Goubert Geoarchitecture EA2219, Geosciences marines & Géomorphologie littorale, Université de Bretagne Sud, Vannes, France

Rachel Helsby School of Ocean and Earth Science, National Oceanography Centre, Southampton, Hampshire, UK

Arnaud Hequette Laboratoire D'Océanologie et des Géosciences, UMR 8187 LOG, Université du Littoral Côte d'Opale, Wimeureux, France

Nathalie Labourdette UPMC Univ Paris 06, CNRS, UMR 7193, ISTeP, Paris cedex 05, France

Benoit Laignel Department of Geology, UMR 6143 CNRS M2C, University of Rouen, Mont-Saint-Aignan, France

Philippe Larroudé UMR 5519, LEGI, Université de Grenoble, Saint-Martin-d'Hères, France

Franck Lartaud UPMC Univ Paris 06, CNRS, Laboratoire d'Écogéochimie des Environnements Benthiques (LECOB) UMR 8222, Observatoire Océanologique de Banyuls, Banyuls-sur-mer, France

UPMC Univ Paris 06, CNRS, UMR 7193, ISTeP, Paris cedex 05, France

Pauline Letortu Lab. Géophen., UMR CNRS-LETG Caen Géophen 6554, University of Caen Basse-Normandie, Caen, Cedex, France

Mohamed Maanan Institut de Géographie et d'Aménagement Régional de l'Université de Nantes, Géolittomer, LETG UMR 6554-CNRS, Nantes Cedex 3, France

Jakub Małecki Cryosphere Research Department, Adam Mickiewicz University, Poznań, Poland

Elena Marrocchino Department of Physics and Earth Sciences, University of Ferrara, Ferrara, Italy

Giuseppe Mastronuzzi Dipartimento di Scienze della Terra e Geoambientali, Università degli Studi "Aldo Moro", Bari, Italy

Khalid Mehdi Environment – Integrated Coastal Zone Management, Department of Geology, Faculty of Sciences, UFR: ST/18/05, El Jadida, Morocco

Faculté des Sciences, Laboratoire des Geosciences Marines et Sciences du Sol (Unité associée CNRST-URAC 45), El Jadida, Morocco

Asmae Mhamdi Alaoui Environment – Integrated Coastal Zone Management, Department of Geology, Faculty of Sciences, UFR: ST/18/05, El Jadida, Morocco

Faculté des Sciences, Laboratoire des Geosciences Marines et Sciences du Sol (Unité associée CNRST-URAC 45), El Jadida, Morocco

Zohra Mokeddem IFREMER Brest, LGG, Plouzané, France

Driss Nachite Faculté Polydisciplinaire, Larache, Morocco

Christina Péron Université du Littoral Côte d'Opale, Laboratoire d'Océanologie et de Géosciences, CNRS UMR 8187 LOG, Wimereux, France

CNRS Guyane, USR3456, Immeuble Le Relais, Cayenne, France

Georges Pichard Département d'Histoire, Université Aix-Marseille, Aix-en-Provence, France

Mireille Provansal Europôle de l'Arbois, CNRS, UM CEREGE, Aix-en-Provence, France

UMR 6635 CEREGE, Europôle Méditerranéen de l'Arbois, Université Aix Marseille, Aix-en-Provence, France

Hervé Regnauld Laboratoire Costel UMR 6554 LETG et IFR Caren, Université de Rennes 2, Rennes, France

UMR CNRS 6554 LETG, Université de Rennes 2, Rennes, France

Marc Robin Institut de Géographie et d'Aménagement Régional de l'Université de Nantes, Géolittomer, LETG UMR 6554-CNRS, Nantes Cedex 3, France

Mateusz Czesław Strzelecki Department of Geomorphology, University of Wrocław, Wrocław, Poland

Rui Taborda LATTEX/IDL, Departamento de Geologia, Faculdade de Ciências, Universidade de Lisboa, Lisboa, Portugal

Georg Umgiesser Institute of Marine Sciences, ISMAR-CNR, Venezia, Italy

Carmela Vaccaro Department of Physics and Earth Sciences, University of Ferrara, Ferrara, Italy

Piotr Zagórski Department of Geomorphology, Maria Curie-Skłodowska University, Lublin, Poland

Bendahhou Zourarah Environment – Integrated Coastal Zone Management, Department of Geology, Faculty of Sciences, UFR: ST/18/05, El Jadida, Morocco

Faculté des Sciences, Laboratoire des Geosciences Marines et Sciences du Sol (Unité associée CNRST-URAC 45), El Jadida, Morocco

About the Editors

Mohamed Maanan is an Associate Professor at University of Nantes (France). His research is concerned with the interaction between coastal environment processes, earth surface materials and impact of human activities. In particular, attention is focussed on sediment delivery processes – the temporal and spatial dynamics of sediment production and transfer (continent-ocean).

Marc Robin is Professor of the University of Nantes (France). He is specialised in watershed and coastal dynamics, policy making and management of coastal areas, risks and hazards issues along coastline, remote sensing of coastal resources and management of coastal data into geographical information systems.

Part I
Sediment Fluxes Changes Link to Climatic Change During Holocene

Chapter 1
The "*Turritella* Layer": A Potential Proxy of a Drastic Holocene Environmental Change on the North–East Atlantic Coast

Agnès Baltzer, Zohra Mokeddem, Evelyne Goubert, Franck Lartaud, Nathalie Labourdette, Jérôme Fournier, and Jean-François Bourillet

Abstract A collection of data including sub-bottom VHR seismic (Seistec boomer), bathymetry and cores, was conducted in three sea lochs of the north west coast of Scotland, as part of an investigation of the sedimentological and climatic change records since the Last Glacial Maximum. Five acoustic facies have been correlated to the sediment of the core MD04-3204 and interpreted in terms of glacial activity, ice retreat and subsequent Holocene sedimentation. Grain size, pollen, foraminifera, geochemical analyses together with ^{14}C dating, indicate a

A. Baltzer (✉)
CNRS – UMR 6554, Laboratoire Géolittomer/IGARUN, Université de Nantes – Campus du Tertre, BP 81227, 44 312 Nantes Cédex 3, France
e-mail: agnes.baltzer1@univ-nantes.fr

Z. Mokeddem
IFREMER Brest, LGG, BP 70, 29280 Plouzané, France

E. Goubert
Geoarchitecture EA2219, Geosciences marines & Géomorphologie littorale, Université de Bretagne Sud, 56 017 cédex Vannes, France

F. Lartaud
UPMC Univ Paris 06, CNRS, Laboratoire d'Écogéochimie des Environnements Benthiques (LECOB) UMR 8222. Observatoire Océanologique de Banyuls, 66650 Banyuls-sur-mer, France

UPMC Univ Paris 06, CNRS, UMR 7193, ISTeP, 75252 cedex 05 Paris, France

N. Labourdette
UPMC Univ Paris 06, CNRS, UMR 7193, ISTeP, 75252 cedex 05 Paris, France

J. Fournier
Muséum National d'Histoire Naturelle, Station Marine, 38 rue du Port Blanc, 35801 Dinard, France

CNRS – UMR 7208 BOREA, Muséum National d'Histoire Naturelle, 43 rue Cuvier, CP 26, 75231 Paris cedex 05, France

J.-F. Bourillet
IFREMER Brest, REM, BP 70, 29280 Plouzané, France

M. Maanan, M. Robin (eds.), *Sediment Fluxes in Coastal Areas*,
Coastal Research Library 10, DOI 10.1007/978-94-017-9260-8_1

complex series of palaeoclimate changes in the loch since the Last Glacial Maximum including "Rapid Climate Changes" described in literature.

A characteristic acoustic reflector, identified into the holocene sedimentary deposit, occurring into the different studied lochs, corresponds to a unique *Turritella* layer. A similar reflector has been identified on the continental shelf of South Brittany and is correlated to a *Turritella* layer. This *Turritella* layer seems to be related, in both case, to a drastic environmental change beginning around the 8,200 year BP cold event and finishing abruptly at 7,500 year BP in the North Atlantic.

1.1 Introduction

As the western Scottish sea lochs (Fig. 1.1) are located at an important junction between the North Atlantic Ocean and the European waters of the North Sea, these sites are adapted for observations on climatic variations at high latitudes, and in particular variations in sedimentation that have resulted from climatic changes since the Last Glacial Maximum (LGM) at high latitudes 56°N. Previous studies

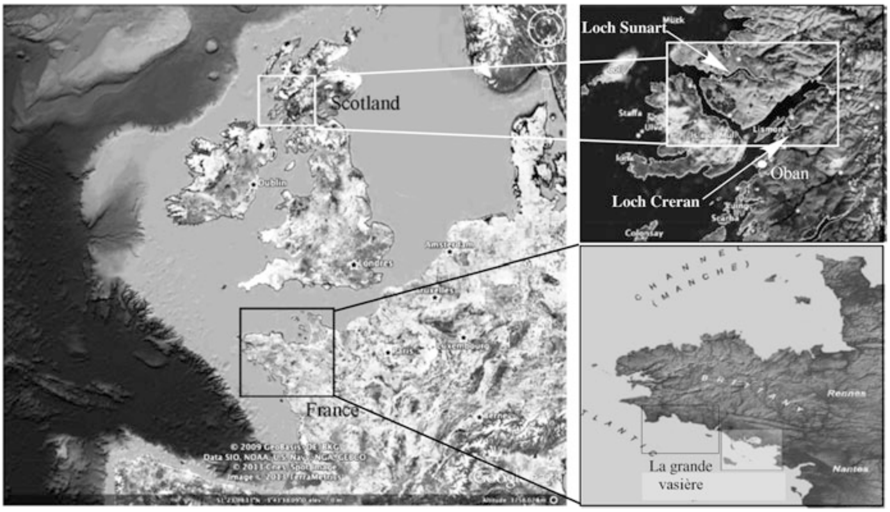

Fig. 1.1 Location of the two studies areas in the north west coast of Scotland and in south Brittany. The *white square* in Scotland, north of Oban, shows the location of two sea-lochs: Loch Sunart and Loch Creran. A first géophysic survey (SUCRE, 2002), allowed to acquire seismic profiles in both lochs and short cores in Creran. An oceanographic cruise with the Marion Dufresne (ORSANE 2004) permit to acquire 2 long cores. The *black square* on the south coast of Brittany shows the location of the "Grande vasière", a huge muddy sand patch occurring on the shelf, up to 100 m of water depth

(Mokeddem et al. 2010; Baltzer et al. 2010) established the chronostratigraphy of sedimentary deposits in the Loch Sunart, based on the correlation between a long core (12 m) and seismic acoustic facies constrained by ^{14}C ages together with sediment analysis. An unusual reflector frequently occurs in the Holocene thick transparent sedimentary unit of Loch Sunart and Loch Creran which corresponds to a 15 cm thick layer of *Turritella communis* (Graham 1938, 1988) dated from base to top at 8,260–7,460 cal year BP.

On the southern part of Brittany, the core VK03-58bis retrieved in the Bay of Biscay gives an integrated image of the climate evolution at mid latitudes (45°N) through pollen and Dinocysts analyses (Naughton et al. 2007) from 8,850 year BP to present days. This core was acquired in "la Grande vasière" (Fig. 1.1) in a homogeneous silt sequence marked by a specific level rich in *T. communis* (Folliot 2004) dated at 8,482–7,520 year BP. In both cases the sudden disparition of *T. communis* seems to correspond to a drastic change of environmental conditions.

This paper presents hypothesis for the establishment and extinction of this *Turritella* layer, and its potential signification.

1.2 General Settings: Scottish Sea Lochs and South Brittany Shelf

1.2.1 Scottish Sea Lochs

The two Lochs presented in this paper, are localised on the West coast of Scotland. Loch Creran is located in the north of Argyll and Bute council whereas Loch Sunart is located near the Ardnamurchan peninsula (Fig. 1.1). These lochs are bordered by mountains whose altitude does not exceed 1,000 m. Vegetation cover is variable, including spaces of forests and grassland.

These lochs present a characteristic morphology of "fjord style lochs" with a steep sided narrow cross section and flat loch floor (Syvitski et al. 1987). This typical morphology provides protection from swell and wave action and could preserve long sedimentation records (Howe et al. 2002). Loch Sunart (Fig. 1.2) is the second longest Scottish loch with 31 km length (Bates et al. 2004), an average of 1.5 km width and has a maximum depth of 124 m. The length and the narrowness of this loch make it possible to meet a spectrum of hydrodynamic conditions, from well exposed conditions at the mouth, to extremely calm conditions at the head of the loch.

The Loch Creran (Fig. 1.3) is smaller than Loch Sunart, with 12.8 km length and a maximum depth of 49 m. Located at 8 km north of Loch Etive, its ocean connection is restricted by the Island of Eriska which protects the inner basin from the energy of the swell. The Loch Creran includes four basins and Glen Creran constitutes the principal supply of fresh water. The water of the Loch Creran is extremely well mixed (Edwards and Sharples 1986; Austin and Inall 2002).

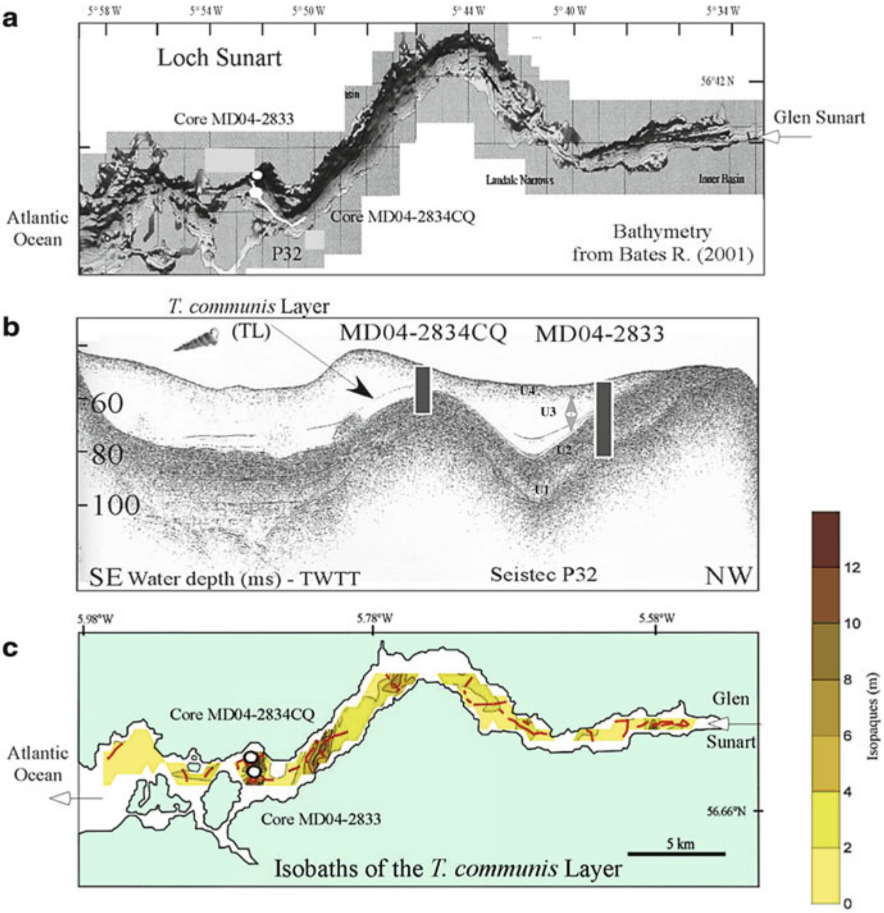

Fig. 1.2 Loch Sunart. (**a**) Bathymetric map of Loch sunart realized by Bates (Bates and Byham 2001). Location of the 2 long cores MD04-2833 and core MD04-234CQ acquired with the Marion Dufresne and the situation of the boomer seismic profile P32. (**b**) Seistec profile P32: characteristic profile with the different seismic units. The Turitella communis Layer is indicated by an *arrow* in the transparent unit (U3). The position of the long CALYPSO core MD04-2833 and the CASQ core MD04-2834CQ are indicated, showing the variation of Turritella Layer (noticed T.L. further on) depth. (**c**) Map of the T.L. isobaths. The seismic reflector related to the TL has been mapped. The resulting isobaths are shown on the figure and reveal the paleo-bathymetry at 7,500 cal year BP (age of the top of the TL.)

1.2.2 South Brittany Shelf

The Bay of Biscay presents a 300 km wide continental shelf in it's north-westernmost area and becomes narrow with a steep slope further south (30 km wide) (Fig. 1.1). This shelf is composed of two small and one large open-shelf mud patches: the West and South Gironde shelf mud fields and the "Grande Vasière"

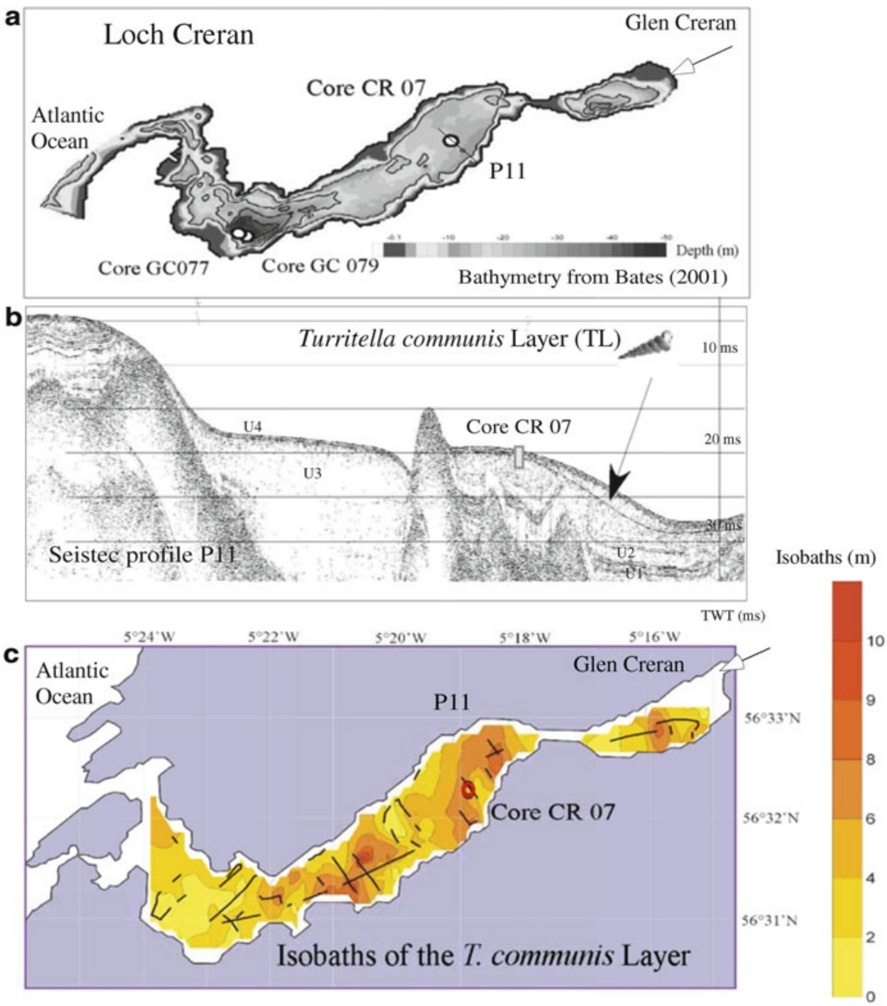

Fig. 1.3 Loch Creran. (**a**) Bathymetric map of Loch Creran realized by Bates (Bates and Byham 2001). Location of the short core CR07 acquired by divers during the SUCRE mission, and the situation of the boomer seismic profile P11. (**b**) Seistec profile P11: characteristic profile with the different seismic units. The Turitella communis Layer is indicated by an *arrow* in the transparent unit (U3). The position of the short core CR 07 is indicated, showing the variation of TL depth. (**c**) Map of the TL isobaths. The seismic reflector related to the TL has been mapped. The resulting isobaths are shown on the figure and reveal the paleo-bathymetry at 7,500 cal year BP (age of the top of the T.L.)

(Fig. 1.4) (Allen and Castaing 1977). According to McCave's classification the "Grande Vasière" is a mid-shelf mud belt (McCave 1972). The "Grande Vasière" is large (more than 225 km length and 40 km wide), located between 80 and 110 m water depth and presents an annual mean sedimentary rate of 0.1–0.2 cm year^{-1} (Lesueur et al. 2001) (Fig. 1.1). Shelf upkeep depends essentially on: (a) continental supply by nepheloid layers (Jouanneau et al. 1999; Lesueur et al. 2001); (b) wave