

Central and Eastern European Development Studies

Jan Harff · Svante Björck  
Peer Hoth *Editors*

# The Baltic Sea Basin



Springer

# **Central and Eastern European Development Studies (CEEDES)**

Editorial Board

B. Müller

W. Erbguth

For further volumes:

<http://www.springer.com/series/3862>

Jan Harff · Svante Björck · Peer Hoth  
Editors

# The Baltic Sea Basin

With 174 Figures and 16 Tables

 Springer

*Editors*

Prof. Dr. Jan Harff  
Leibniz Institute for Baltic Sea Research  
Warnemünde  
Seestr. 15  
18119 Rostock  
Germany  
jan.harff@io-warnemuende.de

Prof. Svante Björck  
Department of Earth and Ecosystem  
Sciences  
Division of Geology, Quaternary Sciences  
Lund University  
Sölveg. 12  
SE-223 62 Lund  
Sweden  
svante.bjorck@geol.lu.se

Dr. Peer Hoth  
Federal Institute for Geosciences and  
Natural Resources  
Berlin Office  
Wilhelmstrasse 25-30  
13593 Berlin  
peer.hoth@freenet.de

ISSN 1614-032X

ISBN 978-3-642-17219-9

e-ISBN 978-3-642-17220-5

DOI 10.1007/978-3-642-17220-5

Springer Heidelberg Dordrecht London New York

Library of Congress Control Number: 2011921542

© Springer-Verlag Berlin Heidelberg 2011

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilm or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German Copyright Law of September 9, 1965, in its current version, and permission for use must always be obtained from Springer. Violations are liable to prosecution under the German Copyright Law.

The use of general descriptive names, registered names, trademarks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

*Cover design:* deblik, Berlin

Printed on acid-free paper

Springer is part of Springer Science+Business Media ([www.springer.com](http://www.springer.com))

# Contents

## Part I Introduction

- 1 The Baltic Sea Basin: Introduction** . . . . . 3  
Jan Harff, Svante Björck, and Peer Hoth

## Part II Geological and Tectonical Evolution

- 2 Geological Evolution and Resources of the Baltic Sea Area from the Precambrian to the Quaternary** . . . . . 13  
Saulius Šliaupa and Peer Hoth
- 3 Glacial Erosion/Sedimentation of the Baltic Region and the Effect on the Postglacial Uplift** . . . . . 53  
Aleksey Amantov, Willy Fjeldskaar, and Lawrence Cathles

## Part III The Basin Fill as a Climate and Sea Level Record

- 4 The Development of the Baltic Sea Basin During the Last 130 ka** . . . . . 75  
Thomas Andrén, Svante Björck, Elinor Andrén, Daniel Conley, Lovisa Zillén, and Johanna Anjar
- 5 Late Quaternary Climate Variations Reflected in Baltic Sea Sediments** . . . . . 99  
Jan Harff, Rudolf Endler, Emel Emelyanov, Sergey Kotov, Thomas Leipe, Matthias Moros, Ricardo Olea, Michal Tomczak, and Andrzej Witkowski
- 6 Geological Structure of the Quaternary Sedimentary Sequence in the Klaipėda Strait, Southeastern Baltic** . . . . . 133  
Albertas Bitinas, Aldona Damušytė, and Anatoly Molodkov

## Part IV Coastline Changes

- 7 Coastlines of the Baltic Sea – Zones of Competition Between Geological Processes and a Changing Climate: Examples from the Southern Baltic . . . . .** 149  
Jan Harff and Michael Meyer
- 8 Palaeogeographic Model for the SW Estonian Coastal Zone of the Baltic Sea . . . . .** 165  
Alar Rosentau, Siim Veski, Aivar Kriiska, Raivo Aunap, Jüri Vassiljev, Leili Saarse, Tiit Hang, Atko Heinsalu, and Tõnis Oja
- 9 Palaeoreconstruction of the Baltic Ice Lake in the Eastern Baltic . . . . .** 189  
Jüri Vassiljev, Leili Saarse, and Alar Rosentau
- 10 Submerged Holocene Wave-Cut Cliffs in the South-eastern Part of the Baltic Sea: Reinterpretation Based on Recent Bathymetrical Data . . . . .** 203  
Vadim Sivkov, Dimitry Dorokhov, and Marina Ulyanova
- 11 Drowned Forests in the Gulf of Gdańsk (Southern Baltic) as an Indicator of the Holocene Shoreline Changes . . . . .** 219  
Szymon Uścińowicz, Grażyna Miotk-Szpiganowicz, Marek Krapiec, Małgorzata Witak, Jan Harff, Harald Lübke, and Franz Tauber
- 12 Holocene Evolution of the Southern Baltic Sea Coast and Interplay of Sea-Level Variation, Isostasy, Accommodation and Sediment Supply . . . . .** 233  
Reinhard Lampe, Michael Naumann, Hinrich Meyer, Wolfgang Janke, and Regine Ziekur

## Part V Sediment Dynamics

- 13 On the Dynamics of “Almost Equilibrium” Beaches in Semi-sheltered Bays Along the Southern Coast of the Gulf of Finland . . . . .** 255  
Tarmo Soomere and Terry Healy
- 14 Modelling Coastline Change of the Darss-Zingst Peninsula with Sedsim . . . . .** 281  
Michael Meyer, Jan Harff, and Chris Dyt

## Part VI Interactions Between a Changing Environment and Society

- 15 Settlement Development in the Shadow of Coastal Changes – Case Studies from the Baltic Rim . . . . .** 301  
Hauke Jöns

**16 Geological Hazard Potential at the Baltic Sea and Its Coastal Zone: Examples from the Eastern Gulf of Finland and the Kaliningrad Area . . . . . 337**  
Mikhail Spiridonov, Daria Ryabchuk, Vladimir Zhamoida, Alexandr Sergeev, Vadim Sivkov, and Vadim Boldyrev

**17 Seafloor Desertification – A Future Scenario for the Gulf of Finland? . . . . . 365**  
Henry Vallius, Vladimir Zhamoida, Aarno Kotilainen, and Daria Ryabchuk

**18 Sources, Dynamics and Management of Phosphorus in a Southern Baltic Estuary . . . . . 373**  
Gerald Schernewski, Thomas Neumann, and Horst Behrendt

**Part VII Hydrogeological Modeling**

**19 Potential Change in Groundwater Discharge as Response to Varying Climatic Conditions – An Experimental Model Study at Catchment Scale . . . . . 391**  
Maria-Theresia Schafmeister and Andreas Darsow

**Part VIII Monitoring**

**20 Monitoring the Bio-optical State of the Baltic Sea Ecosystem with Remote Sensing and Autonomous In Situ Techniques . . . . . 407**  
Susanne Kratzer, Kerstin Ebert, and Kai Sørensen

**Index . . . . . 437**

# Contributors

**Aleksey Amantov** VSEGEI, St. Petersburg, Russia, 4448470@mail.wplus.net

**Thomas André**n School of Life Sciences, Södertörn University, SE-141 89 Huddinge, Sweden, thomas.andren@sh.se

**Elinor André**n School of Life Sciences, Södertörn University, SE-141 89 Huddinge, Sweden, Elinor.Andren@sh.se

**Johanna Anjar** Department of Earth and Ecosystem Sciences, Quaternary Sciences, Lund University, SE-223 62 Lund, Sweden, Johanna.Anjar@geol.lu.se

**Raivo Aunap** Department of Geography, University of Tartu, 51014 Tartu, Estonia, raivo.aunap@ut.ee

**Horst Behrendt** Leibniz Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany

**Albertas Bitinas** Coastal Research and Planning Institute, Klaipėda University, LT-92294 Klaipėda, Lithuania; Department of Geology and Mineralogy, Faculty of Natural Sciences, Vilnius University, LT-03101 Vilnius, Lithuania, albertas.bitinas@corpi.ku.lt; albertas.bitinas@gmail.com

**Svante Björck** Department of Earth and Ecosystem Sciences, Division of Geology, Quaternary Sciences, Lund University, Sölveg. 12, SE-223 62 Lund, Sweden, svante.bjorck@geol.lu.se

**Vadim Boldyrev** Atlantic Branch, P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences (ABIORAS), Kaliningrad, Russia, Vadim\_Boldyrev@mail.ru

**Lawrence Cathles** Cornell University, Ithaca, NY, USA, lmc19@cornell.edu

**Daniel Conley** Department of Earth and Ecosystem Sciences, Quaternary Sciences, Lund University, SE-223 62 Lund, Sweden, Daniel.Conley@geol.lu.se

**Aldona Damušytė** Lithuanian Geological Survey, LT-03123 Vilnius, Lithuania, aldona.damusyte@lgt.lt



**Andreas Darsow** Department of Environmental Geosciences, University of Vienna, 1090 Vienna, Austria, andreas.darsow@univie.ac.at

**Dimitry Dorokhov** Atlantic Branch, P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences, Kaliningrad, Russia, d\_dorokhov@mail.ru

**Chris Dyt** CSIRO Petroleum Resources, Bentley, WA 6102, Australia, chris.dyt@csiro.au

**Kerstin Ebert** Laboratoire d'Océanographie de Villefranche (LOV), Université Pierre et Marie Curie, UMR CNRS 7093, Quai de la Darse, 06230 Villefranche-sur-Mer Cedex, France, kerstin.ebert@obs-vlfr.fr

**Emel Emelyanov** Atlantic Branch, P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences (ABIORAS), Kaliningrad, Russia, abio@atlas.baltnet.ru

**Rudolf Endler** Leibniz Institute for Baltic Sea Research Warnemünde, D-18119 Rostock, Germany, rudolf.endler@io-warnemuende.de

**Willy Fjeldskaar** IRIS, Stavanger, Norway, WF@tectonor.com

**Tiit Hang** Department of Geology, University of Tartu, 51014 Tartu, Estonia, tiit.hang@ut.ee

**Jan Harff** Leibniz Institute for Baltic Sea Research Warnemünde, D-18119 Rostock, Germany; presently at Institute of Marine and Coastal Sciences, University of Szczecin, PL-70-383 Szczecin, Poland, jan.harff@io-warnemuende.de

**Terry Healy**<sup>†</sup> (28.11.1944–20.07.2010) Coastal Marine Group, Earth and Ocean Sciences, University of Waikato, Hamilton 3240, New Zealand

**Atko Heinsalu** Institute of Geology, Tallinn University of Technology, 19086 Tallinn, Estonia, heinsalu@gi.ee

**Peer Hoth** Federal Institute for Geosciences and Natural Resources, Berlin Office, 13593 Berlin (presently at: Federal Ministry of Economics and Technology, Energy Department), peer.hoth@freenet.de

**Wolfgang Janke** 17489 Greifswald, Germany, wofajanke@web.de

**Hauke Jöns** Lower Saxony Institute for Historical Coastal Research, D-26382 Wilhelmshaven, Germany, joens@nihk.de

**Aarno Kotilainen** Geological Survey of Finland, FIN-02151 Espoo, Finland, aarno.kotilainen@gtk.fi

**Sergey Kotov** St. Petersburg State University, St. Petersburg, Russia, kotov\_s@yahoo.co.uk

**Marek Krapiec** University of Science and Technology, Kraków, Poland, mkrapiec@agh.edu.pl

**Susanne Kratzer** Department of Systems Ecology, Stockholm University, 106 91 Stockholm, Sweden, Suse@ecology.su.se

**Aivar Kriiska** Institute of History and Archaeology, University of Tartu, Tartu, Estonia, aivar.kriiska@ut.ee

**Reinhard Lampe** Institut für Geographie und Geologie, Ernst-Moritz-Arndt-Universität Greifswald, D-17487 Greifswald, Germany, lampe@uni-greifswald.de

**Thomas Leipe** Leibniz Institute for Baltic Sea Research Warnemünde, D-18119 Rostock, Germany, thomas.leipe@io-warnemuende.de

**Harald Lübke** Roman-Germanic Commission, German Archaeological Institute, 60325 Frankfurt a.M, Germany, harald.luebke@schloss-gottorf.de

**Hinrich Meyer** Institut für Geographie und Geologie, Ernst-Moritz-Arndt-Universität Greifswald, D-17487 Greifswald, Germany, himeyer@uni-greifswald.de

**Michael Meyer** Leibniz Institute for Baltic Sea Research Warnemünde, D-18119 Rostock, Germany; Institute for Environmental Engineering, University Rostock, 18057 Rostock, Germany, michael.meyer@uni-rostock.de

**Grażyna Miotk-Szpiganowicz** Polish Geological Institute, National Research Institute, Gdańsk, Poland, grazyna.miotk-szpiganowicz@pgi.gov.pl

**Anatoly Molodkov** Research Laboratory for Quaternary Geochronology, Institute of Geology, Tallinn University of Technology, 19086 Tallinn, Estonia, molodkov@gi.ee

**Matthias Moros** Leibniz Institute for Baltic Sea Research Warnemünde, D-18119 Rostock, Germany, Matthias.moros@io-warnemuende.de

**Michael Naumann** Leibniz Institute for Baltic Sea Research Warnemünde, D-18119 Rostock, Germany; presently at Landesamt für Bergbau, Energie und Geologie, 30655 Hannover, Germany, michael.naumann@lbeg.niedersachsen.de

**Thomas Neumann** Leibniz Institute for Baltic Sea Research Warnemünde, Rostock, Germany, thomas.neumann@io-warnemuende.de

**Tõnis Oja** Department of Physics, Tallinn University of Technology, 19086 Tallinn, Estonia, tonis.oja@maaamet.ee

**Ricardo Olea** Leibniz Institute for Baltic Sea Research Warnemünde, D-18119 Rostock, Germany; presently at US Geological Survey, Reston, VA, USA, olea@usgs.gov

**Alar Rosentau** Department of Geology, University of Tartu, 51014 Tartu, Estonia; Institute of History and Archaeology, University of Tartu, Tartu, Estonia, alar.rosentau@ut.ee

**Daria Ryabchuk** A.P. Karpinsky Russian Research Geological Institute (VSEGEI), St. Petersburg 199106, Russia, Daria\_Ryabchuk@vsegei.ru

**Leili Saarse** Institute of Geology, Tallinn University of Technology, 19086 Tallinn, Estonia, saarse@gi.ee

**Maria-Theresia Schafmeister** Institute for Geography and Geology, University of Greifswald, 17489 Greifswald, Germany, schaf@uni-greifswald.de

**Gerald Schernewski** Leibniz Institute for Baltic Sea Research Warnemünde, Rostock, Germany, gerald.schernewski@io-warnemuende.de

**Alexandr Sergeev** A.P. Karpinsky Russian Research Geological Institute (VSEGEI), St. Petersburg, 199106, Russia, sergeevau@yandex.ru

**Vadim Sivkov** Atlantic Branch, P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences (ABIORAS), Kaliningrad, Russia, sivkov@kaliningrad.ru

**Saulius Šliaupa** Institute of Geology and Geography, Vilnius University, Vilnius 01013, Lithuania, sliaupa@geo.lt

**Tarmo Soomere** Institute of Cybernetics, Tallinn University of Technology, 12618 Tallinn, Estonia, soomere@cs.ioc.ee

**Kai Sørensen** Norwegian Institute for Water Research (NIVA), Gaustadalléen 21, NO-0349 OSLO, Norway, kai.sorensen@niva.no

**Mikhail Spiridonov** A.P. Karpinsky Russian Research Geological Institute (VSEGEI), St. Petersburg 199106, Russia, Michail\_Spiridonov@vsegei.ru

**Franz Tauber** Leibniz Institute for Baltic Sea Research Warnemünde, D-18119 Rostock, Germany, franz.tauber@io-warnemuende.de

**Michał Tomczak** Institute of Marine and Coastal Sciences, University of Szczecin, Szczecin, Poland, tomcz.michal@gmail.com

**Marina Ulyanova** Atlantic Branch, P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences, Kaliningrad, Russia, marioches@rambler.ru

**Szymon Uścińowicz** Polish Geological Institute, National Research Institute, Gdańsk, Poland, szymon.uscinowicz@pgi.gov.pl

**Henry Vallius** Geological Survey of Finland, FIN-02151 Espoo, Finland, henry.vallius@gtk.fi

**Jüri Vassiljev** Institute of Geology, Tallinn University of Technology, 19086 Tallinn, Estonia, vassilje@gi.ee

**Siim Veski** Institute of Geology, Tallinn University of Technology, 19086 Tallinn, Estonia, veski@gi.ee

**Małgorzata Witak** Institute of Oceanography, University of Gdańsk, Gdańsk, Poland, ocemaw@univ.gda.pl

**Andrzej Witkowski** Institute of Marine and Coastal Sciences, University of Szczecin, Szczecin, Poland, witkowsk@univ.szczecin.pl

**Vladimir Zhamoida** A.P. Karpinsky Russian Research Geological Institute (VSEGEI), St. Petersburg, 199106, Russia, Vladimir\_Zhamoida@vsegei.ru

**Regine Ziekur** Leibniz-Institut für Angewandte Geophysik, D-30655 Hannover, Germany, Regine.Ziekur@liag-hannover.de

**Lovisa Zillén** Department of Earth and Ecosystem Sciences, Quaternary Sciences, Lund University, SE-223 62 Lund, Sweden, Lovisa.Zillen@geol.lu.se

**Part I**  
**Introduction**

# Chapter 1

## The Baltic Sea Basin: Introduction

Jan Harff, Svante Björck, and Peer Hoth

**Abstract** The Baltic Sea Basin serves as an example of a region where the use of natural resources and the need of environmental protection require a comprehensive and holistic approach in terms of geosciences, environmental sciences, and socio-economics. In this book, authors from countries around the Baltic Sea and overseas shed light on the Baltic Sea Basin with respect to (1) the formation of the Baltic Basin and its geological resources, (2) the stratigraphic record – mirror of climatic changes during the last glacial cycle, (3) coastal processes and sediment dynamics including aspects of coastal engineering, (4) interaction between socio-economic driving forces and the natural environment since the prehistoric colonization, (5) management of the marine ecosystem, and (6) monitoring strategies, respectively remote sensing. The editors intend not only to provide a record of the current state of the art in the investigation of the Baltic Sea Basin, but also to initiate innovative interdisciplinary and international research activities.

**Keywords** Baltic basin · Geology · Tectonics · Climate history · Sea level change · Coastal dynamics · Socio-economy · Archaeology · Coastal zone management · Anthropogenic impact · Monitoring · Remote sensing

The Baltic Sea, connected to the North sea and the North Atlantic via the Danish straits, is the largest brackish water basin in the world. Geologically, the basin is confined to the northwest by the highlands of the Scandinavian Caledonides, situated between two major tectonic regional units: the eastern and the western European platforms. The Baltic basin serves as a natural laboratory for a variety of geological structures and key processes crucial in the exploration of mineral resources and engineering, the formation of intra-continental sedimentary basins, and the interaction of hydrosphere, geosphere, and biosphere in basinal and coastal environments.

---

J. Harff (✉)

Leibniz Institute for Baltic Sea Research Warnemünde, D-18119 Rostock, Germany; presently at Institute of Marine and Coastal Sciences, University of Szczecin, PL-70-383 Szczecin, Poland  
e-mail: jan.harff@io-warnemuende.de

Additionally, Baltic Sea sediments provide high-resolution records of climate and environmental changes during the Quaternary for the eastern North Atlantic realm. That record allows tracing back not only the change in the natural environment for the last 130,000 years but also the human impact and therefore socio-economic developments for at least the last 10,000 years.

The densely populated Baltic drainage area and the exploitation of the Baltic Sea resources cause permanent conflicts between economic interests and the protection of the unique ecological environment of the Baltic Sea. Therefore, the design of an effective interface between the different stakeholders is of vital importance for the community in the Baltic area and of great methodological interest for scientists, managers, and politicians not only in Europe but also worldwide.

The 33rd International Geological Congress (IGC) did provide the unique opportunity to discuss questions related to the points listed above in a very general way with the international geological scientific community. Therefore, a special symposium “The Baltic Sea Basin” was held on August 11, 2008, within the frame of the 33rd IGC at Oslo, Norway, in order to foster the understanding of the Baltic basin as a unit in terms of genesis, structure, ongoing processes and utilization. At the symposium, geoscientists, climate researchers, biologists, archaeologists, and computer scientists discussed questions regarding

- the formation of the Baltic basin and geological resources,
- the stratigraphic record – mirror of climatic changes during the last glacial/interglacial cycle,
- coastal processes and sediment dynamics,
- the feedback between socio-economic driving forces and the natural environment since the prehistoric colonization,
- the management of the marine ecosystem, and
- monitoring strategies and technical device design, including satellite observation methods.

In this book we report the results of the symposium. It is the first time that in a joint publication, scientists from different disciplines give a comprehensive and general overview about the Baltic Sea basin.

After this introduction, Part II is devoted to the *geological and tectonic evolution* of the Baltic basin. Sliupa and Hoth give an overview about the geological history of the Baltic Sea basin from the Precambrian to the Quaternary, including the genesis of geological resources. The chapter gives a summary of the evolution and the known resources of the Baltic sedimentary basin focusing on its central part. According to new evidence for the origin of the Baltic Sea, the basin was formed during Late Ediacaran–Early Cambrian time caused by the reactivation of the weakest lithosphere part of the East European craton. All the following stages of basin subsidence were dominated by extensional tectonics. However, the crust was most intensively structured in NW–SE-directed compression during Late Silurian and Early Devonian time due to the collision of Laurentia and Baltica. The Permian–Carboniferous period is mainly marked by magmatic intrusions in the southern part