The Handbook of Sidescan Sonar

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Preface

Sonar instruments are the only ones capable of accurately mapping large areas of the seabed and any water-covered area, because of the much lower attenuation in water of acoustic radiation compared with, for example, electromagnetic radiation. Sonars are therefore used all around the world, often in areas not mapped before. This meant there was a clear need for a reference book for new users, or users confronted with new features. This was first addressed by the *Handbook of Seafloor Sonar Imagery*, which I wrote in 1997 with the help of my colleagues Bramley J. Murton, D. Milkert and V. Hühnerbach whilst still at the Southampton Oceanography Centre (UK). Since then, we have had the pleasure of seeing this book used as a reference by many colleagues, in academic circles and in industry, during surveying or during processing and interpretation on land. Some university courses have adopted it as their main textbook and some survey companies have used it as the main learning support for their new engineers.

As time passed, and as the last edition went out of print, friends and colleagues everywhere started to press for a new edition. In the meantime, I had moved to the Department of Physics, University of Bath and my research interests (and publications) covered a broader range than just seabed mapping. Looking at other underwater instruments (e.g., bistatic sonars, bio-inspired sonars, passive sensors) has helped broaden the outlook of this book and put sidescan sonar applications in perspective. Continued research in planetary remote sensing also helped better seeing the general aspects of image interpretation, especially when confronted with strange, new environments. These changes are reflected in this *Handbook of Sidescan Sonar*, and in the way the different themes have been approached. After a brief introduction (Chapter 1), this book is divided into three main sections: the acquisition of sonar imagery (Chapters 2–4), covering all technological and scientific aspects of relevance to the sonar user; examples from the different environments (Chapters 5–9), including the increasing presence of man-made objects at all depths on the seabed; and techniques of advanced interpretation (Chapters 10–11), with their latest developments but also an assessment of how far they can be used reliably. I have aimed at making this book widely accessible by pitching it at a scientific graduate level, and reducing the equations to the bare minimum. Wherever necessary, references are available for the reader wanting to go further, essential ones at the end of each chapter and a full reference list at the end of the book.

Reference to commercial products, processes, or services by tradename, trademark, manufacturer, or otherwise does not constitute or imply its endorsement by the author or his institution. Similarly, the presence or absence of particular articles or results does not imply any judgment value, but merely the need to present the basics of sidescan sonar processing and interpretation in a finite space and writing time, focusing on the most representative and readily available examples.

Acknowledgments

This book has used my own research and activities, but has benefited from the influence of working and meeting many people throughout the world. Early on, as a Lavoisier Fellow, I was fortunate enough to work with Jean-Christophe Sempéré, Véronique Robigou, and John R. Delaney at the School of Oceanography, University of Washington, and they gave me the taste for mapping the seabed and discovering new areas on the Earth (closer than Venus, my previous field, but much easier to ground-check and map). I came back to Europe at the Institute of Oceanographic Sciences, Deacon Laboratory (U.K.), which relocated to the Southampton Oceanography Centre in 1995. In both places, I had the pleasure of working with other friends and experts of seabed mapping, including Lindsay Parson, Bramley J. Murton, Peter Hunter, Doug Masson, Neil Kenyon, Tim LeBas, and many others too numerous to mention. The 1997 *Handbook of Seafloor Sonar Imagery* also mentioned (in no particular order) Mike Somers, Roger Searle, Neil Mitchell, R.A. Jablonski, Fran-Jo Hollender, Dave Coller, Martin Critchley, Eric Pouliquen, F. Werner, A. Kuijpers, R. Köster, Graham Westbrook, Rick Hagen, V. Purnachandra Rao, M. Veerayya, Valerie Paskevich, Joe Cann, Sandy Shor, Susan Humphris, Marty Kleinrock, Ken Stewart, Keith Pickering, Bill Schwab, Patty Fryer, Tim LeBas, B. Bader, H.G. Schröder, K. Schwarzer, P. Schäfer, K.W. Tietze, and A. Wehrmann. It is my pleasure to thank them again for their help and input, in whatever form. By their critical reviews of the 1997 book, esteemed friends and colleagues like Rachel Cave, Olga Gómez Sichi, and Veerle Huvenne have made sure that some mistakes or omissions would be corrected in any subsequent work. I am sure they will point out the new ones in this new book . . . A special mention should be made of Doris Milkert and Veit Hühnerbach, who have now moved to different institutions (FWG and National Oceanography Centre, respectively) and have been a constant source of encouragement during the writing of this book. Over the 12 years it took to research (and write) the *Handbook of Sidescan Sonar*, I have strongly benefited from interaction with the Woods Hole Deep-Submergence Group (Dan Fornari, Bob Ballard, Andy Bowen, John Howland, Steve Lerner, Dana Yoerger, and others), with colleagues from the BRIDGE (British Mid-Ocean Ridge Initiative), ECUA (European Conferences on Underwater Acoustics), and InterRidge communities (including Andrea Caiti and all our SITAR partners, Alan Evans, Eulalia Grácia, Thierry Garlan, Chris German, Jean-Pierre Henriet, Tony Laughton, Yves LeGall, Xavier Lurton, Raímon Pallas, François Parthiot, Jean-Pierre Sessarego, Vera van Lancker, Claudia Wienberg, Benoît Zerr, to name but a few), with different researchers from the NATO Undersea Research Centre (past and present, including Gaetano Canepa, Tony Lyons, Lucie Pautet, Alessandra Tesei), with Jaroslaw Tegowski and Aleksandra Kruss from Poland, and with my acoustics-minded colleagues at Bath, including Mario Cosci (now at EMC Projects), Peter Dobbins (now at SEA Ltd.), Cathy Dyer, Victor Humphrey (now at ISVR Southampton), Nisabha Jayasundere (now at the University or Ruhuna, Sri Lanka), William Megill, Nick Pace, etc. These regular interactions often meant going to sea or doing experiments or writing publications and proposals together. This huge list, and the fact I am sure I have forgotten many people I would have liked to include in these acknowledgments, show how much this book has benefited from the research and experience of other scientists around the world, and how much I hope it will profit sonar users internationally.

Last but not least, these acknowledgments should recognize the important role played by Clive Horwood of Praxis Publishing. Numerous unforeseen delays, and others that could have been planned better, have affected the writing of this book. Throughout it all, Clive and his small but dedicated team helped, pushed, and encouraged to make sure this book could be delivered to its end-users, the sonar mapping community. Another steady source of encouragement came from Neil Shuttlewood (OPS Ltd.), whose scientific knowledge also came in handy in the thorough editing of this book. Thank you both very much.

Bath, April 2009

Figures

Tables

Abbreviations and acronyms

AGDS	Acoustic Ground Discrimination Systems
AI	Artificial Intelligence
ANN	Artificial Neural Network
APL-UW	Applied Physics Laboratory, University of Washington
AR	Auto-Regressive model
ARC/INFO	Geographic Information System produced by ESRI Inc. (*http://www.esri.com/software/arcgis/arcinfo/index.html*)
ARMA	Auto-Regressive Moving Average model
ART	Adaptive Resonance Theory
ASA	Acoustical Society of America
ASW	AntiSubmarine Warfare
ATR	Automatic Target Recognition
AUV	Autonomous Underwater Vehicle
AVG	Angle-Varying Gain
AVR	Axial Volcanic Ridge
AWI	Alfred-Wegener Institut (Germany)
BIO	Buque de Investigación Oceanográfica (Oceanographic Research Vessel) (Spain)
BORIS	Bottom Response from Inhomogeneities and Surface
BP	Back-Propagation; Before Present
BP networks	Back-Propagation networks
BRIDGE	BRitish mID-ocean RidGE initiative
CA	Coarse Acquisition (code)
CAC	Computer-Aided Classification
CAD	Computer-Aided Detection
CAR	Circular Auto-Regressive model
CARIS	Series of commercial geomatics software products (*http://www.caris.com/*)

CS3	Combined Survey System (as in the GIMS/CS3 towed survey system)
CSEM	Controlled Source ElectroMagnetic
CTD	Conductivity–Temperature–Depth
CW	Continuous Wave
DCE-GESMA	Laboratory of the Groupe d'Études Sous-Marines de l'Atlantique (France)
DGPS	Differential Global Positioning System
DSL	Deep Submergence Laboratory, WHOI (U.S.A.)
DSS	Decision Support System
ECUA	European Conferences in Underwater Acoustics
EEZ	Exclusive Economic Zone
EPR	East Pacific Rise
ERDAS	Commercial remote-sensing software from ERDAS Inc. (*http://www.ermapper.com/*)
ETOPO5	Earth TOPOgraphy 5′-resolution
ETP-SRTM30	Earth Topography–Shuttle Radar Topography Mission 30′-resolution dataset (*http://www2.jpl.nasa.gov/srtm/*)
EXCAPI	EXpérimentation de Capteurs Acoustiques pour repérer le Pétrole Immergé
GCP	Ground Control Point
GIB	GPS Intelligent Buoy
GIMS	Gamma Isotope Mapping System
GIS	Geographic Information System
GLCM	Gray-Level Co-occurrence Matrix
GLORIA	Geological LOng-Range Inclined Asdic
GLORIA-B	GLORIA with Bathymetry
GPI	Geological and Paleontological Institute (Germany)
GPS	Global Positioning System
HDF	Hierarchical Data Format
HMR-1	A shallow-towed sonar
ICES	International Council for the Exploration of the Sea
IEEE	Institute of Electrical and Electronics Engineers
IET	Institution of Engineering and Technology
IFREMER	Institut FRançais pour l'Exploitation de la MER
IHO-S44	Bathymetry processing standard explained in the Fourth Edition of the International Oganisation Special Publication No. 44
ILSBL	Integrated Long and Short Baseline
INS	Inertial Navigation Systems
IOA	Institute Of Acoustics
ISA	International Seabed Authority
ISODATA	Iterative Self-Organizing Data Analysis Techniques
ISSAMS	*In Situ* Sediment Geoacoustic Measurement System
iUSBL	inverted USBL

IZANAGI	A shallow-towed sonar
JPL	Jet Propulsion Laboratory (U.S.A.)
LBL	Long BaseLine
LOS	Law of the Sea
LUSBL	Long USBL (*see* USBL)
MAK-1	A Russian sonar
MAR	Mid-Atlantic Ridge
MARFLUX/ATJ	Mid-Atlantic Ridge FLUXes/Azores Triple Junction
MARPOL	MARine POLlution
MCM	Mine Counter-Measure
MEDINAUT	Large French/Dutch program on the occurrence of mud volcanoes in the eastern Mediterranean Sea (MEDINAUT, MEDINETH)
MEDINETH	Large French/Dutch program on the occurrence of mud volcanoes in the eastern Mediterranean Sea (MEDINAUT, MEDINETH)
MEDUSA	Multi-Element Detector system for Underwater Sediment Activity
MIT	Massachusetts Institute of Technology (U.S.A.)
MLO	Mine-Like Object
MOR	Mid-Oceanic Ridge
MSG	Measurement Space–Guided clustering
NASA	National Aeronautics and Space Administration (U.S.A.)
NERC	Natural Environment Research Council (U.K.)
NetCDF	Network Common Data Form
NGDC	National Geophysical Data Center (U.S.A.)
NOC	National Oceanography Centre (U.K.) (previously Southampton Oceanography Centre, SOC)
OASES	Ocean Acoustics and Seismic Exploration Synthesis (MIT software)
ORETECH	A sidescan sonar
P	Precision (code)
p.s.u.	practical salinity unit
pixel	picture element
PRF	Pulse Repetition Frequency
PRISM	Processing of Remotely sensed Imagery for Seafloor Mapping
PSAS	Parametric Synthetic Aperture Sidescan
PVDF	PolyVinylidene DiFluoride
PZT	lead–zirconate–titanate alloy
QTC	Quester Tangent Company (Canada)
RIDGE	Mid-Ocean RIDGE Initiative (U.S.A.)
ROV	Remotely Operated Vehicle
RRS	Royal Research Ship
RTK	Real-Time Kinematic (GPS)

RV	Research Vessel
SA	Selective Availability
SAR	Système Acoustique Remorqué (Towed Acoustic System)
SAS	Synthetic Aperture Sonar
SBL	Short BaseLine
SCICEX	Scientific Ice Expeditions (U.S. research pogram)
SeaMARC	Sea Mapping And Remote Characterization
SEG-Y	One of several standards developed by the U.S. Society of Exploration Geophysicists
SHOALS	Commercial airborne lidar bathymetry measurement system, originating from the Scanning Hydrographic Operational Airborne Lidar Survey
SIO	Scripps Institution of Oceanography (U.S.A.)
SITAR	European Union research program on "Seafloor Imaging and Toxicity: Assessment of Risk Caused by Buried Waste"
SMS	Seafloor Massive Sulfide
SMS-960	A sidescan sonar
SOC	Southampton Oceanography Centre (U.K.)
SONAR	SOund Navigation And Ranging
TAG	Trans-Atlantic Geotraverse
TOBI	Towed Ocean-Bottom Instrument
TOPAS	Series of high-resolution bottom profilers developed by Kongsberg
TRANSIT	U.S. Navy satellite navigation system
TVG	Time-Varying Gain
UNESCO	U.N. Education, Scientific and Cultural Organization
USBL	Ultra-Short BaseLine
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
UUV	Unmanned Underwater Vehicle
UW	University of Washington (U.S.A.)
WHIPS	Woods Hole Image Processing Software
WHOI	Woods Hole Oceanographic Institution
WWW	World Wide Web
XBP	eXpendable Bottom Probe
XBT	eXpendable Bathy-Thermograph
XTF	eXtended Triton Format

1

Introduction

1.1 BOOK OVERVIEW

Knowledge of the Earth and its evolving environment is proving increasingly crucial. Scientific, economic, political, and social decisions all depend at some time or another on this knowledge, and we like to think that we know all there is to know about our planet. One may be justified in doing so today, in the 21st century, by looking back at those maps with white unexplored regions that were still prevalent at the beginning of the 20th century. Yet, in many respects, we know more about the solid surface of other planets than about our own Earth. Rovers driving on Mars for years on end, landers on far-away Titan, and now the international missions to the Moon cannot mask the fact that ocean bottom landscapes only a few kilometers from our shores are still completely unknown.

More than half of the world's population live within 100 km of the sea. Thirteen of the 15 largest cities in the world are now located on or near the coast. The effects of denser population and accelerating climate change include the disappearance of ecosystems, coastal erosion, over-fishing, marine pollution, and higher vulnerability to marine disasters such as tsunami or volcanic activity. But the oceans cover more than two-thirds of the Earth's surface, and are not accessible to direct observation. It is only in the last 20 to 30 years that technological advances have allowed us to discover and map the Earth's seafloor, mostly through acoustic remote sensing.

Why only—some would say "primordially"—acoustic remote sensing? Why not use our most intuitive sense, vision, and the plethora of Earth observation satellites in orbit? We are used to seeing satellite-derived topography for the entire Earth, from one pole to the other (e.g., the ETP-SRTM30 dataset, at kilometric resolution). But it is derived from average gravity measurements and even when supplemented with actual bathymetry measurements, it cannot account for evolution over time, and is easily subject to confusion with gravity anomalies. Conversely, more accurate mapping systems (e.g., SHOALS, using airborne lasers) have shown it possible to map coastal areas in great detail. But even lasers can only penetrate through a few tens of meters in very clear water. Diving with submersibles is limited too, because only a handful of submersibles in the world are capable of diving below 3,000 m (thus limiting us to 46% of the planet's surface) and further because their field of view is limited. Most of the light travelling into water is absorbed and converted into heat, and in the visible wavebands, the path length in pure sea water is still limited to a few tens of meters towards the blue part of the spectrum (Figure 1.1). Vision is therefore of limited use under water.

Acoustic waves, by contrast, can travel over long distances without attenuating too much (see Chapter 2 for more details). They can reach all depths in the ocean, from the deepest (>11 km in the Marianas Trench) to the most common ($\sim$ 4 km) and

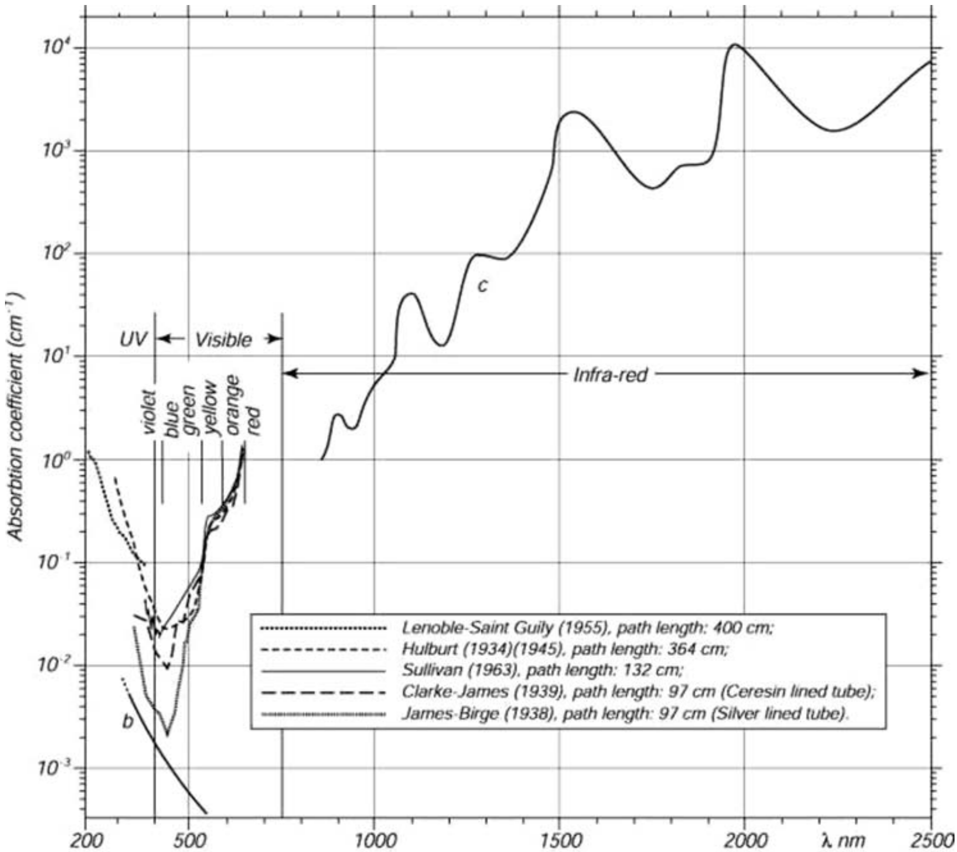

Figure 1.1. Light attenuation in pure water, as measured in different experiments (from *http://oceanworld.tamu.edu/resources/ocng_textbook/chapter06/chapter06_10.htm*). An absorption coefficient of 1 cm^{-1} (coefficient c) means that in a single centimeter, light intensity will be divided by e. Blue light is absorbed least, and red light attenuates very quickly. Seawater contains salt and many heterogeneities (e.g., plankton), increasing the attenuation even more.

the shallowest (a few centimeters). Acoustic echoes inform us about the range travelled (i.e., the depth) and about how they were reflected (i.e., the type of seabed or obstacle). Complex processing can reveal information at very small scales, down to a few centimeters in some cases. They are used in instruments called sonars (for sound navigation and ranging). The images and maps produced by these sensors are not easy to interpret, because of their nature and because of the complex processes at play during their propagation and reflection. There are different types of sonars, mostly single-beam echo-sounders (looking directly beneath the supporting vessel), multibeam echo-sounders (looking on both sides of the vessel, providing mainly bathymetry and sometimes imagery), and sidescan sonars (usually flown closer to the seafloor, providing mainly imagery and sometimes bathymetry). They are all presented in Chapter 2, but because the emphasis of the book is on imagery and its interpretation, it will concentrate on sidescan sonars, whose imagery is much more detailed, complex, and varied. Interpretation of multibeam imagery follows the same principles and does not warrant separate treatment. Following in the footsteps of the first (and then only) work on the subject (Belderson *et al.*, 1972), the *Handbook of Seafloor Sonar Imagery* (Blondel and Murton, 1997) was the first modern and comprehensive book explaining the different steps of sidescan sonar imagery interpretation. It proved a success, and the latest edition is now out of print. Ten years on, it was felt necessary to update this book and expand its scope to the new domains of sidescan sonar remote sensing.

The *Handbook of Sidescan Sonar* is more than just a new edition of the *Handbook of Seafloor Sonar Imagery*, with a few updates and corrections. It has been in fact substantially remodelled, redressing the undue bias toward mid-ocean ridges of the previous version (explained by the domain in which both authors worked) and taking into account more of the wider underwater world. This book has also been substantially affected by many important developments of the last 10 years.

— The democratization of sonars. Once only used by powerful companies and institutions, sonar sales and rentals have greatly increased every year (24% in 1997 alone).
— The emergence of new platforms. Sidescan sonars can still be towed behind ships, but Unmanned Underwater Vehicles (UUVs), whether autonomous (AUV: Autonomous Underwater Vehicles) or tethered (ROV: Remotely Operated Vehicles) have become increasingly common and regularly use sidescan sonar as their main mapping tool.
— The introduction of new manufacturing technologies. Innovative materials and production techniques, and their fast transfer from research to commercial products (e.g., the blazed array technology, patented in 1999 and first commercialized in 2002), have led to advances in the capabilities of sidescan sonars and to a greater portability (some shallow-water applications have even used kayaks).
— The introduction of new transducer configurations, or their easier implementation. This has led in particular to the development of interferometric sonars (providing bathymetry at the same scale as imagery).

— Advances in sonar processing have been made possible by developments in computer technology and processing power. CPU speed has increased more than ten-fold since 1997, and the price of data storage decreased roughly a hundred-fold: Moore's law means this trend is likely to follow for the next 10–20 years.
— Advances in sensor merging. Driven by the advances in processing means that different sonars can be considered together for interpretation, rendering a richer picture of the actual processes on the seabed. Information from other sensors (e.g., attitude and navigation) is also better integrated, making for more accurate maps.
— Developments in navigation and processing techniques. More accurate navigation, or even micro-navigation at scales of millimeters or centimeters, have made possible the development of Synthetic-Aperture Sonars, whose performance does not degrade with range (see Chapter 2).
— The spread of the Internet, even at sea. The ease with which information can now be retrieved, from anywhere in the world, has made redundant long lists of technical specifications in books, as they can be accessed more timely and more completely at the click of a mouse (coupled with the sheer variety of sonars now available on the market, this is the reason the list of sonars and their characteristics has been greatly reduced in this book, to show only the most representative or interesting).
— New advances in knowledge of the seabed. In the last 10 years, our knowledge of the oceans has tremendously increased, because of the wider availability of sonars and because of the wider types of surveys done. Many readers of the *Handbook of Seafloor Sonar Imagery* contributed to these developments themselves, and the present book will try to do justice to their endeavors by showing some of the latest examples of new features.

This long list of developments in the field means that a single book is not enough to describe everything and acknowledge everybody in a varied, rich, and interdisciplinary field, merging research, development, and straight applications. The *Handbook of Sidescan Sonar* does not pretend to be an exhaustive list of everything; it does not aim either at being a "coffee table" book with pretty images of every feature under the sea. And it does not aim to recognize all past research or activities. Rather, we have aimed at making it a convenient book for researchers and practitioners wanting a concrete answer to their questions. Users of the previous *Handbook* have encouraged us in this way by telling us how they used it, often at sea, and what they liked and disliked in it, and we are grateful for their comments. Students new to the field of sidescan sonar have used the book as a base for further learning (starting with the "Further reading" sections at the end of each chapter). Engineers have used it to think about new products. Surveyors have used it to check intriguing images or double-check their analyses. And researchers have used it to think about new ways of processing or analysing the data, as well as to better understand specific images. Such widespread use, by so many experienced users, has led us to bolster the sections on

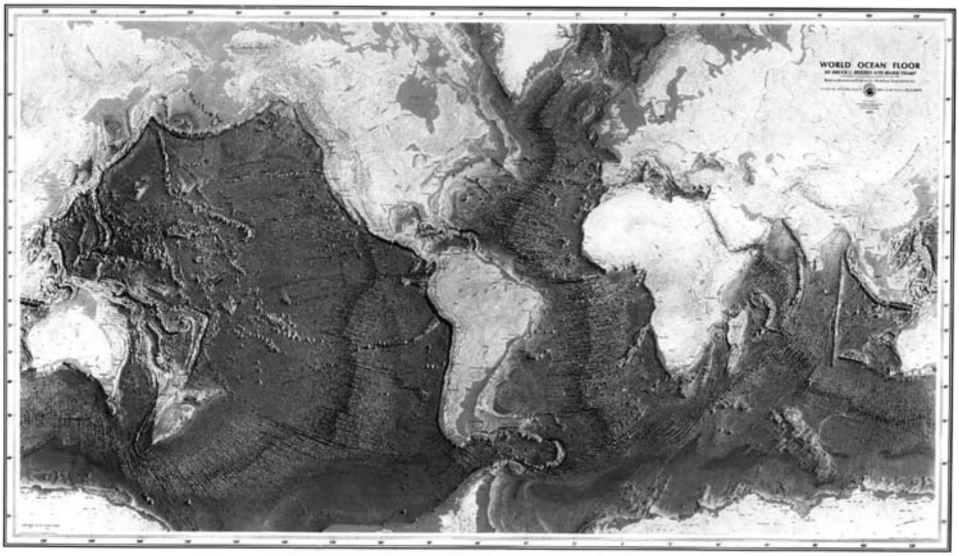

Figure 1.2. The famous map of the seabed, compiled by Mary Tharp and Bruce Heezen during the 1960s, was the first to show so dramatically the variety of the seabed. It is now superseded by more accurate sea-based surveys and satellite measurements, but its scientific and artistic qualities remain.

new techniques, currently on the market or still a few years away, and the sections on computer-assisted interpretation.

This book is divided into chapters that deal first with the stages of sonar data acquisition and processing and then (roughly) to the different regions of the seabed (Figure 1.2). Chapter 2 ("Acoustics for sidescan sonars") presents the basics of acoustics needed to successfully process and interpret sidescan sonar imagery. It also introduces some of the new tools which are currently emerging or will transition from prototypes to finished products in the coming decade. Finally, it synthesizes the performance of sonars: how to choose the one most adapted to the survey in mind, and how to compare different instruments, sometimes widely different. Chapter 3 ("Imagery and bathymetry") presents the acquisition of bathymetric data, either from sidescan sonars or from other sources, and how it can be successfully merged with imagery. Chapter 4 ("Sidescan sonar data processing") explains in detail the different steps to create a true and accurate map of the seabed, finishing with examples of a handful of successful systems (commercial and academic). Chapter 5 ("Spreading and subduction") presents the manifestations of plate tectonics on the seabed, and its varied examples on different types of mid-ocean ridges and subduction environments. Chapter 6 ("Abyssal basins and polar seas") presents sidescan sonar images from poorly known environments, often accessed with great difficulty but nonetheless acoustically rich and scientifically important. Chapter 7 ("Continental margins") summarizes the wide variety of structures—sedimentary, tectonic, and volcanic—visible in these regions of highly varying depths. Chapter 8 (‘‘Shallow-water environments’’) moves closer to shore, presenting features that can also be found in lakes and rivers. Wherever possible, the detailed examples of specific features and processes shown in Chapters 5 to 8 are followed by regional imagery showing a variety of structures as they might appear in a full survey. Chapter 9 (‘‘Synthetic structures’’) acknowledges both the move of sonars to increasingly shallower environments and the pros and cons of the growing influence of human population on the seabed. It will therefore include examples of planned activities (e.g., pipelines, mineral exploitation) and ‘‘accidental’’ discoveries (e.g., shipwrecks, marine pollution, and the effects of trawl-fishing). This chapter will also present examples of problems posed by mines and more peaceful applications to underwater archaeology. Chapter 10 (‘‘Anomalies and artefacts’’) assesses what can go wrong in the acquisition of a sonar image, in its processing, and in its interpretation, drawing on real examples from all over the world. Chapter 11 (‘‘Computer-assisted interpretation’’) presents the different techniques now available to assist (or sometimes replace) the interpreter, from traditional Computer-Aided Detection/Computer-Aided Classification (CAD/CAC) techniques to ATR (Automatic Target Recognition) and the potential of Artificial Intelligence (AI) techniques. All chapters end with a small section suggesting ‘‘Further reading’’. The ‘‘Bibliography’’ chapter at the end of the book bolsters these suggestions with more references. Chapter 12 (‘‘Conclusion’’) aims at putting these distinct topics in a coherent framework, showing the few differences and great similarities in the interpretation of sonar imagery in all environments, as well as thoughts about the evolution of the field in the next decade.

This book is an ambitious project, trying to form a single source of easy reference covering all the stages of data acquisition, processing, and interpretation. It covers all environments found on Earth, from the deepest to the shallowest. It draws on first-hand personal experience, at sea (from 44°S to 79°N) and in the laboratory, of the complexity of acoustic scattering processes. But it would not have been possible without the combined experience of all our colleagues, who opened their ‘‘treasure chests’’ of images for this book, as they did for its predecessor back in 1997. As in the first book, we have endeavoured to give credit where credit is due (i.e., for each image, to mention who acquired it, with which instrument, and if possible to mention the reference publication). Any mistake or omission should be notified to the author or publisher, who will correct it for the next edition. Commercial systems are presented throughout this book, and it should go without saying that their mention does not present any form of endorsement by the author or the publisher.

Finally, ‘‘last but not least’’, this introduction should acknowledge the important role played by Clive Horwood, director of Praxis Publishing Ltd. and his colleagues at Praxis and Springer. Numerous changes to the scope of this project, and (numerous) delays in the writing of this book have taxed patience and nerves, but the unfailing assistance of Clive and his team, combined with the expert support of Neil Shuttlewood, mean that this book is now completed and ready to join the older *Handbook of Seafloor Sonar Imagery* on the bookshelves of colleagues around the world, on land and at sea, with hopefully the same success.