The Sedimentary Record of Sea-Level Change

This unique textbook describes how past changes in sea-level can be detected through analysis of the sedimentary record. In particular, it concentrates on the theory of sequence stratigraphy, which provides a framework for how entire sedimentary systems evolve through geological time. This theory is widely used to understand the genesis of the sedimentary record, to examine the global synchroneity of sedimentary cycles and in the exploration for hydrocarbon reserves. The book explains the current sequence stratigraphy model from basics and shows how the model can be applied to both siliciclastic and carbonate successions. It also covers stratigraphical techniques, mechanisms for sea-level change and forward modelling of stratigraphical geometries. A variety of case studies are presented including a deltaic siliciclastic succession from the Gulf of Mexico; an in-depth study of the fluvial to open-marine siliciclastic deposits exposed in the Book Cliffs, USA; a shallow-marine carbonate platform succession from Mallorca; and a carbonate ramp succession from Spain.

Designed for undergraduate and graduate courses, as well as professionals, this textbook includes numerous features that will aid tutors and students alike including full colour diagrams, case studies, set-aside focus boxes and bulleted questions and answers. The book is supported by a website hosting sample pages, selected illustrations to download, and worked exercises: **http://publishing.cambridge.org/resources/0521831113**

The authors of this book have been closely involved in the testing, development and application of the sequence stratigraphy model since the 1980s. They are all field geologists with much experience of collecting and interpreting data from the sedimentary record. Each of them teaches sedimentology and sequence stratigraphy at their respective institution, and they have combined this experience to write a clear and readable book.

The project was initiated by **Angela Coe** (Senior Lecturer at The Open University, Milton Keynes, UK) and **Chris Wilson** (Professor of Earth Sciences at The Open University) as part of the development of a new Open University Course, and the material has been tried and tested by Open University students. Dr Coe's research includes the identification and interpretation of sedimentary cycles within Jurassic and Miocene deposits, particularly mudrocks, together with developing new stratigraphical techniques. Professor Wilson's interests include sedimentology and, based on work he completed as part of two ODP cruises, the tectonic evolution of the Atlantic margin. **Kevin Church** is an Associate Lecturer at The Open University with expertise on sequence stratigraphy of the Carboniferous of England, an example of which has been used to illustrate the theory presented in Chapters 3 to 5. **Stephen Flint** (Professor of Stratigraphy and Petroleum Geology, Director of the Stratigraphy Research Group, University of Liverpool, UK) and **John Howell** (formerly at Liverpool University, now Professor of Production Geology, University of Bergen, Norway) contributed the Book Cliffs case study, which is based on their extensive work and that of other members of the Liverpool University Stratigraphy Research Group. Professors Flint and Howell continue to work on stratigraphical architecture of sedimentary systems and methods for modelling hydrocarbon reservoirs. **Dan Bosence** (Professor of Carbonate Sedimentology at Royal Holloway University of London, UK) has broad experience of both modern and ancient carbonate deposits. His current research projects include high-frequency Jurassic carbonate cycles in Europe and North Africa and numerical modelling of carbonate platform stratigraphy. His expertise was combined with that of Professor Wilson to produce Part 4 of this book.

Cover photograph Foreshore near Santa Barbara, California, USA. The cliffs expose the Monterey Formation, a thick, laterally extensive organic carbon-rich mudrock succession (weathered to a pale yellow). This is interpreted to have been deposited due to upwelling associated with global cooling and sea-level fall in the mid-Miocene. It has been suggested that deposition of these organic-rich mudrocks enhanced global cooling by a positive feedback mechanism, i.e. that as the mudrock was deposited, it led to drawdown of CO_2 from the atmosphere, which in turn led to further cooling (the Monterey hypothesis). The Monterey Formation is an important source rock for California's oil reserves. The large Pacific waves cause movement of considerable amounts of foreshore and shoreface sediments along this coast as well as making it popular for surfing. *(Angela Coe, Open University.)*

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Preface

The Sedimentary Record of Sea-Level Change is about how we can detect past changes in sea-level from an analysis of the sedimentary record. In particular, it concentrates on the revolutionary new concept of sequence stratigraphy. This concept has changed the way in which many sedimentologists and stratigraphers examine sedimentary rocks because it provides a framework for how entire sedimentary systems evolve through geological time and places emphasis not only on the sediments themselves, but also on gaps between sedimentary units. In addition, sequence stratigraphy incorporates two long-standing observations: first, that the sedimentary record shows repetitions or cycles; and secondly, that some sedimentary units can be traced over long distances.

Sequence stratigraphy is a method of dividing the sedimentary record into discrete packages, where each package is interpreted to represent a cyclic change in sea-level and/or sediment supply. Evidence in the sedimentary record shows that rises and falls in sea-level together with changes in sediment supply have occurred repeatedly throughout geological time. These fluctuations are of various magnitudes and took place on a number of different time-scales. The constituent parts of these sedimentary packages map out the position of sea-level and/or the change in sediment supply within a cycle and enable their inter-relationship through time to be analysed.

There are several reasons why sequence stratigraphy is useful. First, it is a more holistic way of examining the sedimentary record because it considers 'what is missing' as well as 'what is present' in the sedimentary record; and secondly, it places emphasis on examination of the sedimentary record over discrete time periods. Therefore, evolving palaeogeographies are studied together with how different sedimentary environments, from fluvial systems to coastal environments and into the deep sea, have interacted and affected each other. The technique has been widely used in the prediction of hydrocarbon reserves and also to examine the global synchroneity of sedimentary cycles; however, their synchroneity still remains unproved as does the mechanism controlling sea-level change for many parts of the geological record. The aim of this book is to explain the theory of sequence stratigraphy and to illustrate this with several case studies. It does not discuss the global synchroneity (or not) of sequence cycles or cover how the sequence stratigraphy model has evolved; instead, the book attempts to present the current model in a pragmatic, clear and concise fashion.

The book is divided into four parts. The first part examines what it is about sedimentary rocks that makes them important and useful for determining sea-level change, how we can determine geological time, and introduces sea-level change. It also includes an examination of some possible evidence for Noah's flood. Part 2 covers the theory of sequence stratigraphy and mechanisms for sea-level change. It ends with a short case study from the Gulf of Mexico. Part 3 is a longer case study of the famous siliciclastic succession from the Book Cliffs, Utah, USA. The succession comprises fluvial to open marine deposits that are well exposed in a spectacular cliff face about 300 km long and up to 300 m high. Part 4 examines how carbonate sediments respond to sea-level change and shows how these responses can be forward modelled to predict different stratigraphical geometries and successions. Both modelling and exposure information are presented in case studies from Mallorca and north-east Spain. The Mallorcan example is particularly impressive as the present-day topographical height of the crest of the reef approximates to an ancient sea-level curve.

This book is aimed at advanced undergraduates and graduates. Readers are expected to have a basic understanding of sedimentary rocks, processes and depositional environments (though further information can be obtained from the references). It is designed as a teaching text for independent study in a linear fashion, and includes short bulleted questions followed directly by answers. These are designed to make the reader pause for a *moment* and think about a fundamental point concerning the subject matter. Supplementary and/or background information, which some readers may already be familiar with, is placed in boxes.

This book forms a part of an advanced undergraduate course offered by The Open University, UK, entitled S369 *The Geological Record of Environmental Change*.

Angela Coe, February 2003