3-D Seismic Interpretation

3-D seismic data have become the key tool used in the oil and gas industry to understand the subsurface. In addition to providing excellent structural images, the dense sampling of a 3-D survey can sometimes make it possible to map reservoir quality and the distribution of oil and gas. The aim of this book is to help geophysicists and geologists new to the technique to interpret 3-D data while avoiding common pitfalls.

Topics covered include basic structural interpretation and map-making; the use of 3-D visualisation methods; interpretation of seismic amplitudes, including their relation to rock and fluid properties; and the generation and use of AVO and acoustic impedance datasets. Also included is the increasingly important field of time-lapse seismic mapping, which allows the interpreter to trace the movement of fluids within the reservoir during production. The discussion of the acquisition and processing of 3-D seismic data is intended to promote an understanding of important data quality issues. Extensive mathematics has been avoided, but enough detail is included on the effects of changing rock and fluid properties to allow readers to make their own calculations. This new paperback edition also includes an extra appendix presenting material that brings the book fully up to date – including novel acquisition design, pore pressure prediction from seismic velocity, elastic impedance inversion, and time lapse seismics.

3-D Seismic Interpretation is an indispensable guide for geoscientists learning to use 3-D seismic data, particularly graduate students of geophysics and petroleum geology, and new entrants into the oil and gas industry.

Mike Bacon was awarded a Ph.D. in geophysics from the University of Cambridge before becoming a Principal Scientific Officer at the Institute of Geological Sciences in Edinburgh (now the British Geological Survey). After working as a lecturer in the Geology Department of the University of Accra, Ghana, he took a position with Shell UK where he worked for 19 years as a seismic interpreter and as team leader in seismic special studies. He now works for Petro-Canada UK as a geophysical advisor. Dr Bacon is a co-author of *Introduction to Seismic Interpretation* by McQuillin *et al.* (1979) and is a member of the editorial board of the petroleum industry magazine *First Break*. He is a Fellow of the Geological Society and a member of the EAGE (European Association of Geoscientists and Engineers).

Rob Simm is a geophysicist with 16 years' experience in the oil and gas industry and a specialist in the rock physics interpretation of seismic data in both exploration and production. After gaining an M.Sc. and Ph.D. in marine geology at University College London, the early part of his career was spent with Britoil plc and Tricentrol plc as a seismic interpreter. He subsequently took a position at Enterprise Oil and progressed from North Sea exploration to production and equity determination, prior to becoming an internal consultant to asset teams and management. Since 1999 Dr Simm has provided independent consultancy and training services to numerous independent and multi-national oil companies through his company Rock Physics Associates Ltd.

Terry Redshaw gained a Ph.D. in numerical analysis from the University of Wales before becoming a Geophysical Researcher with Western Geophysical. Since 1985 he has been employed by BP in a variety of roles. These have included research into imaging and inversion algorithms, as well as leading a team supplying BP's worldwide assets with support in the areas of seismic modelling, rock properties, AVO and seismic inversion. Dr Redshaw works at present in BP's Exploration Excellence team, which helps operating units to carry out the technical work needed to evaluate oil prospects and decide whether to drill them or not.

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Contents

Preface

Applied geophysics uses a large number of methods to investigate the subsurface. Because of its ability to produce images down to depths of thousands of metres with a resolution of tens of metres, the seismic method has become by far the most commonly used geophysical method in the oil and gas industry. In the past 20 years, the quality of seismic information has been greatly improved by the use of 3-D seismic methods. However, extracting useful information from seismic images remains the interpreter's craft skill, in which elements of geological and geophysical knowledge are combined in varying proportions. This book is intended for people beginning to develop that skill, either as part of a University course or at the beginning of a career in the oil and gas industry. It assumes that the reader has some general background knowledge of the seismic method. There are several excellent texts that cover the whole range of theory and practice (for example, R. E. Sheriff & L. P. Geldart, *Exploration Seismology* (2nd edn, 1995), Cambridge University Press). Our intention is not to replace these volumes, but rather to concentrate on the techniques of interpretation that are specific to 3-D seismic, or are greatly improved in usefulness by applying them to 3-D datasets (such as amplitude studies, AVO analysis, inversion and time-lapse seismic). However, there is enough explanation of the underlying principles to make the book fairly self-contained. In particular, the acquisition and processing of 3-D seismic data are described in some detail. This is partly because the interpreter needs to understand the limitations of his or her data, and whether misleading artefacts are likely to exist in the images that reach his or her desk. Also, he or she will sometimes need to interact with specialists in acquisition and processing, so should understand something of their specialised language. Bearing in mind the diversity of academic background among potential readers, we have avoided any extensive use of mathematics.

The range of topics that might be included is large, and we have tried to concentrate on those that are of most practical application in the authors' experience. There have been rapid advances in interpretation techniques over the past decade. In part this reflects the availability of more computer power at the desktop, so that first-pass interpretations can now often be made in days rather than months. At the same time, data quality has been improving, so that a wealth of detailed subsurface information can be extracted if the right methods are used. We have tried to portray the current state of the art in both

these respects. The combination of the interpreter's ingenuity with even more computer power will surely lead to further developments in the future.

We have included a number of examples of seismic displays to illustrate the various interpretation techniques, and to give the reader a feeling for the typical quality of modern seismic data. We are grateful to the following for permission to reproduce proprietary or copyright material: BP Exploration for figs. 2.2, 2.8, 2.16, 2.23–2.24, 2.27, 2.30, 2.34–2.37, 8.3 and 8.7–8.8; ChevronTexaco and Statoil for fig. 5.12; Shell UK Exploration and Production for figs. 3.1, 3.3, 3.5–3.6, 3.8–3.13, 3.17–3.18, 3.20–3.24, 4.4, 4.6, 5.6, 6.2–6.8 and 6.10; the Wytch Farm partnership (BP Exploration Operating Co Ltd, Premier Oil plc, Kerr McGee Resources (UK) Ltd, ONEPM Ltd and Talisman North Sea Ltd) for figs. 7.1–7.6; the Geological Society of London and Dr R. Demyttenaere for fig. 1.6(b); the McGraw-Hill Companies for fig. 5.3; the European Association of Geoscientists and Engineers (EAGE) and Dr J. Hendrickson for fig. 5.16; the EAGE and Dr P. Hatchell for figs. 8.4–8.5; the EAGE and Dr J. Stammeijer for fig. 8.6; the Society of Exploration Geophysicists (SEG) for fig. 4.1, the SEG and Dr S. M. Greenlee for fig. 1.6(a), the SEG and Professor G. H. F. Gardner for fig. 5.1, the SEG and Dr H. Zeng for fig. 4.7, the SEG and Dr W. Wescott for fig. 4.8, and the SEG and Dr L. J. Wood for fig. 4.9. Figures 3.1, 3.3 and 3.24 were created using Landmark Graphics software, fig. 4.6 using Stratimagic software (Paradigm Geophysical), fig. 5.15(b) using Hampson–Russell software and fig. 6.3 using Jason Geosystems software.

The text is intended as an aid in developing understanding of the techniques of 3-D interpretation. We have not been able to include all the possible limitations on applicability and accuracy of the methods described. Care is needed in applying them in the real world. If in doubt, the advice of an experienced geophysicist or geologist should always be sought.