

North Sea Formation Waters Atlas

Geological Society Memoirs

Series Editor A. J. Fleet

North Sea Formation Waters Atlas

EDITED BY

E. A. WARREN & P. C. SMALLEY

BP Exploration
Sunbury, UK

Memoir No. 15
1994

Published by
The Geological Society
London



The
PETROLEUM SCIENCE
and
TECHNOLOGY INSTITUTE

THE GEOLOGICAL SOCIETY

The Society was founded in 1807 as the Geological Society of London and is the oldest geological society in the world. It received its Royal Charter in 1825 for the purpose of 'investigating the mineral structure of the Earth'. The Society is Britain's national society for geology with a membership of 7500 (1993). It has countrywide coverage and approximately 1000 members reside overseas. The Society is responsible for all aspects of the geological sciences including professional matters. The Society has its own publishing house, which produces the Society's international journals, books and maps, and which acts as the European distributor for publication of the American Association of Petroleum Geologists and the Geological Society of America.

Fellowship is open to those holding a recognized honours degree in geology or a cognate subject and who have at least two years' relevant postgraduate experience, or who have not less than six years' relevant experience in geology or a cognate subject. A Fellow who has not less than five years' relevant postgraduate experience in the practice of geology may apply for validation and, subject to approval, may be able to use the designatory letters C Geol (Chartered Geologist).

Further information about the Society is available from the Membership Manager, The Geological Society, Burlington House, Piccadilly, London W1V 0JU, UK.

Published by the Geological Society from:
The Geological Society Publishing House
Unit 7
Brassmill Enterprise Centre
Brassmill Lane
Bath BA1 3JN
UK
(Orders: Tel 0224 445046
Fax 0225 442836)

First published 1994

The publisher makes no representation, express or implied, with regard to the accuracy of the information contained in this book and cannot accept any legal responsibility for any errors or omission that may be made.

© The Geological Society 1994. All rights reserved. No reproduction, copy or transmission of this publication may be made without written permission. No paragraph of this publication may be reproduced, copied or transmitted save with the provisions of the Copyright Licensing Agency, 90 Tottenham Court Road, London W1P 9HE. User registered with the Copyright Clearance Center, 27 Congress Street, Salem, MA 01970, USA: the item fee code for this publication is 0435-4052/94/\$7.00.

British Library Cataloguing in Publication Data

A catalogue record for this book is available for the British Library
ISBN 1-897799-07-1

Typeset by Lovell Johns Ltd, Oxford, UK.

Printed by Alden Press, Oxford, UK.

Distributors

USA

AAPG Bookstore
PO Box 979
Tulsa
OK 74101-0979
USA

(Orders: Tel (918) 584-2555
Fax (918) 548-0469)

Australia

Australian Mineral Foundation
63 Conyngham Street
Glenside
South Australia 5075
Australia

(Orders: Tel (08) 379-0444
Fax (08) 379-4634)

India

Affiliated East-West Press pvt Ltd
G-1/16 Ansari Road
New Delhi 110 002
India

(Orders: Tel (11) 327-9113
Fax (11) 326-0538)

Japan

Kanda Book Trading Co.
Tanikawa Building
3-2 Kanda Surugadai
Chiyoda-Ku
Tokyo 101
Japan

(Orders: Tel (03) 3255-3497
Fax (03) 3255-3495)

Contents

Introduction, 1

Acknowledgements, 1

Part 1: Field compendium, 3

Abbreviations, 3

Amethyst, 5
Anglia, 6
Argyll, 7
Auk, 8
Barque, 9
Beatrice, 10
Beryl, 11
Brage, 12
Brent (including Brent South), 13
Bruce, 14
Buchan, 15
Central Brae, 16
Cleeton, 17
Clipper, 18
Clyde, 19
Cormorant, 20
Crawford, 21
Cyrus, 22
Deveron, 23
Don, 24
Donan, 25
Duncan, 26
Dunlin, 27
Eider, 28
Ekofisk, 29
Emerald, 30
Esmond, 31
Ettrick, 32
Forbes, 33
Forties, 34
Fulmar, 36
Gryphon, 37
Guillemot, 38
Gullfaks, 39
Gyda, 40
Heather, 41
Heimdal, 42
Highlander, 43
Hild, 44
Hutton, 45
Hyde, 46
Indefatigable, 47
Ivanhoe and Rob Roy, 48
Kittiwake, 49
Leman, 50
Magnus, 51
Miller, 52
Murchison, 53
North Brae, 54
Orwell, 55
Oseberg, 56
Osprey, 57
Pickerill, 58
Piper, 59
Ravenspurn, 60
Scapa, 61
Scott, 62
Sleipner, 63

Snorre, 64
South Brae, 65
Statfjord, 66
Tartan, 67
Tern, 69
Thames Complex (Thames, Yare, Bure and Wensum), 70
Thistle, 71
Tiffany, Toni and Thelma, 72
Troll, 73
Ula, 74
Welland, 75
West Sole, 76
Haltenbanken, 77
Other data, 77

Part 2: SPWLA water resistivity (R_w) atlas, 79

Eocene/Palaeocene (Table 2.2, Map 1a), 80
Danian/Upper Cretaceous (Table 2.3, Map 1b), 82
Lower Cretaceous (Table 2.4, Map 1c), 84
Upper Jurassic (Table 2.5, Map 1d), 86
Middle Jurassic (Table 2.6, Map 1e), 88
Lower Jurassic (Table 2.7, Map 1f), 90
Triassic (Table 2.8, Map 1g), 92
Zechstein (Table 2.9, Map 1h), 94
Rotliegende (Table 2.10, Maps 1i & j), 96
Carboniferous (Table 2.11, Map 1k), 100
Devonian/pre-Devonian (Table 2.12, Map 1l), 102

Part 3: Sulphate and carbonate scale prediction in North Sea oil and gas fields, 105

Barite scale potential (Map 2), 114
Celestite scale potential (Map 3), 115
Anhydrite/gypsum scale potential (Map 4), 116
Calcite scale potential (Map 5), 117
Downhole pH corrosion potential (Map 6), 118

Part 4: Compositional variations in North Sea formation waters, 119

All water data in alphabetical order by field (Table 4.1), 137
Salinity and major ions for the North Sea Basin and Haltenbanken (all data) (Maps 7a-k), 141
Salinity and major ions for the Cretaceous and Tertiary (Maps 8a-k), 152
Salinity and major ions for the Upper Jurassic (Maps 9a-k), 163
Salinity and major ions for the Middle Jurassic (Maps 10a-k), 174
Salinity and major ions for the Lower Jurassic and Triassic (Maps 11a-k), 185
Salinity and major ions for the Permian (Maps 12a-k), 196

References, 207

This atlas provides data on formation water compositions from throughout the North Sea Basin. It is intended for a varied audience with different needs: production chemists for scale prediction, petrophysicists for estimation of water resistivity and geochemists and geologists for the interpretation of water compositions and basin plumbing. The objective at the outset was not simply to provide a table of water compositions, but to supply as much supplementary data on reservoir conditions and geological setting as possible to enable the individual data to be placed in context.

The atlas contains four main sections: a field compendium, comprising a field-by-field compilation of water compositions with accompanying geological description and field maps; a water resistivity (R_w) atlas updating a 1989 publication by the Society of Professional Well Log Analysts (Amiard & Harrison 1989); scale prediction maps estimating susceptibility of produced waters to scaling; and a water chemistry atlas containing maps and figures illustrating the spatial and stratigraphic distributions of water compositions.

It has not been the intention here to provide interpretations of the data; the objectives are to make observations of major trends and clusters of data and to highlight anomalies. Problematic data are indicated within the field notes and consultation of these is strongly recommended.

Acknowledgements

We wish to thank all those parties involved in the preparation of this volume. In particular:

Mike Findlay and Stewart Brown of the Petroleum Science and Technology Institute, Edinburgh who helped with the data gathering process.

Mike Collins of the Geological Society of London Publishing House.

Graham Dean of Amerada Hess and SPWLA supported the R_w mapping work.

John Ager, Brigitte Burton, Martin Myers, Tina Cooper, Wendy Nash and Paula Goodfellow (BP) for preparing the maps, figures and typing.

To the 15 North Sea operators who provided the data, we are most grateful, as this atlas would have been impossible without their co-operation.

AGIP (UK) Ltd, AGIP House, 10 Ebury Bridge Road, London SW1W 9PZ, UK

Amerada Hess Ltd, 33 Grosvenor Place, London SW1X 7HY, UK

ARCO British Limited, London Square, Cross Lanes, Guildford, Surrey GU1 1UE, UK

BP Exploration, Farburn Industrial Estate, Dyce, Aberdeen AB2 0PB, UK

Conoco (UK) Ltd, Park House, 116 Park Street, London W1Y 4NN, UK

Fina plc, Fina House, 1 Ashley Avenue, Epsom, Surrey, UK

Hamilton Brothers Oil and Gas Ltd, Devonshire House, Piccadilly, London, W1X 6AQ, UK

Kerr-McGee Oil (UK) plc, 30 Old Burlington Street, London, W1X 1LB, UK.

Marathon Oil UK Ltd, Marathon House, Rubislaw Hill, Anderson Drive, Aberdeen AB2 4AZ, UK

Mobil North Sea Ltd, 3 Clements Inn, London, UK

Norsk-Hydro a.s., PO Box 200, N-1321 Stabekk, Norway

Ranger Oil (UK) Ltd, Ranger House, 71 Great Peter Street, London SW1P 2BN, UK

Shell UK Exploration and Production, 1 Altens Farm Road, Nigg, Aberdeen AB9 2HY, UK

Sovereign Oil and Gas plc, The Chambers, Chelsea Harbour, London SW10 0XF, UK

Texaco Ltd, 1 Westbury Circus, Canary Wharf, London E14 4HA.

We would particularly like to thank Per-Kristian Egeberg and Per Aagaard for kindly providing location details of their published data on Norwegian Continental Shelf waters.

Finally, this volume could not have been produced without the ceaseless encouragement and enthusiasm of our mentor, Graham Williams.