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Arctic Petroleum Geology

Edited by **A. M. Spencer, A. F. Embry, D. L. Gautier, A. V. Stoupakova and K. Sørensen**

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Arctic Petroleum Geology

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Foreword

The 33rd International Geological Congress (IGC) aimed to cover all aspects of the geosciences and was therefore named the 'Geoscience World Congress 2008'; it had the overall theme 'Earth System Science: Foundation for Sustainable Development'. The congress was hosted jointly by the five Nordic countries, Norway, Sweden, Denmark, Finland and Iceland, and held in Oslo on 6–14th August, 2008. The IGCs have been held every four years since 1878 and this was the third in a Nordic country, after Stockholm in 1910 and Copenhagen in 1960.

A total of 6259 participants from 113 countries registered for the congress and five countries were particularly well represented: Norway (960), Russia (505), USA (394), China (376) and Italy (367). This was the first IGC in which participation from the private sector, both the petroleum and mining industries, was significant. Roughly 25% of the congress' budget came from sponsorships by the petroleum industry and more than 50 symposia were related to petroleum and economic geology, demonstrating the importance for society of the earth sciences. Such partnership with industry will be of great importance for the future of the IGC.

Prior to the congress, a comprehensive account of Nordic Geoscience, comprising 26 papers with over 120 authors was published as an issue of *Episodes* (Vol. 31, No. 1, March 2008) and given to all participants. It covered the geological evolution of Norden from the Archaean until today and the main aspects of earth science of importance for society, including petroleum geology and mineral deposits.

Two major 'international years' coincided with the congress, the International Polar Year (IPY) and the International Year of Planet Earth (IYPE). Seven plenary 'Themes of the Day' symposia covered the main topics of IYPE: early life and evolution; climate change; geohazards; water, health and the environment; mineral resources; future energy; and earth from a cosmic perspective. The majority of these plenary presentations were streamed online over the internet, a feature which will become more common in the future. The presentations and much other information are available on the congress' website (www.33igc.org).

From the initial planning, before the Nordic countries were awarded the congress, a special focus was placed on the Arctic. As well as the Arctic symposia that provided the papers in this book (see Acknowledgements), other symposia covered permafrost, palaeoclimates and metallogeny. New data from the Integrated Ocean Drilling Program (IODP) on the Lomonosov Ridge provided new perspectives on the role of the Arctic Ocean in the Earth's climate system through the Cenozoic. Furthermore, the congress had pre- and/or post-congress excursions to Arctic regions: Arctic Norway, Svalbard, Bear Island and Greenland. The congress received significant attention from the media, both in Norway and internationally, particularly the assessment of Arctic hydrocarbon resources newly released by the US Geological Survey.

A goal of all IGCs is that they should bring together all of the earth science community and publications form an important instrument in achieving this. It is therefore with great satisfaction we see the successful completion of this comprehensive volume on Arctic Petroleum Geology, based on contributions to the 33rd IGC in 2008. We anticipate that it will be widely read and cited for years to come and form the scientific basis for much new research on Arctic geology and petroleum provinces.

Anders Solheim (33rd IGC Secretary General)
Arne Bjørlykke (33rd IGC President)
David G. Gee (33rd IGC Vice President, Science Programme)

Acknowledgements

The 50 papers in this book have been collected from contributions presented at the IGC in Oslo, August 2008. Nine symposia contained a total of about 90 papers that were relevant to the subject of Arctic petroleum geology. These symposia were particularly important, providing most of the papers in the book:

- Palaeogeographic and tectonic evolution of the Arctic region during the Phanerozoic: A. Embry, A. Mørk, R. Scott & A. Grantz;
- Arctic petroleum provinces (i): Petroleum geoscience of the Barents Sea: E. Henriksen, Ø. Birkeland, A. Stoupakova & Y. Matveev;
- Arctic petroleum provinces (ii): Petroleum geoscience of Russian Arctic basins: A. E. Kontorovich, O. I. Suprunenko & A. Stoupakova;
- Arctic petroleum provinces (iii): Petroleum geoscience of the North American and Greenland basins: D. L. Gautier, K. Sørensen & K. Osadetz;
- Russian-Norwegian scientific co-operation in the Barents Sea region: E. Ormaasen, E. Henriksen, A. Morozov & O. Petrov.

Following the congress, the editors decided to issue invitations to contribute written papers. By October, 43 authors had given promises to supply papers. This allowed an application to be made to the Publications Committee of The Geological Society. Their approval to prepare a Memoir was received in January 2009. Formal invitations and instructions were then sent to authors; papers started arriving in March, with the final one coming in February 2010; refereeing and revision were completed by August 2010.

The refereeing of the papers was undertaken by the following geoscientists: S. Bergman, K. Bird, E. Bjerkebæk, H. M. Bjørnseth, J. Bojesen-Koefoed, Y. Burlin, L. Burshtein, M. Cecile, R. Charpentier, K. Chew, J. Clough, M. Colpron, S. Creaney, T. Dahl-Jensen, J. Dixon, S. Drachev, A. Døssing, D. Ellis, A. Embry, D. Evans, T. Funck, R. Gabrielsen, J. Golonka, A. Grantz, U. Gregersen, Y. Grigirenko, T. Hadlari, D. Houseknecht, J. Ineson, M. Jakobsson, E. Johannessen, A. Khudoley, A. Kontorovich, J. Korstgård, Y. Kristoffersen, M. Larsen, L. Lawver, G. Leckie, T. Lien, H. Lorenz, E. Lundin, H. Lykke-Andersen, J. Milne, T. Moore, A Morozov, A. Mørk, P. Nadeau, S. Olaussen, A. Rasmussen, T. Rasmussen, T. Redfield, F. Riis, K. Rønning, R. Scott, R. Sinding-Larsen, A. Spencer, R. Stephenson, O. Suprunenko, D. Stone, A. Stoupakova, K. Sørensen, M. Tennyson, G. Uenzelmann-Neben, G. Ulmishek, R. Whittaker, S. Wienecke and D. Worsley.

Russian papers were prepared and refereed in the Russian language and then translated into English, all organized by A. Stoupakova. Leading geologists and academic institutions made contributions, both as scientific advisers and as co-authors of the nine Russian papers. In this respect acknowledgement must be made to A. E. Kontorovich, O. I. Suprunenko, Yu. N. Grigorenko, to research institutes working in the Arctic such as VNIIOkeangeologia, VNIGRI, VSEGEI, VNIGNI, Sevmorgeo, MAGE and to the Rosnedra agency of the Russian Ministry of Natural Resources.

A. Spencer wishes to thank Statoil for allowing him, over a total of seven years, to participate first in the Scientific Committee of the 33rd IGC and then in the work of compilation of this book. Numerous Statoil colleagues helped with advice over these years, in particular K. G. Røssland and M. Rye-Larsen who gave detailed help in planning the petroleum symposia.

ANTHONY M. SPENCER, ASHTON F. EMBRY, DONALD L. GAUTIER, ANTONINA V. STOUPAKOVA and KAI SØRENSEN (eds)

Preface

The present volume presents nine overviews of the geology, potential field geophysics, tectonic development and hydrocarbon potential of the Arctic Region from 60° or 65°N to the North Pole. These papers are followed by discussions of the geological and (or) geophysical character and hydrocarbon potential of some 28 local areas and sedimentary basins in the Arctic Basin proper and those parts of Baltica, Siberia and Laurentia that fall within the Arctic Region. The volume was inspired by significant recent advances in geological and geophysical knowledge of the Arctic Region, important hydrocarbon discoveries in the margins of the continents and continental shelves that encompass the Arctic Basin, and by more modest advances in our knowledge of the character of the basins and ridges that constitute the more poorly understood Arctic Basin proper. Continuing declines in the world's hydrocarbon resources and known exploration targets and a recent estimate (Gautier *et al.* Chapter 9) that the Arctic Region north of the Arctic Circle may contain as much as 30% of Earth's undiscovered natural gas and 13% of its undiscovered oil has made assembly of the 50 papers that constitute the present volume timely. The editors hope that the volume will encourage and help guide exploration for hydrocarbons in the Arctic Region and provide some useful perspectives on the total hydrocarbon resource remaining to be developed by humanity.

Scientists from all five Arctic Nations (those that encompass the Arctic Basin) and from several non-Arctic nations have contributed to this volume. Interest of the five Arctic Nations in the geology and geophysics of the Arctic is enhanced by the United Nations Convention on the Law of the Sea, which entitles coastal states to Exclusive Economic Zones (EEZ) adjacent and beyond their territorial seas out to 200 nautical miles from their coastal baselines. The coastal states have sovereign rights to resource development and certain other economic activities in their EEZs, and jurisdiction over marine science research, environmental protection and the establishment of artificial islands and other offshore structures. For outer continental shelf areas that lie more than 200, but not more than 350 nautical miles from the coastal baselines or more than 100 nautical miles seaward of the 2500 m isobath, the coastal states have sovereignty over the subsea mineral resources and sedentary or bottom-bound organisms, but not the organisms of the water column itself. Many earth scientists from non-Arctic nations are motivated by the acquisition of geological understanding of the Arctic, others primarily by the search for hydrocarbon deposits. Perusal of the contents of this volume will reveal, however, that both groups of scientists have made important contributions to our understanding of the geological character and history of the Arctic Region.

Marine geological and geophysical mapping in the Arctic by the Arctic Nations in support of their national interests under the United Nations Convention on the Law of the Sea is continuing, or becoming increasingly active, and will soon produce important new information on the geological framework and character of the Arctic Basin. Important contributions to our understanding of the geology of the Arctic Region are also being generated by ongoing hydrocarbon exploration and development in the Russian, Norwegian, Alaskan, Canadian and Greenland sectors of the Circum-Arctic land masses and continental shelves. It is the editors' wish that the present volume will facilitate these important exploration and research endeavours.

ARTHUR GRANTZ