Cross-border subsurface geology in the Atlantic Margin and the Barents Sea: an introduction

Chiarella D.[1], Archer D.G.[2], Howell J.A.[3], Jackson C. A.-L.[4], Kombrink H.[5] and Patruno S.[6]

[1]Department of Earth Sciences, Queen's Building, Royal Holloway, University of London, Egham, Surrey, TW20 0EX, UK

[2]Harbour Energy, Rubislaw House, South Anderson Drive, Aberdeen, AB15 6FZ, UK

[3]Department of Geology and Geophysics, Meston Building, King's College, Aberdeen AB24 3FX, UK

[4]Department of Earth and Environmental Sciences, The University of Manchester, Williamson Building, Oxford Road, Manchester, M13 9PL, UK

[5]North Sea Core, 8 Dubford Terrace, Aberdeen, AB23 8GE, UK

[6]Department of Engineering, University of Nicosia, 46 Makedonitissas Avenue, CY-2417, P.O. Box 24005, CY-1700, Nicosia, Cyprus

Abstract

Over the last 50 years, the North Sea and Atlantic Margin, and more recently the Barents Sea, represented key study areas for academic and professionals interested in the exploration for and production of hydrocarbon from the Earth's subsurface. Nowadays, these areas may play a major role in the so-called 'energy transition', with the energy industry now seeking to reduce emissions related to hydrocarbon consumption, and leading the development of carbon capture and storage activities, such as the Northern Light project (https://northernlightsccs.com). Consequently, there is an increasing interest in advancing our knowledge regarding the stratigraphy, sedimentology, and tectonic development of the North Sea, Atlantic Margin, and Barents Sea with a cross-border approach.

This volume provides a cross-border view of the Atlantic Margin and Barents Sea areas, giving a 'geology-without-borders' analysis of such aspects, with the aim of contributing to the current academic and industrial objectives outlined above. A similar cross-border

analysis for the North Sea Basin across the offshore boundaries of Germany, the Netherland, Norway and the United Kingdom is presented in a companion volume (SP494), entitled, “Cross-Border Themes in Petroleum Geology I: The North Sea” (Archer et al., 2022; Patruno et al., 2022).

The ambition of this Special Publication is to examine the tectonic evolution and the stratigraphic, sedimentological, and reservoir characterisation of the Atlantic Margin and Barents Sea areas (Fig. 1) with a cross-border approach. The aim is to overcome boundaries and limitations due to political jurisdictions and internal organisational structures of companies that usually make across-borders integration and knowledge transfer difficult. Private companies and public national organisations have done several attempts to integrate our cross-border geological understanding resulting, on many occasions, in constructive and rewarding outcomes.

As highlighted by Archer et al. (2022), one of the main challenges for cross-border exploration activities is data that are typically acquired and organised following the political boundaries rather than basins physiography. Other challenges are related to stratigraphic nomenclatures of geological units (e.g., groups, formations, members) and tectonic trends for which a cross-border unified nomenclature would be beneficial since units and structures are transnational and not limited by political boundaries.

Volume organization

The papers presented in this Special Publication are arranged into two main sections, each focusing on a distinct theme. The aim of this introduction is to provide a broader context for the papers in these two sections.

Tectonic evolution

The first group of contributions explores the geometry and evolution of basin-defining faults, the way in which they can be visualised, and the way they control basin physiography and sedimentation. All these aspects are important for the identification and characterisation of potential trap and prospects.

Despite being tectonically complex, the extensive seismic coverage of the Barents Sea area offers the opportunity to investigate its structural geology and tectonic evolution. **Libak et al. (2019)** present the effect of lithology on the geometry of very large faults imaged in seismic data in the Norwegian Barents Sea (Fig. 2). This paper integrates clay volumes derived from well-logs (i.e., gamma-ray), and seismic data to populate 3D surveys with lithological information. Clay volume cubes are then co-rendered with seismic coherence cubes using opacity blending to visualize both lithology and fault geometry. **Anell et al. (2019)** discuss the influence of structural highs on Triassic deposition in the western Barents Shelf (Fig. 2). The authors show that although the Triassic is a relatively tectonically quiescent period, the basin-filling was strongly influenced by tectonic activity marking that defines the boundary between the lower and middle Triassic. **Kristensen et al. (2021)** perform a quantitative analysis of fault and related fold growth in the Sørvestsnaget Basin (Western Barents Sea; Fig. 2). The peculiarity of this basin is that transtension-related shortening led to the modification of the primary patterns of fault displacement, and resulted in some stratigraphic geometries unlike that characterising purely extensional basins.

Trice et al. (2019) present a cross-border study of fractured crystalline basement reservoirs on both the UK and Norwegian continental shelves (Fig. 2). The paper emphasises how, after a series of serendipitous basement discoveries (e.g., Clair and Lancaster fields), the time is ripe, via cross-border knowledge sharing, for a collective advance in our knowledge of basement plays. By doing this we will be able to better assess the distribution of basement fractures, and how these networks impact fluid transport in the subsurface, as well as the impact of weathering processes on reservoir properties. Finally, using extensive new 3D seismic surveys **Millet et al. (2020)** discuss new prospectivity in frontier and underexplored regions of the outer and central Faroe–Shetland, Møre and southern Vøring basins (Fig. 2), extending existing plays into areas impacted by igneous activity, and that have previously not been considered prospective.

Stratigraphic, sedimentological and reservoir characterisation

The second group of contributions cover the stratigraphic distribution and sedimentological characterisation of syn- and post-rift reservoir intervals. The integration of seismic data, well-logs, and core material is used to characterise the spatial arrangement and facies characteristics (e.g., texture, porosity, permeability, etc.) of depositional elements. **Jones et al. (2021)** investigate an example of syn-rift fault-controlled deposits developed along the Vingleia Fault Complex, offshore mid-Norway (Fig. 2). The authors emphasise the impact the formation of normal fault-controlled depocentres have on the sediment routing systems and facies distribution. The position of sediment entry points along the segmented, basin-bounding fault, and the morphology of the adjacent, narrow and deep depocentres, results in rapid lateral facies changes and the spatially limited deposition of coarse-grained clastic material derived from the flanking footwall high. **Chiarella et al. (2021)** use a combination of core, wireline log and 3D seismic data to investigate the stratigraphic distribution and sedimentological characteristics of the Cenomanian–Turonian intra Lange Sandstones in the Gimsan Basin and Grinda Graben (Norwegian Continental Shelf; Fig. 2). Their analysis characterizes the distribution, dimension, and facies organisation to aid post-rift basin reconstruction and reservoir characterisation. **Walker et al. (2020)** reconstruct the offshore volcanic stratigraphy across the northern Faroe–Shetland Basin and Møre Marginal High (Fig. 2) to improve our understanding of the temporal and spatial evolution of the Paleocene-Eocene lava field, and its relationship to NE Atlantic rifting. The result of this study can be used to aid basin modelling and the exploration of sub-basaltic sequences. **Klausen et al (2019)** use new provenance data and core descriptions to discuss the factors controlling the tectonostratigraphic evolution and facies distribution of the Realgrunnen Subgroup (Upper Triassic-Middle Jurassic), Barents Sea (Fig. 2). The authors analyse the stratigraphic evolution of the Realgrunnen Subgroup and its reservoir variability within a source-to-sink framework, linking reservoir properties to the provenance signature and the tectonostratigraphic evolution. **Riis and Wolff (2020)** perform regional mapping of aquifer pressures and dynamics in the Norwegian Continental Shelf (Fig. 2) using pore pressure data from more than 1000 wells. Areas characterised by underpressured, overpressured, and hydrostatically pressured regimes are controlled by depositional and erosional processes associated with Pleistocene glaciations. **Hunt et al. (2020)** investigate the use of a non-destructive infrared spectrometry technique to acquire continuous information about the mineralogy and fluid presence to be used for geological and petrophysical evaluations. The authors use core data acquired within the North Sea and Norwegian Continental Shelf (Fig. 2), showing how this technique can also help to calibrate petrophysical data and link mineralogy to permeability.

Conclusions

In summary, as well as offering valuable insights into current research in the field of structural geology, stratigraphy and sedimentology and reservoir characterisation, papers presented in the current (SP495) and companion volume (SP494) are designed to help academic and industry people working in exploration, appraisal, and development of the subsurface for energy purposes. The current energy transition phase requires the collaboration of all entities involved in the energy sector and the best way to maximise the available dataset and knowledge is to look at basins positioned across political borders as single entity.

Acknowledgements

Convenors and presenters of a series of FORCE workshops organised by the Sedimentology and Stratigraphy Group between 2013 and 2016 are thanked. The editors of this Special Publication would like to thank the Geological Society staff who assisted with the preparation of the volume. Thanks to the reviewers of all the papers, whose diligent work and valuable time has helped to enhance the technical standing of this volume.

References

Anell I., Indrevær K. and Serck C.S. (2019) Influence of structural highs on Triassic deposition on the western Barents Shelf (this volume) https://doi.org/10.1144/SP495-2018-76

Archer S.G., Kombrink H., Patruno S., Chiarella D., Jackson C. A.-L. & Howell J. (2022) Cross-border petroleum geology in the North Sea: an introduction. In: PATRUNO S., ARCHER S. G., CHIARELLA D., HOWELL J. A., JACKSON C. A.-L. & KOMBRINK H. (eds) Cross-Border Themes in Petroleum Geology I: The North Sea. Geological Society, London, Special Publications, 494. DOI: https://doi.org/10.1144/SP494-2021-182

Chiarella D. and Joel D. (2021) Stratigraphic and sedimentological characterization of the Late Cretaceous post-rift intra Lange Sandstones of the Gimsan Basin and Grinda Graben (Halten Terrace, Norwegian Sea) (this volume) https://doi.org/10.1144/SP495-2021-72

Hunt G.A., Williams R., Charnock M.A., Moss A., Meltveit J. and Florescu D. (2020) Geological and petrophysical applications of imaging infrared spectroscopy for mineralogical analysis of core and cuttings: examples from the North Sea, Norwegian Sea and Barents Sea (this volume) https://doi.org/10.1144/SP495-2018-168

Klausen T.G., Müller R., Poyatos-Moré M., Olaussen S. and Stueland E. (2019) Tectonic, provenance and sedimentological controls on reservoir characteristics in the Upper Triassic–Middle Jurassic Realgrunnen Subgroup, SW Barents Sea (this volume) https://doi.org/10.1144/SP495-2018-165

Kristensen T.B., Rotevatn A., Marvik M., Henstra G.A., Gawthorpe R.L. and Ravnås R. (2021) Quantitative analysis of fault-and-fold growth in a transtensional basin: the Sørvestsnaget Basin, Western Barents Sea (this volume) https://doi.org/10.1144/SP495-2020-123

Jones G.E.D., Welbon A.I.F., Mohammadlou H., Sakharov A., Ford J., Needham T. and Ottesen C. (2021) Complex stratigraphic fill of a small, confined syn-rift basins: an Upper Jurassic example from offshore mid-Norway (this volume) https://doi.org/10.1144/SP495-2019-143

Libak A., Torabi A. and Alaei B. (2019) Normal fault geometric attribute variations with lithology: examples from the Norwegian Barents Sea (this volume) https://doi.org/10.1144/SP495-2018-164

Millett J.M., Manton B.M., Zastrozhnov D., Planke S., Maharjan D., Bellwald B., Gernigon L., Faleide J.I., Jolley D.W., Walker F., Abdelmalak M.M., Jerram D.A., Myklebust R., Kjølhamar B.E., Halliday J. and Birch-Hawkins A. (2020) Basin structure and prospectivity of the NE Atlantic volcanic rifted margin: cross-border examples from the Faroe–Shetland, Møre and Southern Vøring basins (this volume) https://doi.org/10.1144/SP495-2019-12

Northern Light Project, https://northernlightsccs.com/, last access 10 March 2022

Patruno S., Archer S. G., Chiarella D., Howell J. A., Jackson C. A.-L. & Kombrink H. (eds) Cross-Border Themes in Petroleum Geology I: The North Sea. Geological Society, London, Special Publications, 494. https://sp.lyellcollection.org/online-first/494.

Riis F. and Wolff A. (2020) Use of pore pressure data from the Norwegian Continental Shelf to characterize fluid-flow processes in geological timescales (this volume) https://doi.org/10.1144/SP495-2018-176

Trice R., Hiorth C. and Holdsworth R. (2019) Fractured basement play development on the UK and Norwegian rifted margins (this volume) https://doi.org/10.1144/SP495-2018-174

Walker F., Schofield N., Millett J., Jolley D., Hole M. and Stewart M. (2020) Paleogene volcanic rocks in the northern Faroe–Shetland Basin and Møre Marginal High: understanding lava field stratigraphy (this volume) https://doi.org/10.1144/SP495-2019-13

Figure

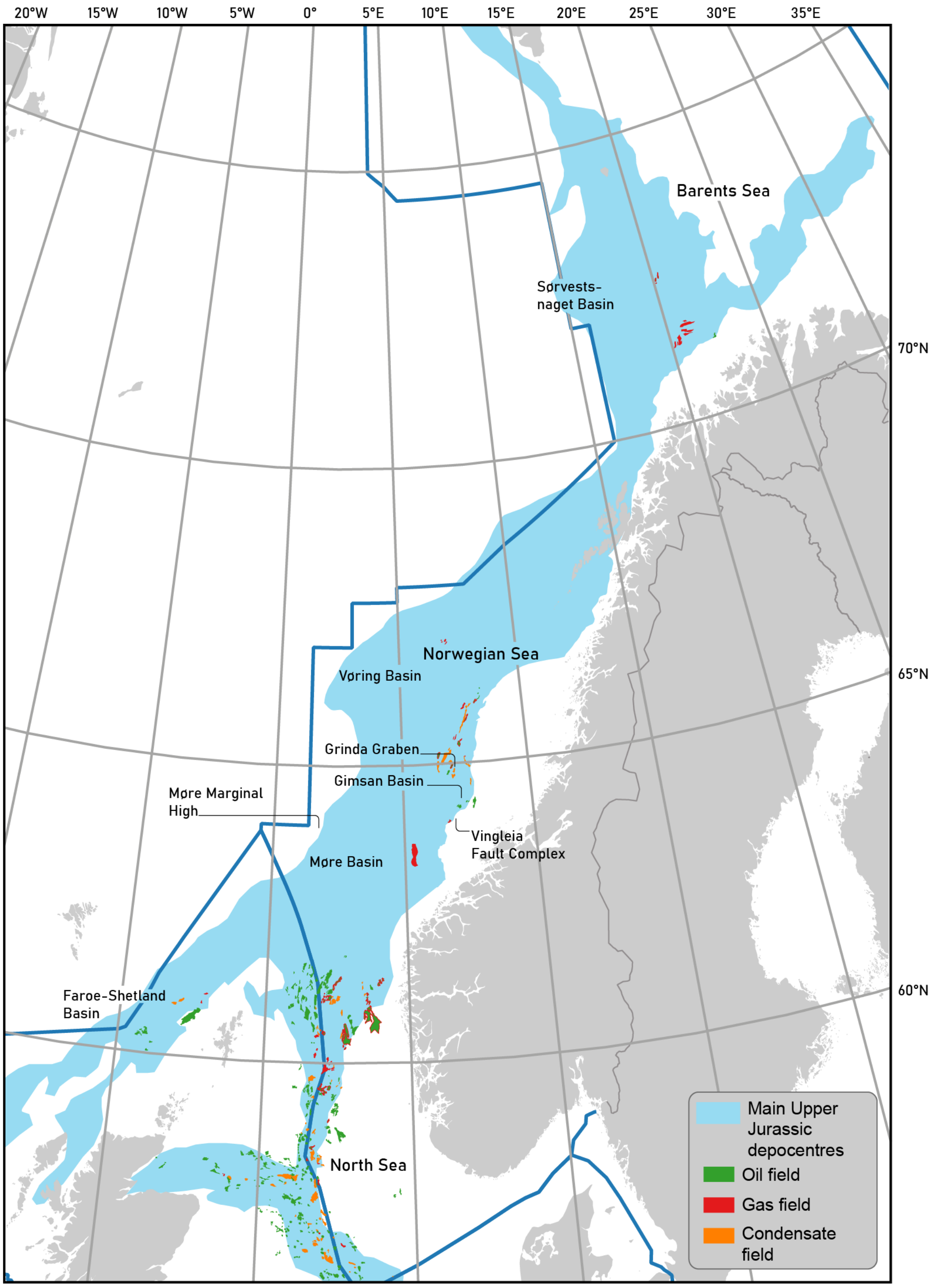

Figure 1. Map of the main geological elements of the Atlantic Margin and Barents Sea, showing the main Upper Jurassic depocenters. The location of hydrocarbon discoveries is also shown.

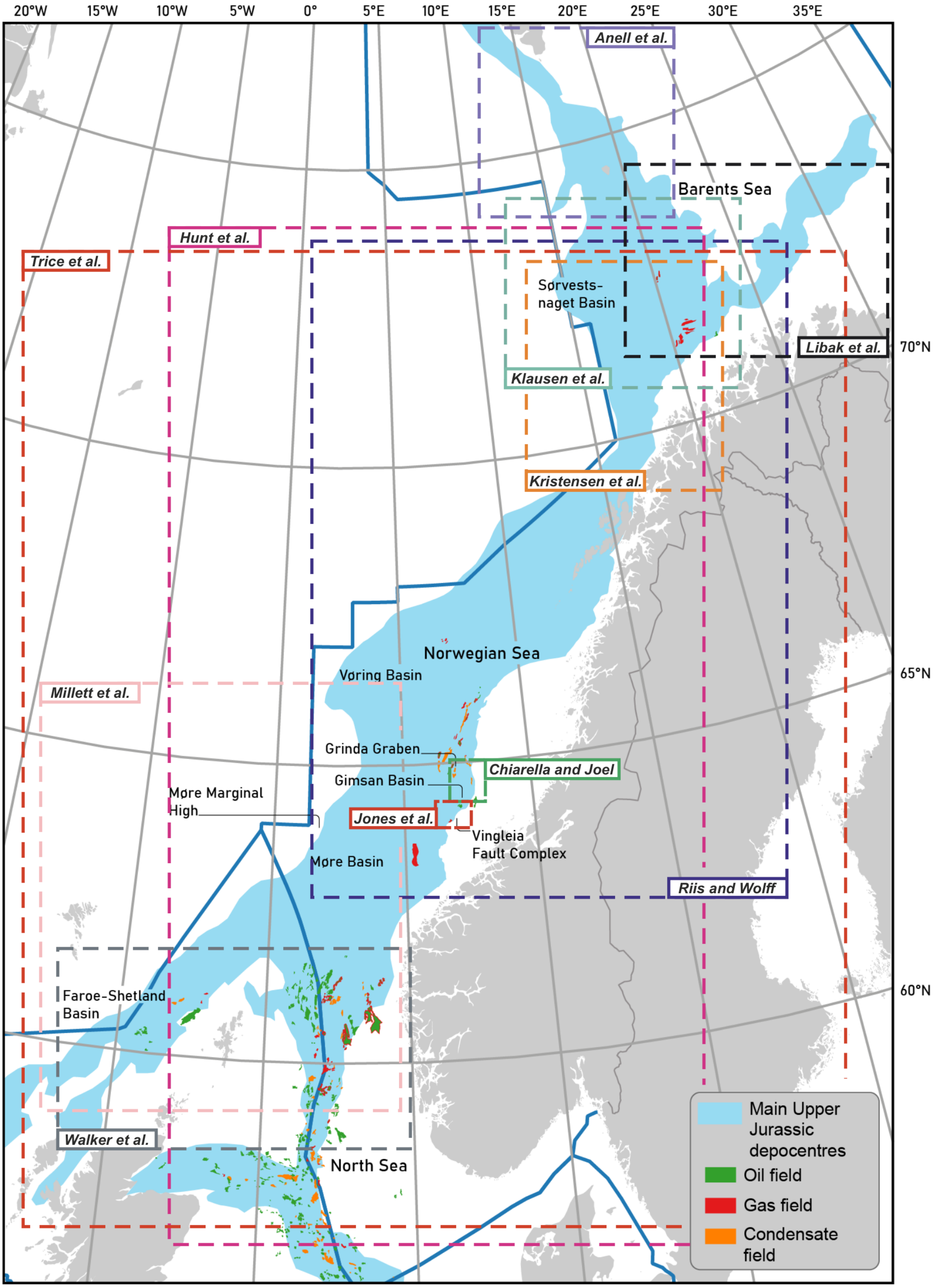

Figure 2. Approximate geographic location of the articles presented in this volume.