Jurassic-Lower Cretaceous basinal studies of the Arctic region - JuLoCrA:

A continuation of the Lower Cretaceous basin studies in the Arctic consortium (LoCrA)

A two year R&D proposal by the University of Stavanger (UiS) and the University Centre in Svalbard (UNIS) in cooperation with other universities and research institutes

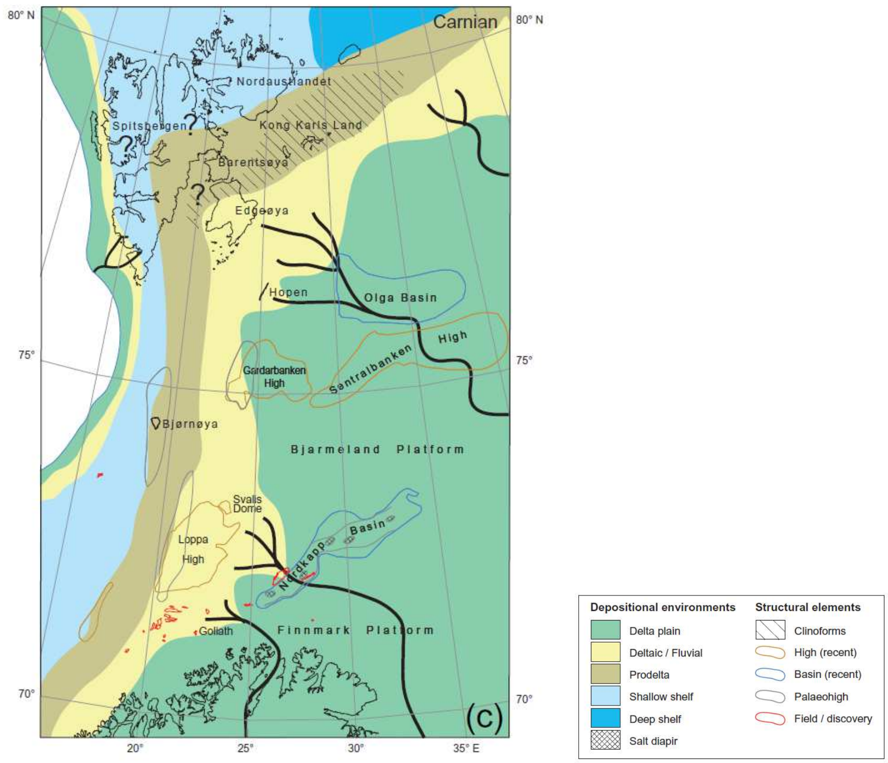
1 EXECUTIVE SUMMARY

The University of Stavanger (UiS) and the University Centre in Svalbard (UNIS) propose a two-year consortium (2017-2018) to expand previous research from the Lower Cretaceous to the Upper Jurassic in the Arctic basins. The project will be in collaboration with Lomonosov Moscow State University (MSU) and the Geological Survey of Denmark (GEUS). The study will build on the existing sequence stratigraphic framework, structural and thickness maps, and paleogeography; analyze geochemical data; and correlate on- and off- shore studies in order to create a holistic understanding of the geologic framework of the Arctic basins from the Barents and Kara seas. The project is budgeted for 350.000 NOK per year per company (700.000 NOK for the two-year period per company). Deliverables include all results from the project (e.g. presentations, publications) and an integrated database including digital products from each of the focus areas (i.e. GIS and gridded data) as well as a final project report.

2 SCOPE OF WORK

A two-year project, Jurassic-Lower Cretaceous basinal studies of the Arctic region (JuLoCrA; January 2017 - December 2018), led by the University of Stavanger and University Center in Svalbard, aims to continue and expand research activities from the Lower Cretaceous basin studies in the Arctic (LoCrA) consortium (2012-2016). The project will continue research in the Lower Cretaceous interval and expand into the Upper Jurassic interval to provide a better understanding of the paleogeography and a fully-integrated, surface and subsurface synthesis of on- and off- shore areas. The Jurassic is one of the most prolific intervals in the Barents and Kara Sea regions with several discoveries in recent years (e.g. Johan Carlsberg, Wisting, Universitetskaya); however, its depositional setting is poorly understood. The Jurassic represents a relatively thin transition from the sand-rich and thick Triassic shallow marine to continental environments sourced from the Urals and northern Norway to the thick, mud-rich Lower Cretaceous, prograding marine-dominated environments sourced from large continental areas in the north and more localized intra-basinal highs. In addition to good quality shallow-marine and transitional reservoir rocks, the Jurassic contains one of the richest source rocks in the region (Hekkingen Fm.). LoCrA studies show that many geological processes are closely linked to Middle and Late Jurassic events (e.g. initiation of extensional basins). A study integrating basin evolution with a common on- and off- shore sequence stratigraphic framework that leads to a better understanding of the paleogeography and the relationship of the Lower Cretaceous to the Upper Jurassic for the entire Barents Sea region is lacking (Figure 1).

A.



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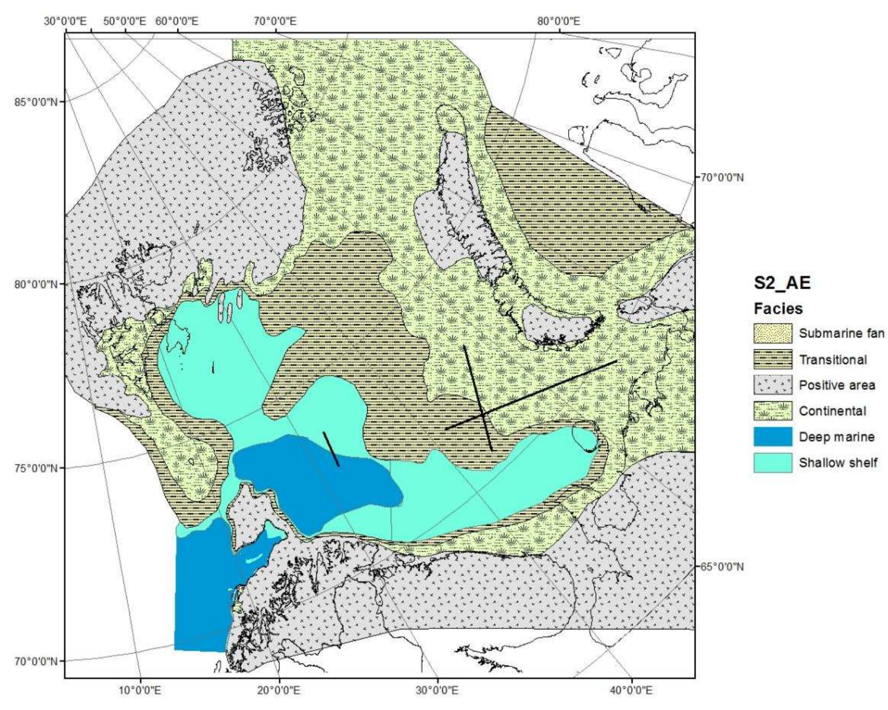


Figure 1. Change in the paleogeography from Late Triassic (A) (Riis, 2009) to Lower Cretaceous (B) (LoCrA) in the Barents Sea.

3 SPECIFIC OBJECTIVES

We request support to expand research from the Lower Cretaceous to the Middle-Upper Jurassic succession of the Barents Sea. The efforts will be focused on improving the sequence stratigraphic framework, structural and thickness maps, and paleogeography; analyzing geochemistry; and correlating on- and off- shore studies. As a result of this project, we expect a large impact similar to LoCrA (Appendix 1), which includes student and post-doctoral training in Arctic geology and petroleum exploration, conference participation, peer-reviewed publications, and an improved understanding of the Middle Jurassic to Lower Cretaceous paleogeography in order to support successful exploration in the Greater Barents Sea region.

3.1 SEQUENCE STRATIGRAPHIC FRAMEWORK

Building a sequence stratigraphic framework for the Middle Jurassic to Lower Cretaceous period (Figure 2 and Figure 3) will act as a basis for other research objectives of the consortium. Similar to LoCrA, detailed biostratigraphy, core analysis, and stacking patterns from well data integrated with seismic will be used (Figure 4). The work will be integrated into the existing framework with our current understanding of the Lower Cretaceous; the Jurassic and Lower Cretaceous represent conformable sequences. Detailed outcrop mapping in Svalbard and on-offshore correlation are critical to better constrain the paleogeography. As part of LoCrA, six sequences (3rd order) have been identified in the subsurface of the Barents Sea on the basis of stacking patterns from logs and seismic stratigraphy tied to new age data from core and cuttings (palynology and foraminifera) (Figure 4, upper figure). Given that the Jurassic represents a more condensed section in many parts of the subsurface of the Barents Sea relative to the Lower Cretaceous, subsurface mapping is more challenging as fewer sequences may be identified (Figure 4, lower figure).

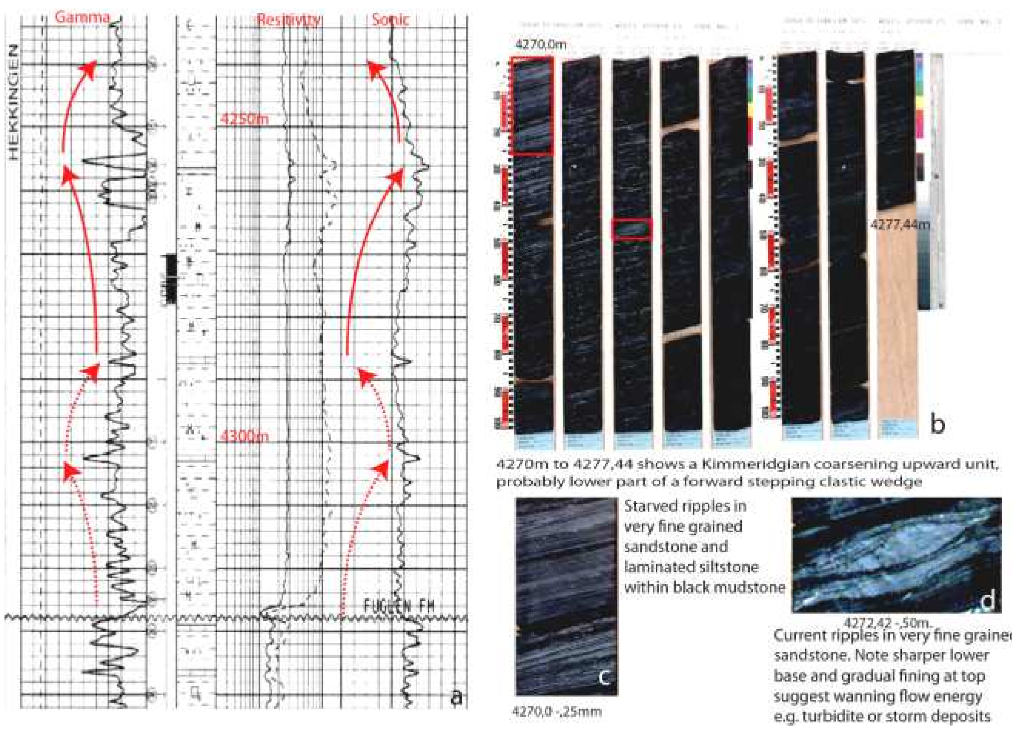


Figure 2. Wireline logs and pictures from the cored sections in well 7219/8-1S. Arrows show coarsening upward (CU) and fining upward (FU) units on the gamma log motifs. Note carbonate peaks on the velocity and gamma log on the turnaround point of the CU-FU units. From NPD fact pages.

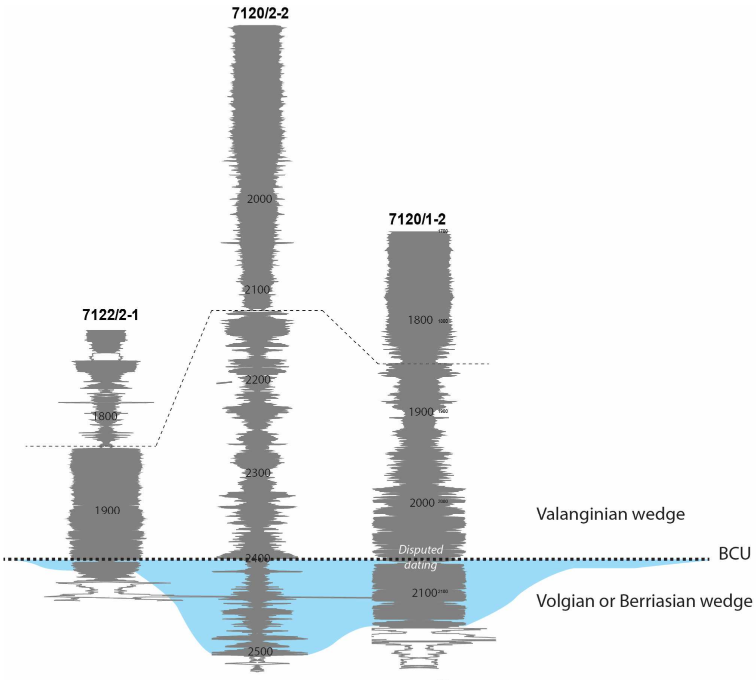


Figure 3. Wireline logs (symmetric gamma logs) from three wells along the southern margin of Loppa High showing intra "Hekkingen sandstones".

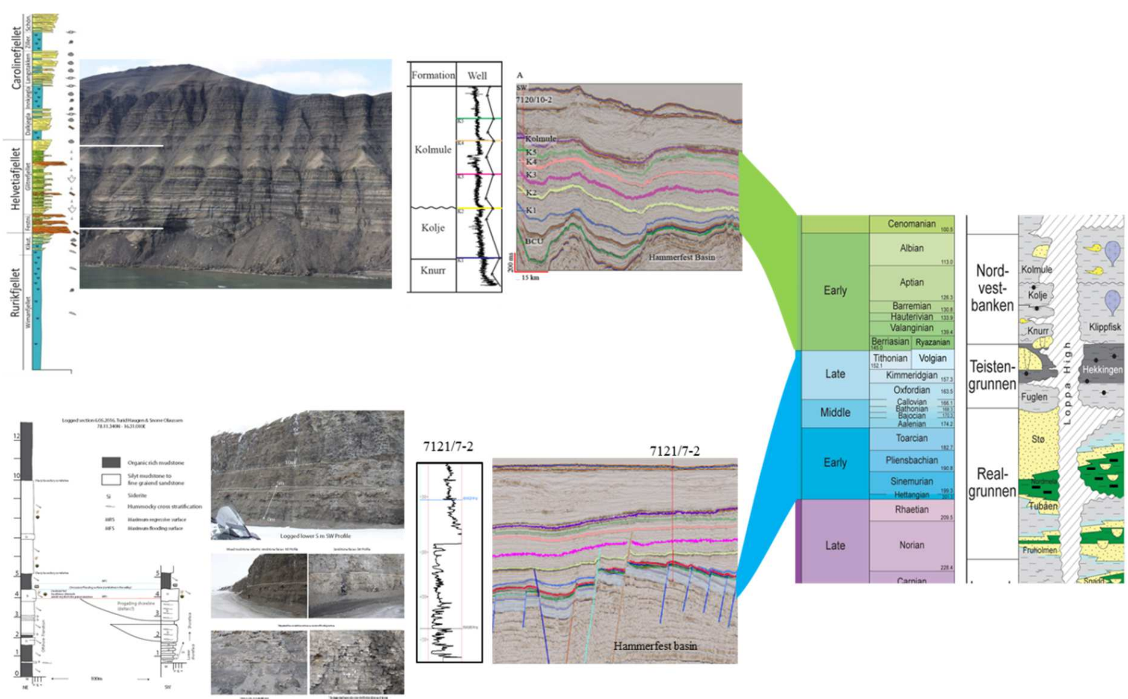


Figure 4. On- and off- shore correlations for the Lower Cretaceous from LoCrA in comparison to the Jurassic interval. Note that the Jurassic succession is very thin relative to the Cretaceous interval in the Hammerfest basin and other regions of the Barents Sea.

On the Barents Platform, the Norian to Bajocian (i.e. Realgrunnen and Wilhelmøya subgroups) represent a transition between the mainly Middle-Upper Triassic, westward-directed progradation of shallow marine to paralic facies sourced from the east and south (i.e. Fennoscandia; Klausen et al., 2015) and the mainly southward-directed, Lower Cretaceous, prograding, shallow marine-dominated units sourced from large continental areas in the north and more localized intra-basinal highs (Gjelberg and Steel, 1995; Midtkandal et al., 2009; Marin et al., accepted pending revisions). LoCrA studies show that the Bajocian/Bathonian to near base Valanginian (BCU) succession appears to be linked to the same drainage pattern as observed in the Lower Cretaceous, which is consistent with the previous conceptual model by Dypvik et al. (2002).

Although the Agardhfjellet and Hekkingen formations are mostly studied as hydrocarbon source rocks and for seal properties, few regional studies are available on facies and sequence stratigraphy in a source to sink approach (Figure 3). In western Spitsbergen, current outcrop and subsurface studies show more proximal facies than hitherto suggested. Shallow marine, clastic wedges, probably of deltaic origin, occur in the western part of central Spitsbergen (Figure 5). The Kimmeridgian succession west of the Loppa High in well 7219/8-1S suggests forward-stepping, clastic wedges. Wells 7122/2-1, 7120/2-2, and 7120/1-2 south of Loppa High exhibit intra-Hekkingen (disputed age; Volgian or Berriasian) sandstone of probable submarine fan origin overlying Valanginian, sandy, clastic wedges (Figure 3)(NPD fact pages http://factpages.npd.no/factpages/Default.aspx?culture=en).

In the eastern Barents Sea, Bathonian to Callovian sandstones were deposited in a paralic environment (Figure 5) (Stoupkova et al., 2013). These sandstones are an important potential reservoir unit and include part of the hydrocarbon accumulation in the Shtokmanovskaya discovery. In addition, Upper Jurassic sandstones occur in Shtokmanovskaya, Arkticheskaya, and Ludlovskaya discoveries (Stoupkova et al., 2013).

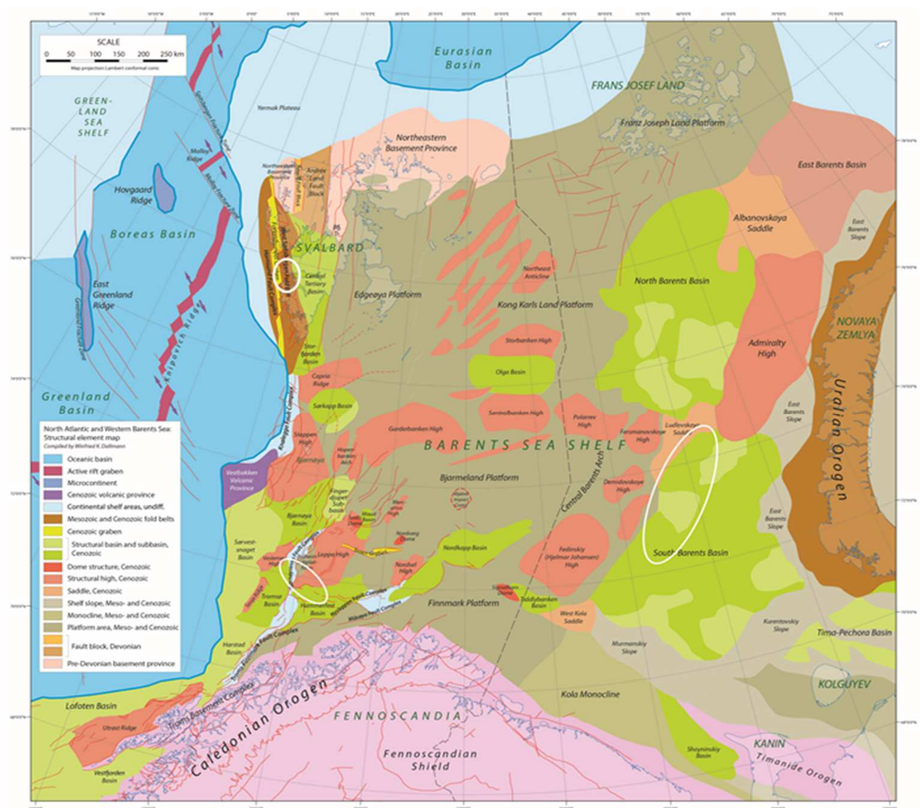


Figure 5. Location of the area discussed here (white circles). Map from Dallmann & Olaussen et al. in prep.

An integrated sequence-seismic stratigraphic framework and more detailed facies studies will lead to a better understanding of the paleogeography of this succession within the entire Barents Sea region and its relation to the Lower Cretaceous interval (Figure 4). It will also shed light on the drainage pattern throughout the Mesozoic in the greater Barents Sea and nearby Arctic basins.

3.1.1 Southwestern Barents Sea

One of the few cored sections in the Hekkingen Formation is from well 7219/8-1S west of Loppa High (Figure 2). Interpretation of wireline logs suggest that the interval from 4285 m to 4235 m (Figure 2) represents a coarsening upward (CU) unit and is followed by a fining upward (FU) unit. The succession from about 4285 m to 4235 m is interpreted as a Kimmeridgian prograding wedge followed by a retrograding wedge. The CU and FU become remarkably similar to the stacking pattern observed in the Kimmeridgian in the western part of central Spitsbergen (Figure 3).

A well south of Loppa High shows clastic wedges are drained from Loppa High. Of great interest is the dramatic change in sandstone composition of the Hekkingen-wedge and Valanginian-wedge versus the overlying Aptian-Albian sandstones. While the latter consists of immature sandstones with garnets and reworked upper Jurassic fossils, the lower two wedges consist of mature quartz arenites with lower-middle Jurassic reworked fossils. The facies was interpreted to be deposited in an inner shelf environment (from Shell completion log NPD fact pages). The three wells, 7122/2-1, 7120/2-2, and 7120/1-2, might be interpreted as part of the same wedge (Figure 3).

3.1.2 Central western Spitsbergen

The fully cored and logged sections of the near 200-meter-thick Agardhfjellet Formation (Fuglen and Hekkingen equivalent) shows a well-organised stacking pattern with several TR sequences (Figure 6). Nearby outcrops also show sandstone beds with hummocky cross-stratification and architecture suggesting nearby delta progradation (Figure 6).

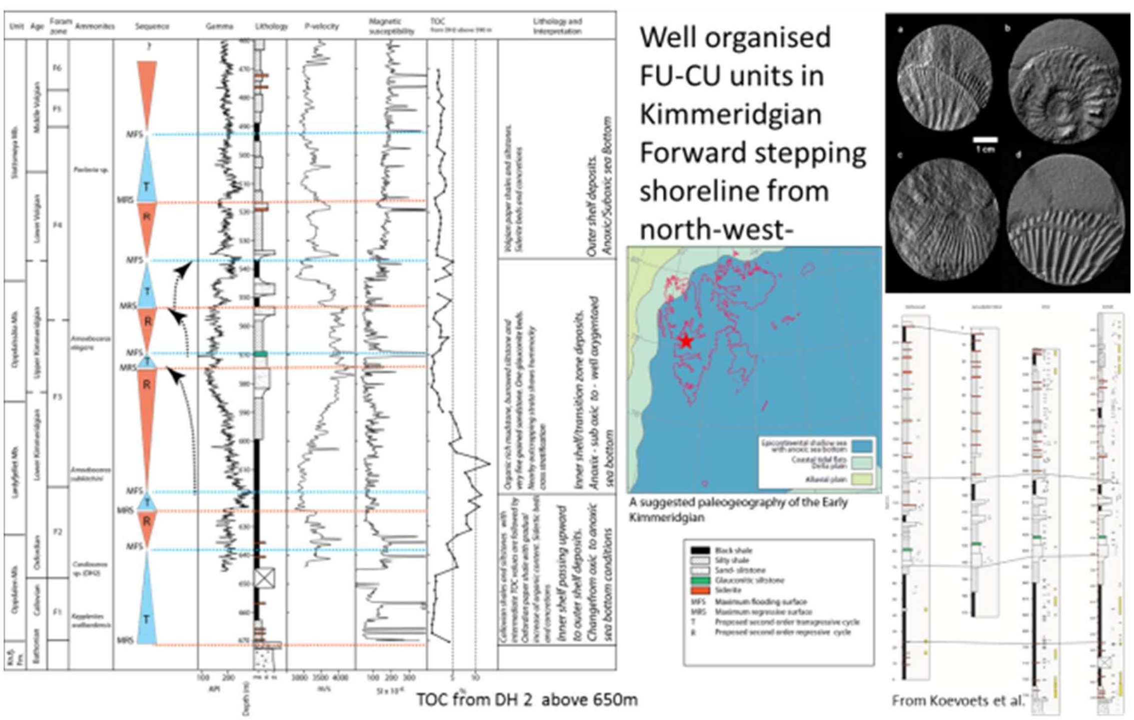


Figure 6. Interpretation of the cored Agardhfjellet Formation in well DH5R in Adventdalen. Geochemical analysis shows kerogen type III in the Lower Kimmeridgian which is consistent with an interpretation of a proximal facies of this CU unit.

3.2 STRUCTURAL AND THICKNESS MAPS

The creation of detailed time structure and thickness maps (Figure 7), in addition to the characterization of subsidence patterns, provides the framework for basin fill, depocenter evolution, and facies distribution. The Jurassic represents a renewal period of extension in the Barents Sea that continues into the Lower Cretaceous and has a major impact on the paleogeography. Six Lower Cretaceous sequences have regional, time structure and thickness maps that are used for different aspects of the LoCrA project. Regional mapping indicates that the main Lower Cretaceous depocenter migrated from the southeastern Barents Sea during the most Upper Jurassic Valanginian-Berriasian time towards the Hammerfest and Tromsø basins during the Aptian-Albian time. This is supported by detailed mapping of clinoforms (high and low relief) by Marin et al. (accepted pending revisions) and Mordasova et al. (work in progress) (Figure 8). Localized depocenters with deposition of coarse-grained clastic wedges along the basin margins of the Hammerfest, Tromsø, and Fingerdjupet basins are observed during the older sequences, whereas a major input from the northwest occurs during the Barremian-Aptian. These observations indicate the complex interplay between regional and local paleodrainage systems and the basin structure.

JuLoCrA intends to create time structure and thickness maps. In contrast to the Lower Cretaceous interval, the subsurface distribution of the Middle and Upper Jurassic differs. Towards the west, the interval is relatively thin, whereas towards the eastern Barents Sea, the interval is thick. However, it is clear from the interpretation that the tectonics that controlled the development of the Cretaceous basins started in the Middle to Upper Jurassic. These maps will allow a better understanding of the distribution of the Middle to Upper Jurassic sequences by integrating other information to provide a better understanding of the paleogeography.

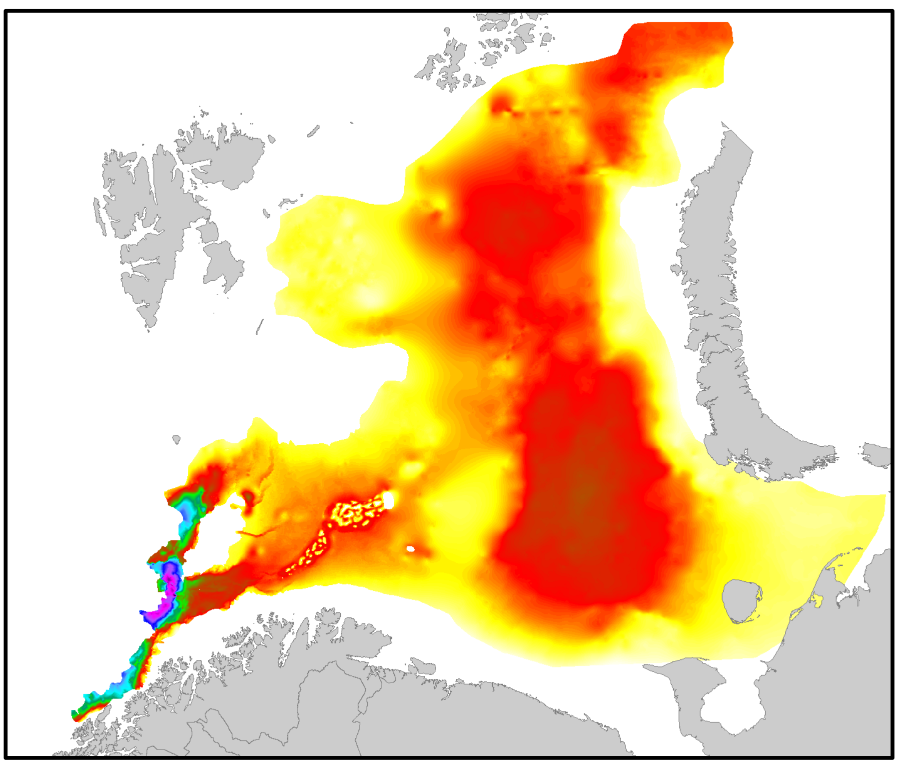


Figure 7. Preliminary time structure map of the base Cretaceous unconformity in the greater Barents Sea area from the LoCrA project. Structure and thickness maps have been created for all Lower Cretaceous sequences.

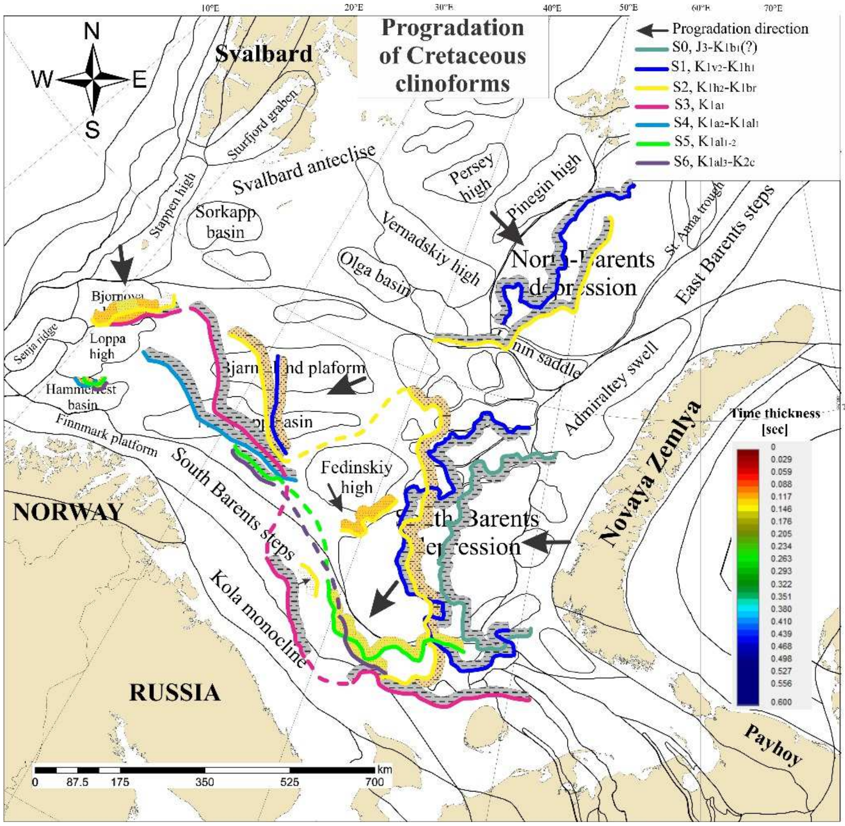


Figure 8. Map showing the distribution of interpreted clinoforms from Upper Jurassic and Lower Cretaceous in the Barents Sea region compiled by LoCrA.

3.3 PALEOGEOGRAPHY

Continuing to improve the Lower Cretaceous paleogeography, based on the six subsurface sequences defined in LoCrA (Figure 8), will allow a more thorough understanding of the geologic framework of the basins and an initial insight into the Middle and Upper Jurassic paleogeography. As previously described, many of the sequences and facies of the Middle and Upper Jurassic intervals seem to correlate more with the Lower Cretaceous source to sink pattern than the Triassic. Figure 8 shows the main LoCrA result of the regional paleogeography of the six Lower Cretaceous sequences. Detailed mapping of all sequences, clinoforms, well analysis, dating, and on- and offshore correlations have provided a better understanding of the complex evolution of the basin and facies distribution through time and has an impact for hydrocarbon exploration in the region.

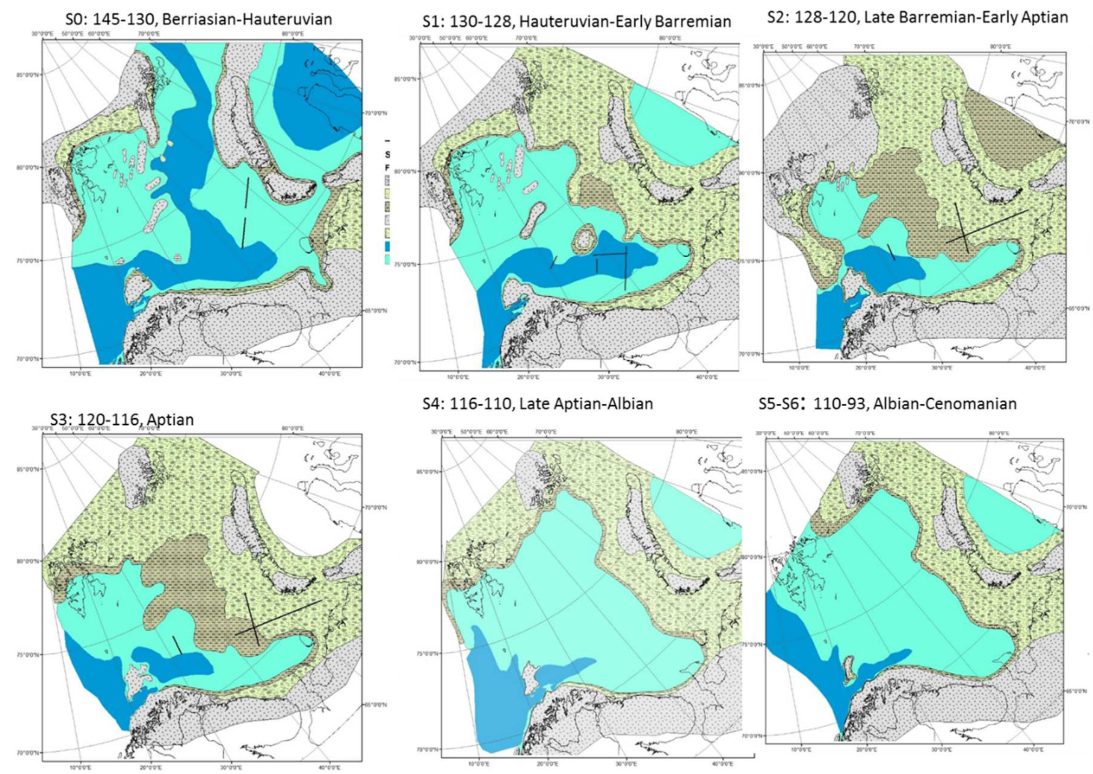
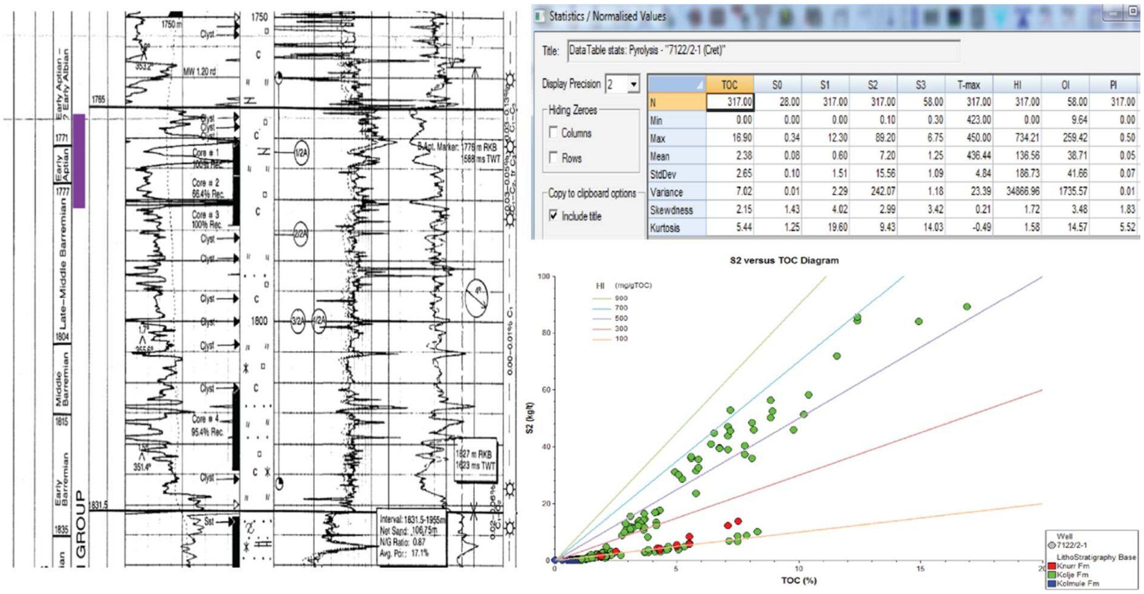


Figure 9. Paleogeographic maps from LoCrA for each sequence defined in the project

3.4 GEOCHEMICAL ANALYSIS

Few organic geochemical data or analyses have been published from the Hauterivian to Aptian successions in the Barents Sea (Leith et al. 1992). Ohm et al. (2008) refer to organic-rich marine mudstones (OMM) in the Valanginian to ?Barremian Knurr, Barremian to Aptian Kolje, and ?Aptian to Albian Kolmule formations. Unfortunately, all three units are poorly dated (Mørk et al., 1999); therefore, correlative sequences with OMM may have been overlooked or stratigraphically miscorrelated. Ongoing, new analysis and revision of the biostratigraphy coupled with sequence stratigraphy create the opportunity to improve mapping of Lower Cretaceous OMM in the Barents Sea. For example, the Kolje Formation in well 7122/2 has a 15-meter-thick unit (1767-1782 m) of probable Late Barremian-Early Aptian age with 1.5 to 17% TOC and HI values between ~90-700 mg/g TOC (Figure 10). Similarly, well 7321/9-1 in the Fingerdjupet basin shows the Barremian-Early Aptian source rock (Figure 11). The other wells in the Fingerdjupet subbasin (wells 7321/8.1 and 7321/7-1) do not show any indication of the presence of source rocks, most likely due to erosion of an Early Cretaceous unconformity or non-deposition, suggesting a complex structuration of the Lower Cretaceous basins and distribution of the source rocks (Figure 11) (Acharyya, 2016).



Statistics / Normalised Values

Title: DataTable stats: Pyrolysis - "7122/2-1 (Cret)"

	TOC	S0	S1	S2	S3	T-max	HI	OI	PI
N	317.00	28.00	317.00	317.00	58.00	317.00	317.00	58.00	317.00
Min	0.00	0.00	0.00	0.10	0.30	423.00	0.00	9.64	0.00
Max	16.90	0.34	12.30	89.20	6.75	450.00	734.21	259.42	0.50
Mean	2.38	0.08	0.60	7.20	1.25	436.44	136.56	38.71	0.05
StdDev	2.65	0.10	1.51	15.56	1.09	4.84	186.73	41.66	0.07
Variance	7.02	0.01	2.29	242.07	1.18	23.39	34866.96	1735.57	0.01
Skewdness	2.15	1.43	4.02	2.99	3.42	0.21	1.72	3.48	1.83
Kurtosis	5.44	1.25	19.60	9.43	14.03	-0.49	1.58	14.57	5.52

Figure 10. Data compiled from well 7122/2-1 Northeast Hammerfest Basin. Left: sedimentological log and wireline logs from the well. Note the lower velocity and higher gamma. Upper right: rock evaluation analysis from 1766 to 1782 m. Lower right: High TOC and HI values suggesting marine, potentially oil-prone source rocks.

Two OMM horizons in Svalbard have shown potential to be hydrocarbon source rocks which might have offshore counterparts: 1) Late Hauterivian/Early Barremian. Analysis from a 5-meter-thick, well-laminated mudstone gives TOC: 15.83 %, S1: 1.18 mg/g, S2: 31.79 kg HC/ ton rock, and HI = 200, and Tmax of 443^{o}C and PI = 0.04 suggesting a very prolific gas/oil-prone source rock; and 2) The Barremian-Early Aptian Helvetiafjellet Formation with coal, coal shale, and dark shale units in the flood plain facies and interdistributary facies association are not analyzed but are preliminarily suggested to be potential gas-prone source rocks.

Furthermore, the Early Aptian flooding *Odontochitina nuda* (II) zone, which is the basal part of the Carolinefjellet Formation and corresponds to the Aptian oceanic anoxic event (OAE1a) (Midtkandal et al., 2015; Vickers et al., 2016), has an interesting regional trend in Svalbard. In well DH5R, the wireline logs show high gamma and low velocity (Figure 12a). Analysis shows TOC around 2%, HI around 200, and Tmax of approximate 450°C (Figure 12b). The relatively high maturity may, however, have lowered the initial HI. The samples show relatively high concentrations of long chained n-alkanes. The Pr/Ph ratios are fairly high (>2) compared to very anoxic, marine-derived oils (Pr/Ph<1). A wet gas-condensate-prone source rock is suggested for the unit. This suggests that the analyzed samples were not deposited in an anoxic, marine setting but influenced by terrestrial "run-off" organic material and, hence, deposited in a more coastal setting which is consistent with the interpreted depositional environment.

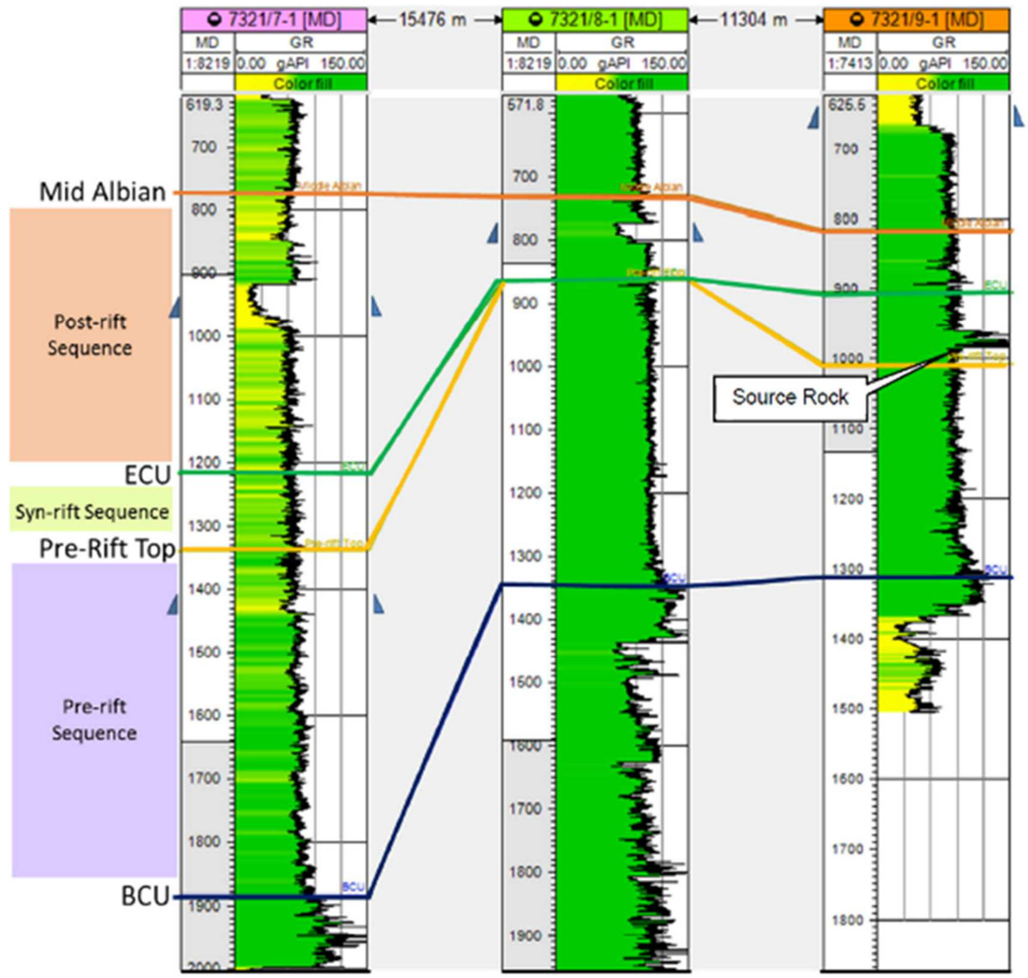
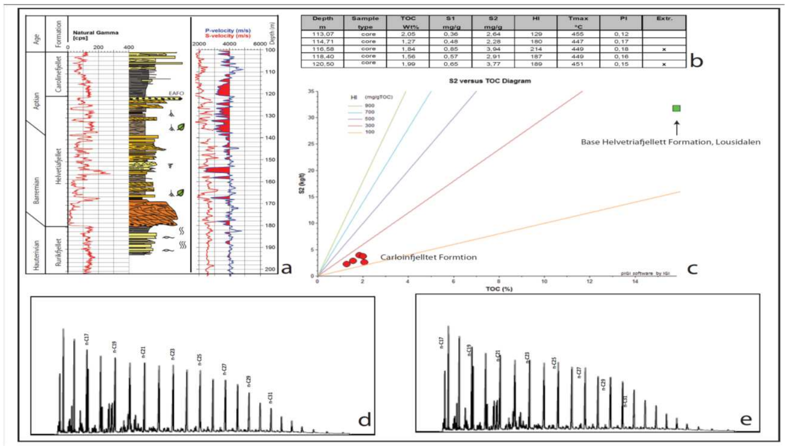


Figure 11. Well correlation in the Fingerdjupet basin showing the presence of Lower Cretaceous source rocks in well 7321/9-1 (Acharyya, 2016).

The early Aptian drowning is one of the most widespread flooding events in the geological record (Jenkyns, 1980) and occurs as an anoxic event in several basins. Together with the Upper Jurassic, the Aptian and Turonian are the two most important global source rocks (Klemme & Ulmishek, 1991). Is there a link of the Early Aptian potential source rock seen in Svalbard and the OMM in the southwestern Barents Sea? Due to its proximal position of the prograding Lower Cretaceous clastic wedge, a more oil-prone source rock might be expected in distal positions (i.e. southwards). Proving the source rock potential of the "mid" Cretaceous sections shown here might in some areas have exploration consequences where the Hekkingen Formation currently is/was more gas-prone.



Depth m	Sample type	TOC Wt%	S1 mg/g	S2 mg/g	HI	Tmax °C	PI	Extr.
113,07	core	2,05	0,36	2,64	129	455	0,12	
114,71	core	1,27	0,48	2,28	180	447	0,17	
116,58	core	1,84	0,85	3,94	214	449	0,18	x
118,40	core	1,56	0,57	2,91	187	449	0,16	
120,50	core	1,99	0,65	3,77	189	451	0,15	x

Figure 12. Logs and geochemical data for from well DH5R and a sample from Louisdalen, Adventfjorden. a); Sedimentological log and wireline logs from Well DH5R. EAFO = Early Aptian Flooding OMM. Lower velocity horizons (red colored) and higher gamma readings might be candidates for organic-rich units, b); rock evaluation analysis of EAFO at 116.5 m, c); HI values in the range of 200-250 suggest influence of terrestrial-derived organic matter and, hence, deposition in a marine but proximal land setting. d); gas chromatogram which shows relatively high concentrations of long-chained n-alkanes. The Pr/Ph ratios are fairly high (>2) compared to very anoxic, marine-derived oils (Pr/Ph<1).

3.5 BASIN MODELLING FOR MATURITY INVESTIGATION OF THE UPPER JURASSIC AND LOWER CRETACEOUS DEPOSITS

The study is planned to be carried out in 2018 upon time, availability, and budget. Few attempts have been made to integrate data from the Norwegian and Russian sectors in order to determine the relationship, if any, of source rock distribution, maturation, and preservation of source rocks and hydrocarbons. The main goal of this task is to improve our current knowledge of source rock preservation, maturation, and migration of the greater Barents Sea region (Norwegian and Russian sectors) with a focus on Late Jurassic and Lower Cretaceous. Using the geochemical information database and regional mapping, transects will be built and modeled in order to evaluate the maturity trends and critical time for preservation. The basin models will include all previous understanding of uplift, erosion, and flexural effects at different stages as well as how each event may have influenced source rock maturation and preservation of hydrocarbons (Figures 13, 14, and 15).

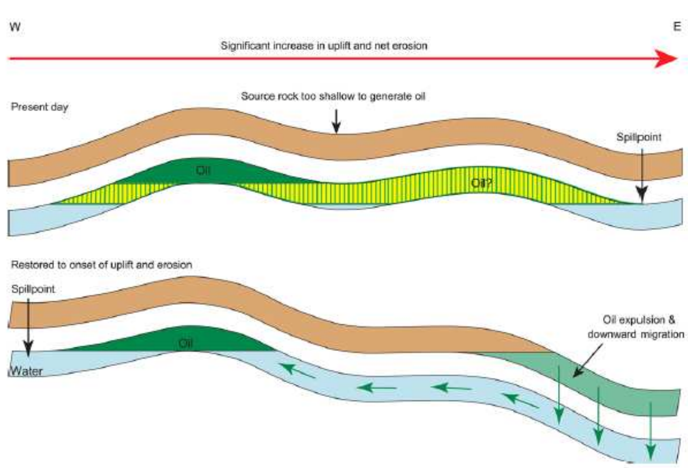


Figure 13. Diagram to illustrate the effect of uplift on structures and the consequences for generation, migration, and trapping of hydrocarbons (Henriksen et al., 2011).

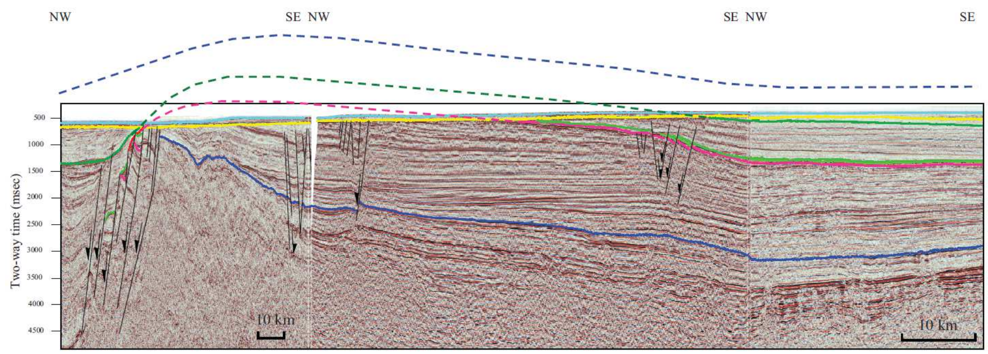


Figure 14. Interpreted seismic line in the Loppa High area, western Barents Sea, showing estimates of Cenozoic and Mesozoic uplift and erosion on a time section. Blue dashed line=Top Paleogene; Green= Late Cretaceous; and Pink=Triassic-Early Cretaceous (Modified from Nazarova, 2009).

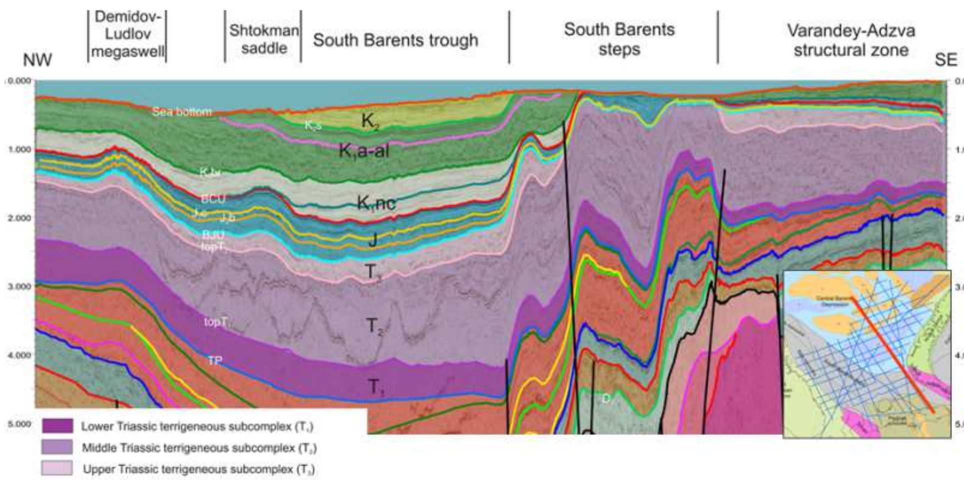


Figure 15. Interpreted seismic line in the eastern Barents Sea showing the severity of uplift and erosion during the Late Mesozoic-Cenozoic (Stoupakova et al., 2011). From this seismic line, estimates of timing and magnitudes of uplift and erosion can be performed.

Several R&D projects led by the University of Oslo and the University Centre in Svalbard on the Middle to Lower Cretaceous organic rich shales (i.e. Agardhfjellet and Hekkingen formations) and on maturation trends have been published recently and will be published in the near future (Abay et al., 2014; Koevets et al., 2016; Lerch et al., 2016; Marshall et al., 2015). These data will be used as input for a renewed approach to the basin modelling in the greater Barents Sea region. In addition, several ongoing studies on uplift will be released in 2017.

3.6 ON- AND OFF- SHORE CORRELATIONS

Another objective of JuLoCrA will be, similar to LoCrA, to continue the attempt to correlate the Jurassic and Lower Cretaceous Barents Sea with other Arctic basins with particular focus on northeast Greenland and the Sverdrup basin (Figure 16). A well-established correlation for the Lower Cretaceous for the eastern and western Barents Sea has been successfully built in LoCrA with a common sequence stratigraphic framework. We aim to expand our efforts to other regions in order to have a better understanding of the paleogeography, major seaways, tectonics, and regional source of sedimentation. We will continue our cooperation with GEUS and possibly with Canadian research institutes.

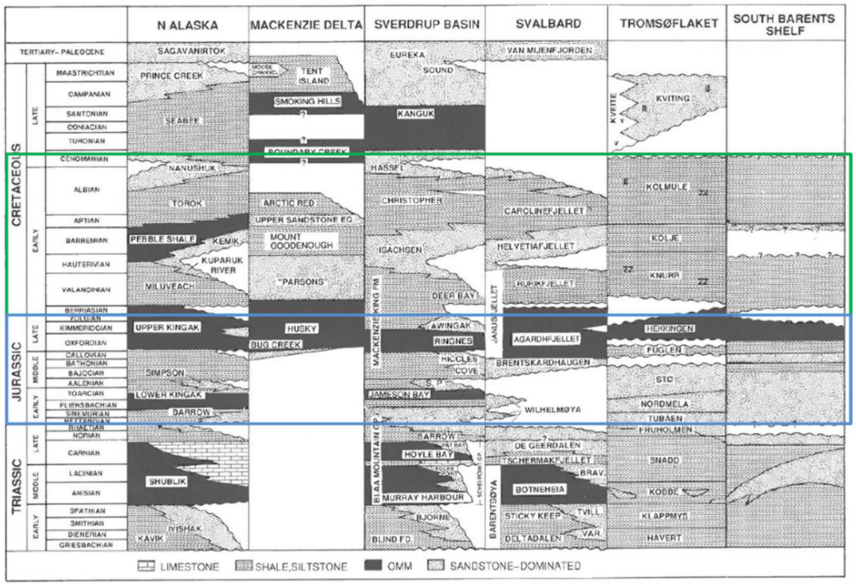


Figure 46. Simplified stratigraphic column showing the relation between the different Arctic basins from North Alaska to the Barents Sea (from Leith et al., 1990).

4 DELIVERABLES

Similar to LoCrA, the focus areas and deliverables for each year of the project will be discussed during each annual meeting with sponsors and will be subject to changes depending on the availability of new data and students. Deliverables provided will include: (1) an integrated and user-friendly GIS database which is updated during the project and accessible through our secure website; (2) paleogeographic models built in GIS and updated as new data is accessed; (3) a series of structural and stratigraphic maps of key seismic surfaces in the region based on our own sequence stratigraphic framework; (4) our original interpretations of seismic data and well data; (5) modeling results using the most complete compilations of available data; (6) all student and researcher oral and poster presentations from national and international meetings; and (7) all student and researcher publications.

Our work is largely driven by data available via DISKOS, Moscow State University, and onshore fieldwork. In addition, proprietary data via service companies or sponsors may be accessible but in general limited to the intellectual property of the work.

5 PROJECT MANAGEMENT OF JULOCRA

Similar to LoCrA, this project will be a scientific and educational collaboration between research groups at GEUS and Lomonosov Moscow State University led by the University of Stavanger (co-PI: Alejandro Escalona) and the University Centre in Svalbard (co-PI: Snorre Olaussen). The funds of the project will be used mostly to support young Masters of Sciences students and post-doctoral researchers. Given the scope and length of the project, and that it is a continuation of the LoCrA project, we envision that most of the funds will be used for post-doctoral researchers who will lead the project and co-supervise masters students.

6 COST FOR JULOCRA.

The cost per sponsor for the JuLoCrA project is NOK 350.000 per year with a two year financial commitment for a total of NOK 700.000. We aim for a minimum of 10 sponsors and estimate a total budget of NOK 7M for the two-year period. However, similar to LoCrA, upon total amount of sponsors, the original budget and activities will be adapted. A total of 2 post-doctoral researchers are expected and several student assistants and MSc students. Extra funds will be used to expand activities. The starting date is desired in January-February 2017, but it will depend upon discussion with all sponsors interested in the project.

Budget proposal for JuLoCrA 2017-2018

(in million NOK)

	2017	2018	
Post-doc UiS	1,05	1,05	
Post-doc UNIS	1,05	1,05	
Master students MSU	0,25	0,25	
Dating GEUS	0,25	0,25	
Masters students UiS	0,2	0,2	
Masters students UNIS	0,2	0,2	
Field work	0,2	0,2	
Equipment and analysis	0,1	0,1	
Travel costs	0,2	0,2	
Total MNOK	3,5	3,5	7,0

7 REFERENCES

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Klemme, D. & Ulmishek, G.F Effective Petroleum Source Rocks of the World: Stratigraphic Distribution and Controlling Depositional Factors 1991 AAPG Bull., 75, 1809-1851.

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Thierry, J., Rusciadelli, G., Amedro F., de Graciansky, P-C. and Magniez-Jannin, F., 1998. The North Atlantic Cycle: An Overview of 2nd-Order Transgressive/Regressive Facies Cycles in the Lower Cretaceous of Western Europe Mesozoic and Cenozoic Sequence Stratigraphy of European Basins, SEPM Special Publication No. 60 p 396-409.

Worsley, D. 2008. The post-Caledonian development of Svalbard and the western Barents Sea. Polar Research, 27, 298–317.

8 APPENDIX I: OVERVIEW OF LOCRA PARTICIPATING STUDENT AND POST-GRADUATE RESEARCHERS

	YEAR OF COMPLETION					
	2014	2015	2016	2017 (EXPECTED)	2018 (EXPECTED)	TOTAL SUPPORTED
POST-DOC		1	2			3
PHD (FULL SUPPORT)				3	5	8
PHD (PARTIAL SUPPORT)				2		2
MSC	4	2	5	1	2	14

8.1 POST-DOCTORAL RESEARCHERS

- Katarzyna Kamila Sliwinska, Grønland and Danmark Geologiske Undersøgelse, 2014-2017: Biostratigraphy
- Naomi Elizabeth Thompson, University of Stavanger, 2015-2016: Provenance, Drainage pattern
- Sten-Andreas Grundvåg, University Centre of Svalbard, 2014-2015 (now associate professor at University in Tromsø): Facies, sequence stratigraphy

8.2 PHD STUDENTS

- Laura Borromeo, University of Stavanger, 2015-2017: Petrology/petrophysics
- Dora Luz Marin Restrepo, University of Stavanger, 2015-2017: Seismic studies mapping regional
- Bereke Kairanov, University of Stavanger, 2016-2018: Tectonic seismic studies and regional mapping.
- Mads Engholm Jelby, University of Copenhagen and University Centre in Svalbard, 2016-2018: Facies, sequence stratigraphy: Genetic link between the lowermost Cretaceous strata in Svalbard, NE Greenland and the Barents Sea.
- Hanna Rosa Hjalmarsdottir, University Centre in Svalbard and University of Oslo, 2016-2018: Biostratigraphy: Micropalaeontology and sequence stratigraphy of the Lower Cretaceous in Svalbard and SW-Barents Sea

- Christopher Sæbø Serck, University of Oslo, 2016-2018. Tectonic, structural: Latest Jurassic to Early Cretaceous basin configuration(s) in the Fingerdjupet Subbasin area from detailed 3D mapping.
- Alina Kayukova, Moscow State University, 2015-2017: Seismic studies mapping regional.

8.3 Associated PhD students, support from LoCrA

- Maayke Jacqueline Koevoets, University of Oslo and University Centre in Svalbard: Biostratigraphy: Invertebrate paleontology, stratigraphy and environments of the High Boreal (Arctic) Upper Jurassic.
- Anna van Yperen, University of Oslo and University Centre in Svalbard: Facies, sequence stratigraphy: Sedimentary facies transitions – shale-out distances and characterization of reservoir properties in low gradient ramp settings. A field analogue study for the Lower Cretaceous strata in the Barents Sea.

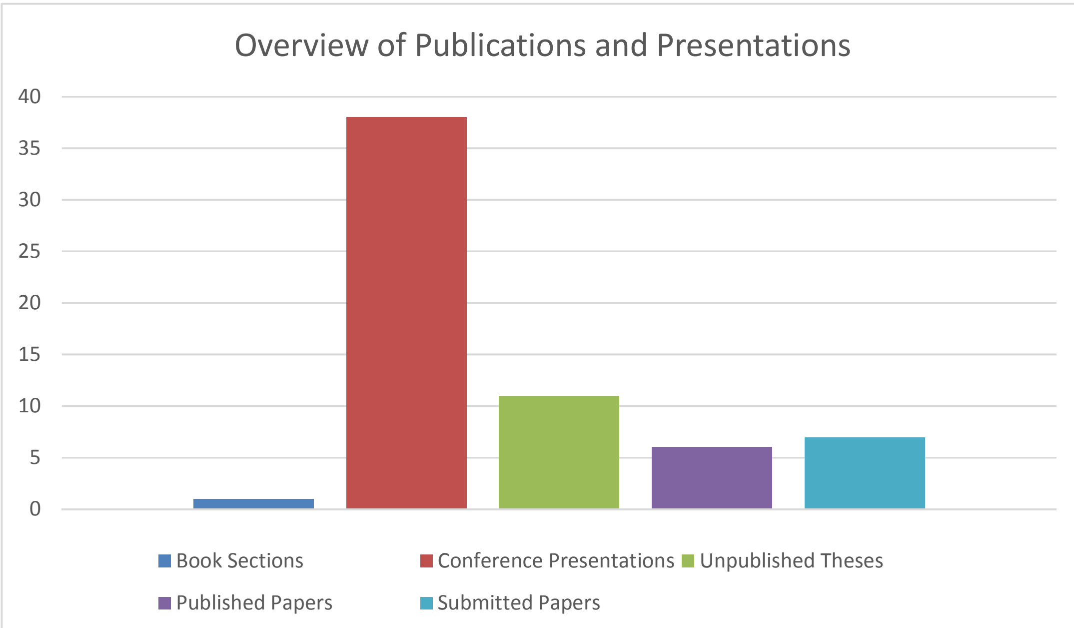
8.4 Masters students, Graduated:

- Aadland, T., 2014. A sedimentological, stratigraphical and petrographical analysis of the Dalkjegla Member, Carolinefjellet Formation, Spitsbergen, Svalbard Univ. Bergen/UNIS
- Acharyya, B., 2016. Lower Cretaceous structural evolution of the Fingerdjupet Sub-basin, SW Barents Sea, Norway. MSc thesis, University of Stavanger, Stavanger, Norway, 63pp
- Andersen, F., 2016. A Sedimentary Facies Analysis of the Lower Cretaceous Strata. At Forkastningsfjellet, Spitsbergen, Svalbard. MSc thesis, University in Oslo, Oslo, Norway,110pp
- Fjeld, T., 2014. Seismic Characterization of Lower Cretaceous clastic wedges in the Tromsø Basin: MSc thesis, University of Stavanger, Stavanger, 71 p.
- Hinna, C., 2016. Seismic Characterization of Lower Cretaceous Clinoform Packages in the Fingerdjupet Sub-basin, Southwestern Barents Sea. MSc thesis, University of Stavanger, Stavanger, Norway,
- Iqbal, J., 2016. Reservoir characterization of the Lower Cretaceous clastic wedges in the southwestern Barents Sea using seismic analysis and rock physics diagnostic MSc thesis, University of Stavanger, Stavanger, Norway,
- Jelby, M., 2015. Sedimentology and sequence stratigraphy of the Lower Cretaceous Rurikfjellet Formation, central Spitsbergen. Univ. Copenhagen/UNIS.
- Li, Z., 2014. Mesozoic and Cenozoic Evolution of the Harstad Basin from 2D Seismic Data: MSc thesis, University of Stavanger, Stavanger, 68 p.
- Sandvik, S., 2014. Description and Comparison of Lower Cretaceous deposits from Svalbard and the southern Loppa High.
- Rodriguez Gomez, I., 2015. Petrophysical characterization of the Lower Cretaceous clastic wedges in the southwestern Barents Sea: MSc thesis, University of Stavanger, Stavanger, Norway, 117 p.
- Østebø, H., 2016. 2D Flexural Deformation of the Barents Sea MSc thesis, University of Stavanger, Stavanger, Norway.

8.5 Current master students:

- Arlebrand, A. Comparison of Lower Cretaceous reservoir rocks in the southern margin of the Loppa High (Salina, Juksa and Skalle). University of Stavanger. To be finish in June 2017

9 Appendix II: Overview of Publications and Presentations



9.1 Book sections

Grundvåg, S., 2015, Historical geology: Cretaceous, *in* W. K. Dallmann, ed., Geoscience Atlas of Svalbard: Tromsø, Norwegian Polar Institute, p. 118-121.

9.2 Conference presentations

Acharyya, B., Escalona, A., Bryn, B.K.L. and S.S. Haaland, 2016, Lower Cretaceous Evolution of the Fingerdjupet Sub-basin. I: 78th EAGE Conference & Exhibition 2016 Student Programme. European Association of Geoscientists and Engineers 2016 ISBN 2-7637-6912-8.

Escalona, A., 2015, Lower Cretaceous clastic wedges in the Barents Sea- A new exploration play, 77th EAGE Conference and Exhibition, Madrid, EAGE.

Fjeld, T. L., and A. Escalona, 2014, Seismic characterization of Lower Cretaceous clastic wedges in the Tromsø basin, EAGE, St. Petersburg, Russia.

Fjeld, T. L., and A. Escalona, 2014, Seismic characterization of Lower Cretaceous clastic wedges in the Tromsø basin, NGF Arctic Days, Tromsø, Norway.

Grundvåg, S., I. Midtkandal, S. Olaussen, J. Hurum, and H. A. Nakrem, 2012, A review of Lower Cretaceous clastic wedges in Svalbard: a key to the prognosis of prolific sandstone units in the Barents Sea?, Norwegian Geological Society Winter Conference, Norwegian Geological Society.

Grundvåg, S., and S. Olaussen, 2013, The onshore-offshore link of Lower Cretaceous clastic wedges in the Barents Sea and Svalbard: a tool for risk mitigation of plays, AAPG 3P Arctic Conference, Stavanger, Norway, AAPG.

Grundvåg, S., S. Olaussen, M. E. Jelby, S. Elvelund, and T. Aadland, 2014, An integrated approach for improving the understanding of Lower Cretaceous clastic wedges in the Barents Sea: new observations from outcrop and subsurface studies in Svalbard, NGF Arctic Days, Tromsø, Norway.

Grundvåg, S., S. Olaussen, M. E. Jelby, D. Marin, A. Escalona, K. Sliwinska, and H. Nøhr-Hansen, 2015, The architecture of Lower Cretaceous clastic wedges in Svalbard and the northern Barents Sea: the influence of sea-level change in a low-angle ramp setting, 31st IAS Meeting of Sedimentology, Krakow, Poland, IAS.

Grundvåg, S., S. Olaussen, I. Midtkandal, and K. Sliwinska, 2015, The architecture of a regressive wedge in an overall transgressive shelf sequence: the Schönrockjellet member of the Carolinefjellet Formation, southeastern Spitsbergen, NGF Winter Conference, Stavanger, Norway, NGF.

Grundvåg, S.-A., D. Marin, S. Olaussen, M. E. Jelby, A. Escalona, K. Sliwinska, and H. Nøhr-Hansen, 2015, Towards a refined depositional model for the Lower Cretaceous in Svalbard and the northern Barents Shelf: implications for onshore-offshore correlations, 3P Arctic, Stavanger, Norway, AAPG.

Henstra, G., S.-A. Grundvåg, E. P. Johannessen, J. Korstgård, T. Kristensen, I. Midtkandal, J. P. Nystuen, R. Ravnås, A. Rotevatn, F. Surlyk, T. Sæther, and J. Windelstad, 2015, Reservoir architecture of deep marine rift climax deposits: an outcrop study from East Greenland: AAPG Annual Conference. Denver, CO, USA, 31 May - 3 June 2015.

Hinna, C., Escalona, A., Bryn, B.K.L. and S. S., 2016, Seismic Characterization of Lower Cretaceous Clinoform Packages in the Fingerdjupet Subbasin, Southwestern Barents Sea. I: 78th EAGE Conference & Exhibition 2016 Student Programme. European Association of Geoscientists and Engineers 2016 ISBN 2-7637-6912-8.

Hurum, J., P. Druckenmiller, Ø. Hammer, H. A. Nakrem, and S. Olaussen, 2015, New dinosaur tracks at Kvalvågen, Svalbard, Geological Society of Norway Winter Conference, Stavanger, Norway, Geological Society of Norway, p. 44-45.

Iqbal, J., Escalona, A., 2016, Characterization of Lower Cretaceous Clastic Wedges in the Southwestern Barents Sea Using Seismic Attributes. I: 78th EAGE Conference & Exhibition 2016 Student Programme. European Association of Geoscientists and Engineers.

Iqbal, J., A. Escalona, and B. Kairanov, 2016, Reservoir characterization of Lower Cretaceous clastic wedges in the southwestern Barents Sea using seismic attributes and rock physics diagnostics: NPF Arctic Exploration. Tromsø, 31 May to 2 June.

Jelby, M. E., S.-A. Grundvåg, S. Olaussen, and L. Stemmerik, 2015, Storm deposits in the High Arctic (Lower Cretaceous Rurikfjellet Formation, central Spitsbergen): sequence stratigraphic and hydrodynamic significance, 3P Arctic, Stavanger, Norway, AAPG.

Jelby, M. E., S. Olaussen, L. Stemmerik, and S. Grundvåg, 2014, Sedimentology and sequence stratigraphy of the Lower Cretaceous Rurikfjellet Formation, Svalbard: preliminary results, Geological Society of Denmark Annual Meeting, Copenhagen, Denmark, Geological Society of Denmark.

Kairanov, B., A. Escalona, A. Kayukova, and D. Marin, 2016, Overview and timing of main structural elements in the North Central Barents Sea and impact on the Lower Cretaceous deposition: EAGE. Saint Petersburg, Russia, 11-14 April.

Kairanov, B., D. Marin, and A. Escalona, 2015, Structural controls in progradation direction of Lower Cretaceous clinoforms in the Barents Sea, 3P Arctic, Stavanger, Norway, AAPG.

Kiryukhina, T. A., A. Stoupakova, G. Ulyanov, N. Kiryukhina, D. Norina, and A. Suslova, 2011, Petroleum Systems of the Russian Western Arctic Basins: Arctic Technology Conference. Houston, TX, USA, 7-9 February 2011.

Kristensen, T. B., A. Rotevatn, G. A. Henstra, I. Midtkandal, and S.-A. Grundvåg, 2015, Geometry and Architecture of Syn-Rift Border Faults: Implications for the Definition and Integrity of Structural Traps: AAPG Annual Conference. Denver, CO, USA,

Lawver, L., L. Gahagan, and I. Norton, 2013, Impact of a fixed Siberian Traps mantle plume on the tectonics of the Arctic, AAPG 3P Arctic Conference, Stavanger, Norway, AAPG.

Li, Z., and A. Escalona, 2014, Mesozoic and Cenozoic Evolution of the Harstad Basin from 2D Seismic Data, NGF Arctic Days, Tromsø, Norway.

Marin, D., and A. Escalona, 2014, Architecture and Distribution Analysis of the Lower Cretaceous clinoforms in the Western Barents Sea, EAGE, St. Petersburg, Russia.

Marin, D., and A. Escalona, 2015, Architecture of Lower Cretaceous clastic wedges in the SW Barents Sea and hydrocarbon potential, 3P Arctic, Stavanger, Norway, AAPG.

Marin, D., and A. Escalona, 2015, Characterization of Lower Cretaceous seismic clinoforms in the SW Barents for sandstone prediction, NGF Winter Conference, Stavanger, Norway, NGF.

Marin, D., Escalona, A., 2016, Early Cretaceous Basin Margin Development in the SW Barents Sea, Norway: 78th EAGE Conference & Exhibition 2016 Student Programme. European Association of Geoscientists and Engineers.

Marin, D., A. Escalona, A. Kayukova, A. Stoupakova, and A. Suslova, 2014, Characterization of Lower Cretaceous seismic clinoforms in the SW Barents Sea: Implication to sand prone bodies prediction, NGF Arctic Days, Tromsø, Norway.

Matthews, N., U. Zimmermann, E. Mostafa, C. Ruud, L. Støle, T. J. Lapen, and R. Andreasen, 2015, Provenance data from Mesozoic rock successions in the Hammerfest basin, NGF Winter Conference, Stavanger, Norway, NGF.

Mathews, N., Zimmermann, U., Marin, D., Escalona, A., Sliwinska, K., Støle, L., Ruud, C. and Lapen T., 2016, Zircon geochronology of Lower Cretaceous sediments in the SW Barents Sea: Insights into sediment provenance. NGF Arctic Days, Tromsø, Norway.

Mostafa, E., C. Ruud, L. Støle, N. Matthews, U. Zimmermann, S. Andò, and L. Borromeo, 2015, High resolution heavy mineral studies of Mesozoic rocks of the Hammerfest basin, NGF Winter Conference, Stavanger, Norway, NGF.

Reppen, I., M. Nordberg, and A. Escalona, 2014, Understanding geological processes for the non-presence of Lower Cretaceous strata in the northwestern Barents Sea, NGF Arctic Days, Tromsø, Norway.

Rodriguez Gomez, I., K. A. Lehne, and A. Escalona, 2015, Petrophysical characterization of Lower Cretaceous clastic wedges in the south-western Barents Sea, 3P Arctic, Stavanger, Norway, AAPG.

Śliwińska, K. K., D. Marin, M. E. Jelby, S.-A. Grundvåg, H. Nøhr-Hansen, A. Escalona, and S. Olaussen, 2016, Refining the age control of the Lower Cretaceous strata of Spitsbergen and the Barents Sea: NPF Arctic Exploration. Tromsø, 31 May to 2 June.

Sliwinska, K. K., H. Nøhr-Hansen, M. E. Jelby, S.-A. Grundvåg, and S. Olaussen, 2016, Dinocyst biostratigraphy of the Lower Cretaceous succession of central and southeastern Spitsbergen: EGU General Assembly. Vienna, Austria, 17 -22 April.

Stoupakova, A., 2013, Russian Western Arctic Basins and their Hydrocarbon Prospectivity, AAPG 3P Arctic Conference, Stavanger, Norway, AAPG.

Suslova, A., 2013, Sequence stratigraphy of Jurassic oil and gas reservoirs in the Barents Sea, AAPG 3P Arctic Conference, Stavanger, Norway, AAPG.

Østebø, H., Escalona, A. and N. Cardozo, 2016, 2D Flexural Modelling of the Barents Sea. I: 78th EAGE Conference & Exhibition 2016 Student Programme. European Association of Geoscientists and Engineers 2016 ISBN 2-7637-6912-8.

9.3 UNPUBLISHED THESES

Aadland, T., 2014, A sedimentological, stratigraphical and petrographical analysis of the Dalkjegla Member, Carolinefjellet Formation, Spitsbergen, Svalbard: MSc thesis, 167 p.

Acharyya, B., 2016, Lower Cretaceous structural evolution of the Fingerdjupet Sub-basin, SW Barents Sea, Norway: MSc thesis, University of Stavanger, Stavanger, Norway, 73 p.

Fjeld, T. L., 2014, Seismic Characterization of Lower Cretaceous clastic wedges in the Tromsø Basin: MSc thesis, University of Stavanger, Stavanger, 71 p.

Hinna, C., 2016, Seismic Characterization of Lower Cretaceous Clinoform Packages in the Fingerdjupet Sub-basin, Southwestern Barents Sea: MSc thesis, University of Stavanger, Stavanger, Norway, 101 p.

Iqbal, J., 2016, Reservoir characterization of the Lower Cretaceous clastic wedges in the southwestern Barents Sea using seismic analysis and rock physics diagnostic: MSc thesis, University of Stavanger, Stavanger, Norway, 106 p.

Jelby, M. E., 2015, Sedimentology and sequence stratigraphy of the Lower Cretaceous Rurikfjellet Formation, central Spitsbergen, University of Copenhagen, Copenhagen, Denmark.

Li, Z., 2014, Mesozoic and Cenozoic Evolution of the Harstad Basin from 2D Seismic Data: MSc thesis, University of Stavanger, Stavanger, 68 p.

Reppen, I., and M. Nordberg, 2014, Understanding Geological Processes for the Non-Presence of Lower Cretaceous Strata in the Southwestern Barents Sea: BSc thesis, University of Stavanger, Stavanger, 81 p.

Rodriguez Gomez, I., 2015, Petrophysical characterization of the Lower Cretaceous clastic wedges in the southwestern Barents Sea: MSc thesis, University of Stavanger, Stavanger, Norway, 117 p.

Sandvik, S., 2014, Description and Comparison of Lower Cretaceous deposits from Svalbard and the southern Loppa High: MSc thesis, 135 p.

Østebø, H., 2016, 2D Flexural Deformation of the Barents Sea: MSc thesis, University of Stavanger, Stavanger, Norway, 92 p.

9.4 In progress or Submitted papers for publication

Dora, M., Escalona, A., Olaussen, S. and K.K. Śliwińska Kasia K., in prep., Lateral and vertical variation of Lower Cretaceous seismic wedges in the Hammerfest Basin, southwestern Barents Sea: an interplay between rift events and renewed fault activity, Marine and Petroleum geology.

Grundvåg, S-A, Marin, D., Kairanov, B., Nøhr-Hansen, H., Śliwińska, K.K., Escalona, A. and S. Olaussen, submitted, The Lower Cretaceous succession of the western Barents Shelf: onshore and offshore correlations. Marine and Petroleum Geology

Grundvåg, S-A., Engholm Jelby, M., Śliwińska, K.K., Nøhr-Hansen, H., Nemec, W., Aadland, T., Elvelund Sandvik, S., Warchol, M. and S. Olaussen, in prep, Lower Cretaceous clastic wedges and dinoflagellate biostratigraphy as revealed from subsurface data and nearby outcrops in central Spitsbergen, Svalbard. Norwegian Journal of Geology

Hjalmarsdottir, H: R., Nakrem H. A. and J. Nagy, in prep. Foraminifera from Late Jurassic – Early Cretaceous hydrocarbon seep carbonates, central Spitsbergen, Svalbard. Journal of Micropalaeontology.

Kairanov, K., Escalona, A. and A. Kayukova, in prep., Lower Cretaceous tectonostratigraphic evolution of the northcentral Barents Sea. Marine and petroleum geology

Śliwińska, K. K., Nøhr-Hansen, H., Marin, D. and S. Olaussen, in prep., Dinoflagellate cysts biostratigraphy of the Volgian to Cenomanian strata in the southeastern Barents Sea, central Hammerfest Basin. Cretaceous Research

Sæbø Serck, C., Faleide, J. I., Braathen, A., Kjølhamar, B. and A. Escalon, submitted, Jurassic to Early Cretaceous basin configuration(s) in the Fingerdjupet Subbasin, SW Barents Sea. Marine and Petroleum Geology

9.5 Peer reviewed papers - international journals

Hurum, J., P. Druckenmiller, Ø. Hammer, H. A. Nakrem, and S. Olaussen, 2015, The theropod that wasn't - an ornithopod tracksite from the Helvetiafjellet Formation (Lower Cretaceous) of Boltodden, Svalbard, in B. P. Kear, J. Lindgren, J. H. Hurum, J. Milàn, and V. Vajda, eds., Mesozoic Biotas of Scandinavia and its Arctic Territories, v. Special Publications: London, *Geological Society London*, p. 434.

Henstra, G.A., Grundvåg, S.A., Johannessen, E.P., Kristensen, T.B., Midtkandal, I., Nystuen, J.P., Rotevatn, A., Surlyk, F., Sæther, T., Windelstad, J., 2016, Depositional processes and stratigraphic architecture within a coarse-grained rift-margin turbidite system: The Wollaston Forland Group, east Greenland. *Marine and Petroleum Geology* 76, 187-209.

Hurum, J.H., Roberts, A.J., Dyke, G.J., Grundvåg, S.-A., Nakrem, H.A., Midtkandal, I., Śliwińka, K.K., and Olaussen, S. 2016, Bird or maniraptoran dinosaur? A femur from the Albian strata of Spitsbergen. *Palaeontologia Polonica* 67, 137–147.

Grundvåg, S-A. & Olaussen, S. in press, Forced regressive deposits in the Lower Cretaceous at Kikutodden and Keilhaufjellet, southern Spitsbergen*. Polar research*.

Marin D., Escalona A., Śliwińska, K., Nøhr-Hansen, H. and Mordasova A. , accepted, Sequence stratigraphy and lateral variability of Lower Cretaceous clinoforms in the southwestern Barents Sea. *AAPG Bulletin.*

Midtkandal, I., H. H. Svensen, S. Planke, F. Corfua, S. Polteau, T. H. Torsvik, J. I. Faleide, S.-A. Grundvåg, H. Selnes, W. Kürschner, and S. Olaussen, in press, The Aptian (Early Cretaceous) oceanic anoxic event (OAE1a) in Svalbard, Barents Sea, and the absolute age of the Barremian-Aptian boundary: Palaeogeography, Palaeoclimatology, Palaeoecology.