

Final report for the Research Centre for Arctic Petroleum Research (ARCEX)

– grant number 228107

Research partners



Industry partners



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Foreword

by **Alfred Hanssen**
Professor and director ARCEX

The Research Centre for Arctic Petroleum Exploration (ARCEX) has come of age, and it has reached its end. It is therefore time to recollect our achievements and accomplishments. I will start with the conclusion: I am extremely proud of the large volume of high-quality research that we have been able to produce individually and as a collective.

Originally, ARCEX consisted of five workpackages. After the midway evaluation we merged two of the geology-oriented work packages, leading to the following more convenient structure:

WP1&2 Geology

(led by Sten-Andreas Grundvåg, UiT, and Kim Senger, UNIS)

WP3 Environmental risk management

(led by JoLynn Carroll, Akvaplan-niva and UiT)

WP4 Technology for eco-safe exploration in the Arctic

(led by Tor Arne Johansen, UiB and UNIS)

WP5 Education and outreach

(led by Jasmine Nahrgang and Jan Sverre Laberg, UiT)

The structure can be summarized by the following infogram:



Infogram showing the structure of ARCEX.

In this report, we will give an overall summary of the centre's activities over its entire eight-year period. We believe that the resulting report gives a very good insight into the activities and main results.



Alfred Hanssen

Foreword

by **Matthias Forwick**
Professor and Head of Dept. of Geosciences, UiT

ARCEX has played a significant role in the daily life of the Dept. of Geosciences at UiT The Arctic University of Norway from its inception in 2013 until its end in 2021. Serving as the host institution for ARCEX, we have benefitted resource-wise, and the centre has contributed significantly to the scientific activities at the department, as well as to the design of new education activities. The centre has recruited an impressive number of excellent PhD students and postdocs, and several of our senior scientists have played key roles in shaping and executing the scientific program of ARCEX. In addition, a large number of Master students have received their education through ARCEX.

I have observed with pleasure the role ARCEX has played on the national scene. The centre has matured to become an important instrument for research, education and national coordination in the field of petroleum research in the high north. The level of collaboration with industry has strengthened significantly, and new projects have been initiated through ARCEX. The generous funding from NFR and industry partners has made it possible to carry out collaborative field work and research cruises that would otherwise be difficult – and partly impossible – to perform.

For the Dept. of Geosciences at UiT, it has been very interesting and fruitful to be engaged in a centre with such a unique inter- and cross-disciplinary approach to the field. In addition to geoscientists, also marine biologists, ecotoxicologists, risk analysts, technologists and physicists have collaborated within ARCEX to materialize the large volume of research.

As the Head of the Dept. of Geosciences, I would personally like to thank everyone who has contributed to make ARCEX such a great success. It is my duty to manage the heritage of ARCEX in the best possible way, and to make sure that we utilize the knowledge and competence we have gained to improve our education and research for future generations.



Matthias Forwick

Summary

The main vision of ARCEX is to reduce risk connected to petroleum activities in the Arctic. To carry out the research, a consortium consisting of 9 academic partners, 6 user partners, and one partner from the authorities has been constructed. About 230 peer reviewed publications have been published so far, and some of the activities have received prestigious awards from scientific organizations and journals. The results from the centre are used in various ways by partners and society: (1) the geological research is used by our partners to increase the precision when assessing the geological setting and conditions. (2) the environmental risk assessment is used to suggest reasonable response scenario in case of an unwanted spill, and (3) the technological research is geared towards developing eco-friendly exploration and imaging techniques. ARCEX has been a geographically distributed centre, with high-quality researcher training taking place at all academic partners. There has been a high focus on educating master students, and we have documented a large number of graduates who have received their training through ARCEX. The centre structure has implied collaboration across disciplines and across geographical distances. We think the collective feeling of the centre researchers has a great impact on the ability to finish on time. ARCEX is definitely over now, but we already see that the heritage of ARCEX is to engage in cross-disciplinary research wherever possible.



Oppsummering

Hovedvisjonen til ARCEX er å redusere risiko knyttet til arktiske petroleumsaktiviteter. For å utføre forskningen har det blitt dannet et konsortium som består av 9 akademiske partnere, 6 brukerpartnere, og en partner fra myndighetssiden. Omlag 230 fagfellevurderte publikasjoner har blitt publisert så langt, og noen av aktivitetene har blitt tildelt prestisjetunge priser fra vitenskapelige organisasjoner og fagtidsskrifter. Resultatene fra senteret har blitt brukt på mange forskjellige måter av partnere og samfunnet forøvrig: (1) den geologiske forskningen blir brukt av våre partnere til å øke presisjonen ved studier av de geologiske forholdene, (2) miljørisikoanalyse brukes for å angi fornuftige respons-scenarier ved uønskede utslipp, og (3) den teknologiske forskningen er rettet mot å utvikle øko-vennlige lette- og avbildningsteknikker. ARCEX har vært et geografisk distribuert senter hvor høykvalitets forskerutdanning finner sted hos alle de akademiske partnerne. Vi har hatt et stort fokus på å utdanne mastergradskandidater, og vi har dokumentert et stort antall uteksaminerte som har fått sin utdanning og opplæring gjennom ARCEX. Senterets struktur har medført samarbeid på tvers av fagdisiplin og geografi. Vi mener at den kollektivistiske tilnærmingen i senteret har hatt stor innvirkning for at folk skal gjøre seg ferdig i tide. ARCEX er definitivt over nå, men vi ser allerede at arven etter ARCEX er at man engasjerer seg i tverrfaglig forskning der det er mulig.

Vision and goals

The Research Centre for Arctic Petroleum Exploration (ARCEX) addresses key cross- and multi-disciplinary challenges in petroleum research and development in the Arctic. The overarching research goal for ARCEX is to reduce risk. This can be further broken down for the three main pillars (geology, environment, technology) as follows: the geological research activity aims to reduce the risk for not finding petroleum, the environmental research activity aims to reduce the operational risk, and the technological research activity aims to reduce the risk for inaccurate and incorrect measurements and analysis. Thus, the research activities in the three research pillars are highly interwoven and interconnected, providing a collective, coordinated and coherent approach to solve the overarching research goal of ARCEX in a holistic manner.

In essence, the midway evaluation led the centre management to change the vision from an almost entirely *exploratory* focus, to one that had *risk reduction* as its vision. This allowed for new ways of collaboration and a more coherent approach to carry out the research in the centre.



Basic facts about the centre

Research Partners:

The composition of research partners has been stable throughout the lifespan of ARCEX. When NORCE was established in 2018, our original partners Norut and IRIS both continued as part of NORCE.

Universities:

UiT (host), UNIS, UiB, UiS, UiO, NTNU

Institute sector:

Akvaplan-niva, NGU, Norut/NORCE, IRIS/NORCE

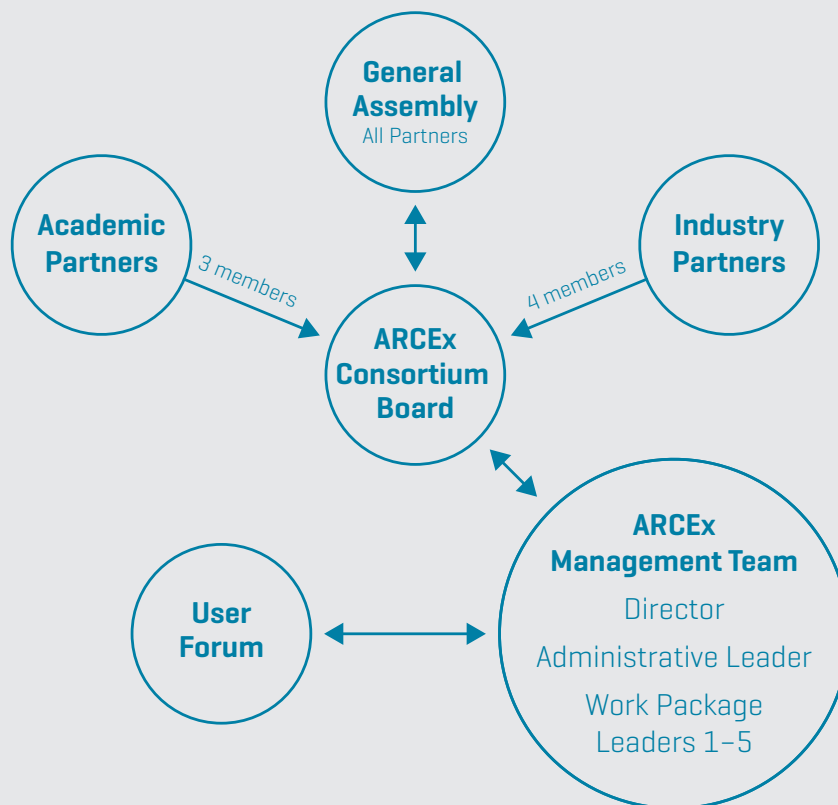
User Partners:

The composition of the group of user partners has been dynamic during the life span of ARCEX. Four of the companies in the consortium have remained stable user partners from the start. There have been several mergers and rebrandings among the user partners, and this is reflected by listing both the old and the new names in the dated list below:

Statoil/Equinor (2013 – 2021)
Det norske/AkerBP (2013 – 2021)
Lundin (2013 – 2021)
Eni Norge/Vår Energi (2013 – 2021)
OMV (2017 – 2021)
Wintershall DEA (2018 – 2021)
GDF Suez/Engie (2013 – 2018)
Tullow Oil (2013 – 2017)
DONG Energy/INEOS (2013 – 2017)
Shell Norge (2015 – 2017)
ConcoPhillips (2013 – 2015)

Public Partners:

While we have not had any formal public partners, the Norwegian Petroleum Directorate (NPD) has been a very active and important collaborator to ARCEX. Several of the master theses have received supervision and support from NPD, and several of the PhD projects have received co-supervision from central NPD employees.



The organization of ARCEX

Governance and organization

The ARCEX Consortium Board was the main decision-making body in ARCEX. The ARCEX General Assembly (GA) was composed of one representative from each of the partners. The GA was an arena for information exchange between the academic and industry partners and for election of the board.

The day-to-day management was handled by the Management Team - a multi-disciplinary group of experts from several of the participating academic institutions. The responsibility was to ensure an efficient day-to-day coordination and supervision of the project with respect to scientific and technical matters, as well as administrative and financial issues.

Management Team:

Centre Director: Prof. Alfred Hanssen, UiT

Deputy Director: Assoc. prof. Sten-Andreas Grundvåg, UiT

Work Package leaders:

WP1 & 2 – Assoc. prof. Sten-Andreas Grundvåg, UiT
, Assoc. prof. Kim Senger, UNIS

WP3 – Adj. prof. JoLynn Carroll, Akvaplan-niva

WP4 – Prof. Tor Arne Johansen, UiB

WP5 – Prof. Jan Sverre Laberg & Prof. Jasmine Nahrang, UiT

The User Forum was an arena for technical interaction and discussions between the academic and industry partners, and was important to make sure that the activities and results were relevant for the industry partners as well as for the scientific community.

The organization of ARCEX

Board

The ARCEX board has consisted of seven persons. The majority (four persons) have represented the industry partners, and the minority (three persons) have represented the academic partners. UiT has had the permanent chair of the board, with the Dean of the Faculty of Science and Technology permanently in this role. To ensure continuity, it was informally decided that Akvaplan-niva and Statoil/Equinor should maintain a continuous place in the board. All the other positions rotated among the consortium members, ensuring in particular that all the industry partners could serve in the board at least once in the lifetime of the centre.

Originally, the board included two observers, one from the Research Council of Norway, and one from the Norwegian Petroleum Directorate. After the midway evaluation, the host institute (Dept. of geosciences, UiT) also got a permanent observer in the board, with the Head of Department entering as observer.

The last ARCEX board starting in 2020 had the following composition:

Arne O. Smalås, UiT (Chair)
Salve Dahle, Akvaplan-niva
Martin Landrø, NTNU
Finn Roar Aamodt/Knut Harald Nygård, Equinor
Terje Solheim, AkerBP ASA
Balasz Badics, Wintershall DEA AS
Heidi Rydningen, OMV
Erik Bjørnbom, Vår Energi AS (alternate)
Geir Birger Larssen, Lundin (alternate)
Ingrid Anne Munz, The Research Council of Norway (observer)
Torgeir Stordal, The Norwegian Petroleum Directorate (observer)
Matthias Forwick, Dept. of Geosciences, UiT (observer)

The key persons in the centre administration and work package managers are as follows:



Prof. Alfred Hanssen, UiT, director



Ellen Ingeborg Hætta, UiT, administrative leader (now at UiB)



Assoc. Prof. Sten-Andreas Grundvåg, UiT, deputy director and co-leader of WP1 & 2



Assoc. Prof. Kim Senger, UNIS, co-leader of WP1 & 2



Prof. JoLynn Carroll, Akvaplan-niva and UiT, leader of WP3



Prof. Tor Arne Johansen, UiB and UNIS, leader of WP4



Prof. Jasmine Nahrgang, UiT, co-leader of WP5



Prof. Jan Sverre Laberg, UiT, co-leader of WP5

Cooperation within the centre

Several measures were taken to enhance cohesiveness at the centre. We arranged a very useful cross-disciplinary annual workshop, we arranged regular management meetings, the centre management visited all industry partners annually, and we arranged an Early Career Forum gathering at least once per year.

To encourage active user participation in projects, we arranged a number of focused workshops on specialized topics where we had substantial industry attendance. In addition, all our PhD students were assigned co-supervisors from user partners to ensure direct involvement and user participation in projects. As a result, we had a very high percentage of publications with academic and industry co-authorship.

Financing through the life of the centre

Summary sheet for the main categories of partners (NOK 1000)

Contributor	Cash	In-kind	Total
Host	-	38 678	38 678
Research partners	-	38 992	38 992
Companies	70 655	-	70 655
Public partners	9 800	-	9 801
Research Council of Norway	75 200	-	75 200
Sum	155 656	77 670	233 326

Distribution of resources (NOK 1000)

Type of activity	NOK 1000
Research projects	
WP 1 & 2	90 871
WP3	53 142
WP4	55 737
Common centre activities	
WP5 activities	12 463
Management operating costs	4 369
Administration	
Salary costs for centre management and administrative staff	16 744
Total	233 326

Results - Key figures

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Total
Scientific publications [peer reviewed]	0	2	7	24	26	45	47	40	38	5	234
Dissemination measures for users		3	106	70	156	63	106	50	31		585
Dissemination measures for the general public		1	8	33	4	13	7	5	7		78
PhD degrees completed - ARCEX funded candidates						4	1	2	2	1	10
Master degrees		8	18	14	9	21	9	9			88

Note that ARCEX has been mainly devoted to basic research and knowledge building, so we do not report or register any patents or new products as a result of the centre.



Research

Original research plan and development of research plan

The original project proposal contained a description of the centre's research activities and how they should be organized. When the present director entered the centre after it had been running for about 1.5 years, we saw a clear need for revision of the project description. It was however not very easy to change the priorities due to a very rigid layout and because all the project resources had been allocated all the way to the project end. After a while, we however found ways to retract unspent allocations at the end of each year, and thereby make room for new priorities.

The midway evaluation gave us another possibility to rearrange and revise our priorities. E.g., we merged two work packages after the midway evaluation, thus reducing the number of work packages from five to four. This simplified the management of the centre substantially. Furthermore, we reallocated funds to establish a dedicated task force to study many different aspects of shallow reservoirs. This received strong support from the board, and we made it possible to employ four early career scientists to undertake this task.

The midway evaluation pointed to the fact that we had a severe gender imbalance in the first phase of the centre. To mitigate this imbalance, we took extra care to announce all vacant positions in such a way that they would become attractive for both genders. This extra focus led to a radical increase in successful female candidates in all work packages, bringing the percentage of female early career scientists up to almost 40%.

Research achievements

The geological research has mainly been carried out in WP1&2. The main research topics have been tectonics and basin formation, uplift and subsidence, and erosion and sedimentation. In particular, one has carried out research to show when and how the sedimentary basins of this region form, and how this is linked to deeper structures. Also, the question of when and how deep the maximum burial was for the different organic rich intervals of the Barents Sea sedimentary succession is crucial to assess the potential for the existence of hydrocarbons.

The environmental risk assessment research has been organized in WP3. The main research topics have concentrated on marine ecosystems, the sensitivity of Arctic key species, and risk assessment and management. In particular, we have achieved deep insight about how Arctic key species (from plankton via fish to sea mammals) respond to anthropogenic activity, and we have developed a thorough understanding of the baseline ecology in the Barents Sea.

The technological research has been carried out in WP4. The main research has focused on developing new ways to ensure eco-safe exploration, how to perform seismic on ice and snow, and the development of optimal data analysis and numerical models for Arctic conditions. In particular, we have achieved results that gives the explorational constraints that maximize data quality and minimize environmental impact.

Highlights of scientific results

Project example: Underpressure in reservoirs

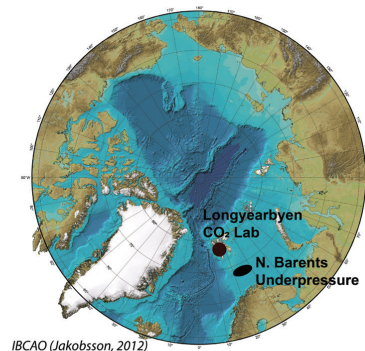
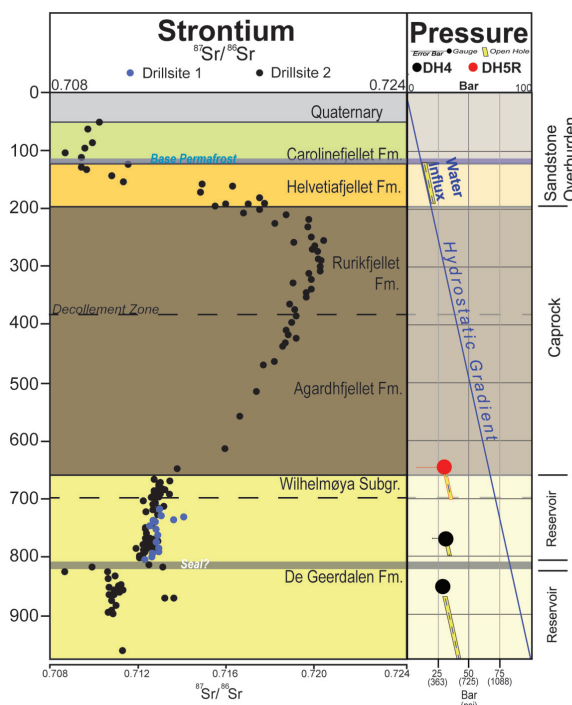
Dr. Tom Birchall from UNIS has shown that there is severe underpressure in many reservoirs both on shore Svalbard, and at several drill sites in the Barents Sea. This result is very significant, because the underpressure precludes the possibility to store liquid CO₂ in reservoirs with underpressure. The reason is that a rapid pressure drop will cause CO₂ in the liquid phase to experience an abrupt phase transition to the gas phase, and a rapid expansion of the carbon dioxide gas renders the system very unstable. Also, it is a safety risk to drill into underpressured reservoirs, as the drilling mud is at risk to be sucked out and destabilized. Tom has published these results in his PhD thesis, and in a series of journal papers.



Tom Birchall, UNIS

The ground beneath our feet is anything but dry; there is more water held in Earth's rocks than all the world's oceans combined. Fluids in the subsurface are always on the move and understanding this is important in the fields of hydrocarbon exploration, CO₂ storage and hydrogeology. Pore pressure is the pressure of fluids found within rock pore spaces and is the principal driver of subsurface fluid movement. Abnormally high pore pressures are a well-documented phenomenon throughout the world, whereas abnormally low pore pressures are rare and poorly understood. The northern Barents shelf provides a globally unique example of the latter, where extremely low pore pressures are observed offshore and onshore.

Tom Birchall's PhD research shows that all cases of abnormally low pressure have undergone geologically recent uplift and typically occur at relatively shallow depths. In the Barents shelf, including the High Arctic Svalbard archipelago, low pressures must have developed in the last few thousand years and are in a present state of disequilibrium. Indeed, this disequilibrium has probably driven geological recent fluid migration and is almost certainly still happening today.



Isotope data from boreholes in Adventdalen, Svalbard [left], and pressure data measured directly in two different boreholes [middle]. The straight line denotes the hydrostatic pressure, and the measured pressure is severely lower than the hydrostatic pressure. Map [right] showing locations where Dr. Birchall has documented underpressure.

Project example: Passive seismic

Dr. Helene Stemland, UiB, and Dr. Rowan Romeyn, UiT have carried out inventive research aimed at demonstrating the potential in using passive seismic for studies of near-surface geophysics. They have shown that spontaneous motion in the underground may act as a random impulsive source that allows for accurate imaging and characterization of the underground. In particular, by combining appropriate array signal processing methods with a good theoretical model of the medium, one may infer layer structure and the associated elastic properties, including wave propagation velocities. Contrary to intuition, their research demonstrates that passive imaging may yield sharper images of the underground than would be the case from active experiments. This is the case when the signal processing is augmented by good physical models. For geophysical imaging of the underground, this research points in a direction where passive (source-free) methods may replace ordinary active seismic measurements. Passive seismic imaging has the potential to become an important technology branch, and where the Norwegian seismic industry may find new export market possibilities.



Helene Stemland, UiB



Rowan Romeyn, UiT

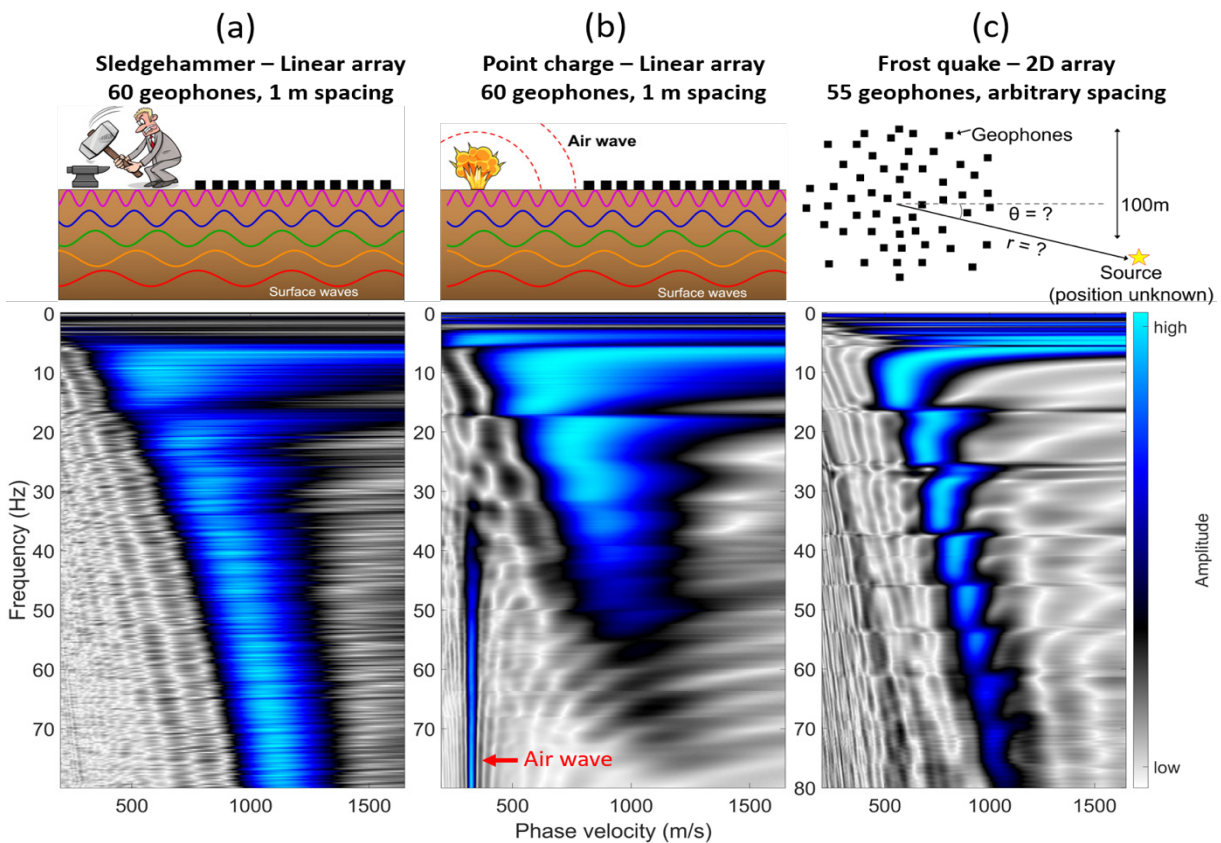


Illustration of the difference in dispersion images using a sledgehammer as a source [left], a detonating cord as a source [middle], and passive listening where random frost quakes act as natural source [right]. Note how sharp and well defined the rightmost image is.

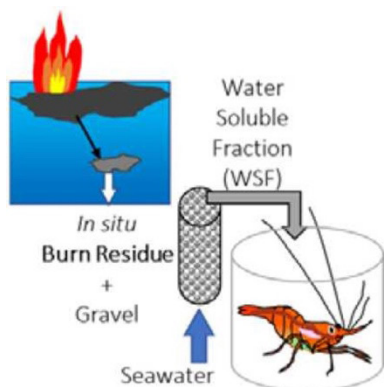
Dr. Stemland and Dr. Romeyn have demonstrated that these passive geophysical methods are well suited to monitor changes in the Earth's permafrost layer. Hence, it is possible that methods meant for petroleum research can actually be used to quantify the thawing of the permafrost due to global warming. This is a nice example of cross-fertilization where unexpected connections appear due to the generality of the methods.

Project example: Exposing Arctic key species to crude oil and residue

Dr. Frederike Keitel-Gröner, NORCE, has performed controlled experiments by exposing several key Arctic species to crude oil, and to the residue from in-situ burning of the same oil products. Her results show that the crude oil has far worse toxic effects on the shrimp than the residue. The main driver for damages to the shrimp appears to be the concentration of polyaromatic hydrocarbons (PHA) in the water. Dr. Keitel-Gröner’s research concludes that oil-contaminated seafloor resulting from in-situ burning clean-up actions does not appear to cause serious effects on bottom-living shrimp.



Frederike Keitel-Gröner in the lab preparing oil covered gravel to be put in test tanks.



Effects on shrimp	After 2 weeks WSF exposure		After 2 weeks recovery	
	Crude oil	In Situ Burn Residue	Crude oil	In Situ Burn Residue
Mortality				
Swimming activity				
Feeding rate	Reduced			
Gill histopathology	Mild to moderate effects			
Larval development			Delayed	
Tissue concentration (mg sumPAH/kg ww)	Shrimp exposed to 12 g oil/residue per kg gravel			
	344	46	60	5

Sketch of the controlled experiments (left), and a table summarizing the results for experiment comparing the effects of crude oil vs in-situ burn residue.

Awards

Tor Arne Johansen, UiB, has received two prestigious awards for the groundbreaking work on geophysical measurements on floating ice:



Prof. Tor Arne Johansen, UiB and UNIS, leader of WP4

The 2021 *EAGE Ludger Mintrop Award* for the paper “Characterization of seabed properties from Scholte waves acquired on floating ice on shallow water”, *Near Surface Geophysics*, Vol. 18, pp. 49 – 59, 2020 (co-authored with Bent Ole Ruud).

The 2019 *Best Paper Award* from the *Geophysical Prospecting* EAGE journal for the paper “Seismic on floating ice: data acquisition versus flexural wave noise”, *Geophysical Prospecting*, Vol. 67, pp. 532 – 549, 2019 (co-authored with Bent Ole Ruud, Ronny Tømmerbakke, and Kristian Jensen).

Kim Senger, UNIS, was awarded the *EAGE Nigel Anstey Award* in 2018 for the paper “Effects of igneous intrusions on the petroleum system: a review”, published in *First Break* Vol. 35, No 6, 2017 (co-authored with John Millett, Sverre Planke, Kei Ogata, Christian Haug Eide, Marte Festøy, Olivier Galland, and Dougal A. Jerram)



Assoc. Prof. Kim Senger, UNIS, co-leader of WP1 & 2

International cooperation

All the academic members of ARCEX have their own large international networks of collaborators. Many of these networks have been brought in to provide an international perspective and level to our research. Several of our early career personnel have spent periods abroad working with international collaborators. Also some of our senior scientists have spent sabbatical terms abroad in the lifetime of ARCEX, thus performing research relevant for the centre in these environments.

The key international partners are Alfred Wegener Institute and GEOMAR in Germany, the Polish Academy of Sciences and University of Warsaw in Poland, CNRS and University of Rennes in France, Stanford University and University of Nebraska at Omaha in USA, Utrecht University in the Netherlands, and University of Copenhagen in Denmark.

We are unsure whether the centre status of ARCEX has any effect on the ability to arrange and maintain international collaboration. These connections are most often made on an individual basis at conferences and other networking arenas.



Training of researchers

The PhD students apply to, and have to be accepted by the individual member universities. All PhD students and postdocs associated with ARCEX have been organized in the Early Career Forum, (ECF) which serves as a cross-disciplinary and cross-institutional arena for our recruits. The ARCEX management supports and helps organize the ECF events.

All vacant positions have been announced nationwide through Jobbnorge, and in addition we employ various international networks to attract good international applicants. There is a special focus to identify potential Norwegian candidates, e.g. by encouraging talented master students with good grades to apply. ARCEX personnel supervise many master students, and this has turned out to be a very reliable channel to recruit also Norwegian doctoral students. As a result, we have been able to employ a substantial fraction of Norwegian doctoral students.

The first PhD student to join ARCEX was Amando Lasabuda from Indonesia. Amando got his masters degree in geology from University of Bergen. After earning the master's degree, he worked in industry for a while. When the opportunity to start as a PhD scholar in ARCEX appeared, he moved to Tromsø to pursue his degree at UiT. Amando has expressed that his strong urge to get a research education and the fact that the topic was Arctic marine geology carried out at the newly established research centre was decisive. Amando was the first PhD research scholar to earn his degree, and shortly after the graduation appeared the opportunity to become a postdoc in the Akademia project "Numerical modelling and validation of geological processes". His ambition is to pursue an academic career, but with strong collaboration with industry. His present postdoc project involves a very interesting numerical modelling approach to understanding erosion, subsidence and uplift of the Barents Sea, and it involves collaboration with another postdoc from the Centre of Excellence CAGE (Centre for Arctic Gas Hydrates and Environment) at UiT. Amando speaks Norwegian very well, and he and his little family have bought a house in Tromsø.



Amando Lasabuda, UiT

Another former PhD student from the first batch is Ana Sofia Aniceto from Portugal. She was employed at Akvaplan-niva when the possibility to join ARCEX appeared. Her application was successful, and she got the position. Her project was a cross-disciplinary approach to marine mammal surveys using unmanned aerial vehicles. Ana Sofia has said that she considered ARCEX to be a good place to carry out her research due to the access to technological equipment and competence that would otherwise be difficult to acquire. Through collaboration with Norut, she was able to perform digital video observations of marine mammals, and to use these observations to study population abundances and migratory behaviour of whale and seal along the coast. After she earned her PhD she won a highly competitive VISTA postdoc project with the title "Spatial and temporal analyses of marine mammals vocalizations using unmanned systems". In this project, Ana Sofia employs passive acoustic sensors on various gliders managed by Akvaplan-niva. Her research is therefore directly connected to the DEMO2000 glider project that has received support from the Research Council of Norway.



Ana Sofia Aniceto, Akvaplan-niva and UiT

Employment of PhD candidates (as of 2021)

Employment of PhD candidates (number)									
	By centre company	By other companies	By public organisations	By university	By research institute	Outside Norway	Other	In progress	Total
ARCEX funded PhD candidates	-	3	-	6	2	1	1	4	17
PhD candidates with funding outside the centre	1	1	-	3	-	2	1	7	15
Sum	1	4	-	9	2	3	4	11	32

Communication / Popular dissemination of knowledge

ARCEX has emphasized high research quality above all. This has resulted in a large number of publications and presentations at international conferences. Still, we have tried to convey our results in a popularized manner to a general public reaching beyond the research community.

As time has passed, however, it has become successively more and more difficult to flag fossil energy projects to the general public. Despite this, we have strived to participate in the public discussion through numerous popular presentations and participation in panel debates, radio programs, and science fairs. For example, we have participated in “Forskningsdagene”, “Lørdagsuniversitetet”, “Karrieredagene”, and “Abels tårn”.

Effects of centre for the host institution and research partners

ARCEX has shaped both the education and the research of the host institution. New master specializations in petroleum geology and ecotoxicology have been established, and numerous new courses have been initiated. The research program of ARCEX has paved the way to a much deeper understanding of petroleum systems at UiT, and it has strengthened and expanded the research in ecotoxicology.

There are several examples of reduced fragmentation and new national collaboration as a consequence of ARCEX. E.g., the unique master/PhD-level course AG-335/835 *Arctic seismic exploration* is being taught at UNIS with teaching personnel from four of the academic ARCEX partners (UiB, UiO, NTNU, UiT), and with financial support from an industry consortium. It is highly competitive to become a student in AG-335, with close to 100 students applying for the 20 available seats. The Norwegian universities have a reserved quota of students that are allowed to attend the course, so this is an excellent way to offer students a collaborative course that does not have a counterpart at any of the mainland universities.

Another example is iEarth, which is a Centre for Excellence in Education (SFU). This centre is a consortium comprised of UiB (host), UiO, UNIS, and UiT. ARCEX personnel have been central in developing iEarth, and the goal is to improve educational quality in the geosciences, and to employ collaborative means to offer courses to several universities simultaneously.

Effects of centre for the company partners, public partners and society at large

Review of what are considered the most important effects

ARCEX has served as a coordinator for high-north oriented research in Norway since its inception. As such, several new projects that have been initiated by user partners and academic partners have been organized as side projects to ARCEX. In that respect, ARCEX has played a role for the R&D and innovation strategies of the partners. In addition, for the smaller companies in the consortium, ARCEX has to some extent served as their de facto R&D department.

The research activities in environmental risk assessment are in many ways “license to operate” for Arctic operations. The user partners have collaborated extensively through WP3, and the summary of this research are concrete best practices that will be implemented by our partners. This can be regarded as positive both for the environment and for the society.

Much of the research that has been carried out in ARCEX can be regarded as basic research. The unique collaboration between academia and user partners ensures that the knowledge base is strengthened, and that the activities are research based.

The networks among user partners and academia has been vastly strengthened. This may lead the industry to achieve improved access to relevant competence and research personnel. Also, the collaboration may play a role for the recruitment of qualified and highly skilled personnel who have completed their research training.

Success stories

We have achieved new estimates of the past glacial erosion rates in the Barents Sea. This work has been published as a massive review paper, and we observe that the results of the paper is highly regarded by the user partners (and other readers).

The complete geological picture of the Barents Sea can be compiled from the many papers written by ARCEX scientists. This, with the addition of publications containing new chemical analyses of the source rock and the caprock properties can bring the energy companies closer to unravelling the enigma of petroleum resources in the Barents Sea.

Exchange of personnel between the partners

A direct effect of the midway evaluation was that we required all new PhD projects to include at least one co-supervisor from industry. As a result, several of our early career personnel have spent short- and longer-term stays with industry partners and relevant authorities. Our observation is that even short-term visits are important for the students, and it allows for bilateral information exchange and sharing of knowledge and experience that would otherwise be very difficult to achieve. In particular, PhD students with co-supervisors from industry partners have used the opportunity to gain valuable industry input and views on their research projects. The centre management see a multitude of positive side effects of this kind of personnel exchange. In particular, we see that it is very motivating for the early career scientists to experience how the industry partners actually work, and how they utilize the knowledge developed through ARCEX.

Feedback from some active company or public partners

ARCEX has turned out to be a good collaborative arena for industry partners and academic partners. After a reluctant start, we have developed many functional ways to meet and discuss, and this is reflected in the feedback received from active industry partners.

As one of our major industry partners expressed in conjunction with the midway evaluation:

“Equinor is actively contributing to developing petroleum resources in Arctic areas, especially on the Norwegian Continental Shelf to provide energy to growing markets in a safe, profitable, and safe way. The ARCEX activities are contributing significantly to meet these objectives.”

Furhermore, they state that:

“All the five work packages are highly relevant to Equinor, and as mentioned above more than 20 Equinor employees are actively following up the projects, and many more are taking advantage of the outcome of these projects.

There is a strong industry support and collaboration in all the ARCEX projects.”

About national collaboration, they express:

“ARCEX is characterized by high standards and extensive cooperation among experts from all relevant academic institutions – an example to follow for other programs.

ARCEX has a strong, professional, and dedicated leadership.”

To conclude, Equinor states that:

“ARCEX plays an important role in coordinating Arctic research activities, and Equinor is very supportive to the ARCEX projects.

We strongly recommend a continuation of the project, and we will continue to actively engage in the project to secure the highest possible value for Equinor as a user of the results and to support the institutions and persons involved in the project.”

This kind of positive expressions from one of the central user partners make us feel confident that the centre has served its purpose, and that the way we have organized the centre is productive and efficient.

There has been extensive contact between the user partners and the academic partners. After the midway evaluation, the level of contact increased due to a number of measures that was taken. In particular, it was decided that every new PhD student was to have at least one co-supervisor from the industry partners. This has proven to be a very effective way of increasing the mutual commitment and participation in the research projects.

Future prospects

The collaborative networks that have been formed holds a great potential to be utilized for future project proposals to the Research Council or EU. Some projects have already received support, but now that ARCEX is over, there will actually now be time available to develop proposals. One can expect proposals on focused projects on fundamental basic research within the different disciplines, but as we have demonstrated the potential for cross-disciplinary research is high. This may lead to new constellations and original combinations of disciplines.

We see a huge potential in transforming the knowledge acquired through ARCEX to some very complex and useful fields. In particular, we believe that CO₂-storage in geological structures is important, and that ARCEX scientists may contribute significantly to this field. Also, the measurement, modelling, and prediction of geohazards could become an important spin-off, and the combination of computational methods with geosciences to form useful geodynamical models could have far reaching consequences.

ARCEX has “inherited” a large number of geophone nodes on Svalbard. These geophone sensor networks have been very important for our research on seismic on floating ice, on permafrost, and on glaciers. The sensors will be stored at UNIS and maintained through the consortium that is responsible for giving the course *AG-335/835 Arctic seismic exploration* at UNIS.

The ARCEX board decided in the startup phase that a central data repository would be very impractical due to the complexity, heterogeneity, and possible conflict of commercial interests. It was therefore decided that the data should reside with the individual research collaborators. When it comes to reports, publications, and presentations, however, all ARCEX partners have access to an intranet site where both preprints and final versions are stored. Digital traffic statistics shows that this huge repository of relevant research has been used very actively by our user partners.



Conclusions

In the following, we offer some reflections of what is meant to be a Societal and Industry-oriented Research Centre.

We have observed a whole host of positive effects of being organized as a research centre. The collaboration between research groups and users has been very good, and we have established connections that would otherwise never have seen the light otherwise. Being organized as a centre has led to exciting synergies and collaboration across disciplines.

Being a true national centre encompassing all major academic institutions from across the whole country (from Stavanger at 58° north, to Svalbard at 78° north, with Tromsø in the middle at 69° north), the leading institutions from the Norwegian institute sector, and an outstanding group of trustworthy industry partners, we have benefited from a massive bank of highly competent participants. Admittedly, it has been very demanding to knit the plethora of specializations, cultures, expectations, and scientific traditions to a fully functioning national research centre. However, we believe that we have succeeded. Why? We think it has something to do with the adoption of what we call “Arctic flexibility”, and that the ARCEX management has tried to be very service minded all the way.

The initiative to strategy work and annual work plans has been taken by centre director and the local management group (consisting of the director, deputy director, and administrative leader). Thereafter, we conducted discussions with the extended management group consisting of the local management group and the work package leaders, before the plans were presented to the board. All strategies and annual work plans were discussed and approved by the ARCEX board before they were executed.

In order to execute the approved research strategies, the work package leaders have had the responsibility to make sure that the research project have been carried out and maintained. The center management have communicated both with the work package leaders, the senior researchers responsible for the research projects, and the early career scientists involved. This has secured a tight follow-up of ongoing projects, and it has implied a high production of publications and a very high throughput of PhD candidates.

The management group has had regular meetings with the whole group of work package leaders, in addition to individual meetings as often as necessary. The connection between the management and the researchers has been close, ensuring that the active researchers have had access to the resources necessary to perform the research.

The centre has developed many different arenas to build a centre identity for the young researchers. The annual conference was the largest such arena, and it was compulsory for all early career scientists to participate and to contribute. In addition, we arranged so-called Early Career Forum meetings once or twice per year. These early career forum meetings focused on 21st century skills, and they served as a meeting place to build a centre identity for the junior scientists, and to encourage cross-disciplinary thinking. The majority of the ECF gatherings were organized by the early career scientists themselves, with practical and administrative support from the centre management.

Senior scientists from the participating institutions were appointed as leaders of the various projects comprising the centre. The project leaders reported to the work package leaders, who in turn reported to the centre management and administration. All projects received attention and were followed up to ensure progress according to the annual work plans. The centre management served as the point of contact both with the Research Council and the user partners. The annual work plans and their associated Gantt diagrams turned out to be very important tools for the centre management on a day-to-day basis.

ARCEX did not have a dedicated person to deal with information and communication management. Instead, this task was maintained mainly by the administrative leader, with some support from the centre director. We constructed a web site for ARCEX as the main portal for public information, and a password protected intranet was constructed to share non-public information with the user partners. In retrospect, we wish we had allocated resources to employ a person dedicated to the communication tasks.

The majority of the board consisted of members from the user partners. This ensured a high focus on the importance of research activities that was regarded as relevant for the users. At the execution level, we ensured active participation from industry partners through co-supervision status of PhD students, and co-authorship of publications. To further enhance the relation between academia and industry, members of the management group conducted a yearly visit to all the industry partners. These visits were very demanding to carry out, but they documented positive effects to secure participation, commitment and dedication from the user partners.

Appendix 1

Statement of accounts for the complete period of centre financing

Note: Funding and cost summarised for the entire centre period.

Final accounting report 2013-2022

Costs (All figures in 1000 NOK)

Item	Collaboration project*	UIT	APN	NGU	Norve (tidl. IRIS)	Norve (tidl. NTNU)	UIS	UIO	UIS	EQUINOR ENERGY AS	AKER BP ASA	VAR ENERGI ASA	LUNDA ENERGY NORWAY AS	OMV (NORGE) AS	WINTERSHAL L L DEA NORGE AS	AS Norske Shell	NEPTUNE ENERGY NORGE AS	TULLOW OIL NORGE AS	CONOCOPHILLIPS SKANDINAVIA AS	INEOS EAP NORGE AS	Public funding (Troms fylkeskommune / RDA)	Total cost	
WPI/WP2	V	37 924	-	4 069	-	-	10 299	20 244	18 336	-	-	-	-	-	-	-	-	-	-	-	-	90 871	
WP3	V	16 067	23 807	6 832	-	-	6 336	-	-	-	-	-	-	-	-	-	-	-	-	-	-	53 142	
WP4	V	8 880	1 513	-	8 653	17 317	17 265	4 287	863	-	-	-	-	-	-	-	-	-	-	-	-	53 737	
WP5	V	12 463	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12 463
Herkomst (if relevant)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MGT	V	21 113	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21 113
Total budget		93 458	25 420	4 069	8 653	17 317	27 603	24 541	6 336	19 186	-	-	-	-	-	-	-	-	-	-	-	-	233 326

* Collaboration project: YES / NO / N/A; explain the reasons in a separate annex.

Funding (All figures in 1000 NOK)

Item	RGN Grant	UIT	APN	NGU	Norve (tidl. IRIS)	Norve (tidl. NTNU)	UIS	UIO	UIS	EQUINOR ENERGY AS	AKER BP ASA	VAR ENERGI ASA	LUNDA ENERGY NORWAY AS	OMV (NORGE) AS	WINTERSHAL L L DEA NORGE AS	AS Norske Shell	NEPTUNE ENERGY NORGE AS	TULLOW OIL NORGE AS	CONOCOPHILLIPS SKANDINAVIA AS	INEOS EAP NORGE AS	Public funding (Troms fylkeskommune / RDA)	Total funding	
WPI/WP2		27 948	15 038	-	-	-	4 061	6 665	-	5 098	4 118	4 118	3 716	2 230	1 859	1 796	1 610	1 517	991	929	4 531	90 871	
WP3		19 345	7 238	4 616	179	-	471	-	471	2 850	2 850	2 572	2 336	1 943	1 288	1 243	1 135	1 050	686	643	3 116	53 142	
WP4		7 506	3 864	1 513	3 820	5 482	4 596	384	-	2 879	2 879	2 323	2 114	1 367	1 054	1 125	1 069	951	621	852	1 588	53 737	
WP5		3 711	3 850	-	-	-	-	-	-	947	947	483	446	246	247	239	214	201	52	123	-	12 463	
Herkomst (if relevant)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MGT		6 600	7 572	-	-	-	-	-	-	986	986	800	603	534	445	430	385	363	237	222	566	21 113	
Total budget		75 200	38 678	6 123	1 271	5 482	8 659	7 019	471	5 951	11 080	10 000	9 080	6 000	5 000	4 833	4 333	4 083	2 666	2 800	9 801	233 326	



Appendix 2

List of Post-docs, Candidates for PhD and MSc degrees during the full period of the centre

Key Researchers

Name	Institution	Main research area
Alvar Braathen	UiO	WP1&WP2 Geology
Atle Rotevatn	UiB	WP1&WP2 Geology
Jan Inge Faleide	UiO	WP1&WP2 Geology
Jan Sverre Laberg	UiT	WP1&WP2 Geology
Kim Senger	UNIS	WP1&WP2 Geology
Morgan Ganerød	NGU	WP1&WP2 Geology
Roy Helge Gabrielsen	UiO	WP1&WP2 Geology
Sebastien Gac	UiO	WP1&WP2 Geology
Snorre Olaussen	UNIS	WP1&WP2 Geology
Steffen Bergh	UiT	WP1&WP2 Geology
Sten-Andreas Grundvåg	UiT	WP1&WP2 Geology
Stig-Morten Knutsen	Oljedirektoratet/UiT	WP1&WP2 Geology
Sverre Planke	UiO/VBPR	WP1&WP2 Geology
Tom Arne Rydningen	UiT	WP1&WP2 Geology
Øyvind Hammer	UiO-NHM	WP1&WP2 Geology
Ingrid Wiedmann	UiT	WP3 Environmental risk management
Jasmine Nahrgang	UiT	WP3 Environmental risk management
JoLynn Carroll	Akvaplan-niva	WP3 Environmental risk management
Marianne Frantzen	Akvaplan-niva	WP3 Environmental risk management
Michael Carroll	Akvaplan-niva	WP3 Environmental risk management
Paul E. Renaud	Akvaplan-niva	WP3 Environmental risk management
Paul Wassmann	UiT	WP3 Environmental risk management
Roger Flage	UiS	WP3 Environmental risk management
Thierry Baussant	NORCE	WP3 Environmental risk management
Agnar Sivertsen	NORCE	WP4 Technology for eco-safe exploration in the Arctic
Alfred Hanssen	UiT	WP4 Technology for eco-safe exploration in the Arctic
Bent Ole Ruud	UiB	WP4 Technology for eco-safe exploration in the Arctic
Leiv J. Gelius	UiO	WP4 Technology for eco-safe exploration in the Arctic
Martin Landrø	NTNU	WP4 Technology for eco-safe exploration in the Arctic
Rune Storvold	NORCE	WP4 Technology for eco-safe exploration in the Arctic
Stian Solbø	NORCE	WP4 Technology for eco-safe exploration in the Arctic
Tor Arne Johansen	UiB	WP4 Technology for eco-safe exploration in the Arctic

Postdoctoral researchers with financial support from the Centre budget

Name	Gender	Nationality	Scientific area	Period	Topic	Main contact
Agnar Sivertsen	M	Norway	WP4	2014-2017	Unmanned aerial systems for detection of sea ice and ice floes	Rune Storvold
Aleksandra Smyrak-Sirakova	F	Poland	WP1&2	2020-2021	Onshore-offshore correlations of the Billefjorden fault zone, Svalbard.	Kim Senger
Eric Salomon	M	Germany	WP1&2	2017-2019	Structure and fluid flow evolution of basin bounding fault systems in rift basins	Atle Rotevatn
Frederike Keitel-Gröner	F	Germany	WP3	2018-2022	Arctic species sensitivity to petroleum discharges with special emphasis on the effects of mechanically and chemically dispersed oil	Thierry Baussant
Gareth Lord	M	United Kingdom	WP1&2	2020-2022	The Norian to Bathonian reservoir interval of Svalbard and examples of correlation to the northern Barents Sea.	Kim Senger
Hannah Kriesell	F	France	WP4	2019-2021	Assessing the impact of seismic surveys on acoustic communication and behaviour of cetaceans	Martin Landrø
Helene Stemland	F	Norway	WP4	2020-2022	Potential use of seismic for Arctic climate monitoring.	Tor Arne Johansen
Ibsen Cardenas	M	Colombia	WP3	2020-2022	A systematic study of geological risk analysis in the framework of probabilistic risk analysis	Roger Flage
Ingrid Wiedmann	F	Germany	WP3	2016-2019	Arctic pelagic ecosystems and vertical transport of organic carbon	Paul Wassmann
Kjetil Indrevær	M	Norway	WP1&2	2015-2018	Tectonic inversion in the SW Barents Sea	Jan Inge Faleide
Lea Bouffaut	F	France	WP4	2019-2021	Detection and Localization of Marine Mammals During Seismic Acquisition	Martin Landrø
Marcus Landschulze	M	Germany	WP4	2015-2017	Seismic on Ice using simulations and field data; processing of full wave field data	Tor Arne Johansen
Mohamed Mansour Abdelmalak	M		WP1&2	2019-2021	North Atlantic-Arctic tectonics related to the wider Barents Sea paleogeography and basin evolution	Jan Inge Faleide
Nathalie Morata	F	France	WP3	2015-2018	The impact of changes in environmental conditions on benthic communities	JoLynn Carroll
Willy Røed	M	Norway	WP3	2015-2017	Application of risk and uncertainty concepts, principles and methods	Roger Flage

Postdoctoral researchers working on projects in the centre with financial support from other sources

Name	Gender	Nationality	Source of funding	Scientific area	Period	Topic	Main contact
Amando Lasabuda	M	Indonesia	Akademia	WP1&2	2019-2023	Numerical modelling and validation of geological processes	Alfred Hanssen
Ana Sofia Aniceto	F	Portugal	VISTA	WP3	2019-2022	Spatial and temporal analyses of marine mammal vocalizations using unmanned systems	Raul Primicerio
Jasmine Nahrgang	F	Germany	UiT	WP3	2013-2014	Ecotoxicology	Paul Wassmann
Kamaldeen Omosanya	M	Nigeria	NTNU	WP4	2014-2016	Tectonic evolution and hydrocarbon prospectivity of the Barents and Norwegian Seas	Ståle Emil Johansen
Mathias Bockwoldt	M	Germany	Symbioses III	WP3	2020-2023	Environmental Modeling	JoLynn Carroll
Thomas Berg Kristensen	M	Norway	3T/Statoil, UiB	WP1&2	2017-2018	Petroleum Geology: Using seismic reflection data to investigate the structural evolution of the Utsira High and South Viking Graben, North Sea.	Atle Rotevatn

PhD students with financial support from the Centre budget

Name	Gender	Nationality	Scientific area	Period	Thesis title / topic	Main thesis Advisor
Amando Lasabuda	M	Indonesia	WP1&2	2015-2018	Cenozoic tectonosedimentary development and erosion estimates for the Barents Sea continental margin, Norwegian Arctic.	Jan Sverre Laberg
Ana Sofia Aniceto	F	Portugal	WP3	2014-2018	Unmanned aerial vehicle for marine mammal studies in arctic and sub-arctic regions.	JoLynn Carroll
Babak Khodabandelo	M	Iran	WP4	2015-2018	Modeling and characterizing acoustic signals from cavity clouds generated by marine seismic air-gun arrays.	Martin Landrø
Fredrik Wesenlund	M	Norway	WP1&2	2017-2021	Lithostratigraphy and chemostratigraphy of Triassic black shales on Edgeøya, eastern Svalbard: Implications for understanding Triassic source rock formation on the Norwegian Barents Shelf	Sten-Andreas Grundvåg
Helene Stemland	F	Norway	WP4	2017-2020	Seismic acquisition and analysis in a changing Arctic.	Tor Arne Johansen
Jean-Baptiste Koehl	M	France	WP1&2	2015-2018	Mid/Late Devonian-Carboniferous extensional faulting in Finnmark and the SW Barents Sea.	Steffen Bergh
Julian Janocha	M	Germany	WP1&2	2020-2024	Effects of tectonic and climatic forcing on rift basin sequences – the Upper Paleozoic of Bjørnøya and southern Spitsbergen revisited	Sten-Andreas Grundvåg
Muhammad Hassaan	M	Pakistan	WP1&2	2018-2021	Evaporite-influenced rift basins and salt tectonics in the southeastern Norwegian Barents Sea.	Jan Inge Faleide
Renate Paulsen	F	Norway	WP1&2	2018-2021	Trap and Seal analysis of the northern Barents Shelf	Sten-Andreas Grundvåg
Ronny Tømmerbakke	M	Norway	WP4	2015-2018	Sea ice and erosional uplift: impact on Arctic seismic exploration	Tor Arne Johansen
Ryan Dillon	M	USA	WP3	2015-2018	Modelling the behavior and movements of marine mammals in the Lofoten-Barents Sea region.	JoLynn Carroll
Terje Solbakk	M	Norway	WP4	2015-2020	Different aspects of detecting karst with geophysical methods – Tales from the underworld.	Philip Sefton Ringrose
Thomas Birchall	M	United Kingdom	WP1&2	2017-2021	Pore Pressure Regimes of the Northern Barents Shelf – Implications for Fluid Flow.	Kim Senger
Tore Aadland	M	Norway	WP1&2	2015-2018	Disentangling time from siliciclastic sedimentary rocks.	William Heland-Hansen
Tyler Appleyard	M	USA	WP1&2	2016-2018	Sequence stratigraphy of U. Paleocene paralic wedges at Svalbard	Snorre Olaussen
Vemund Thorkildsen	M	Norway	WP4	2019-2022	Use of Passive and Active Electromagnetics in the Barents Sea	Leiv J. Gelius
Victoria Engelschiøn	F	Norway	WP1&2	2018-2022	Biofacies of the Middle Triassic dysoxic succession in the Arctic	Øyvind Hammer

PhD students working on projects in the centre with financial support from other sources

Name	Gender	Nationality	Funding	Scientific area	Period	Thesis title / topic	Main thesis advisor
Aleksandra Smyrak-Sirakova	F	Poland	UNIS	WP1&2	2013-2019	Development of extensional growth basins: A field based study, Svalbard, Norway.	Snorre Olaussen
Andreas Hagset	M	Norway	Wintershall Dea	WP1&2	2018-2022	Organic geochemical assessment and mapping of potential oil-prone Lower Cretaceous source rocks in the Vøring and Western Barents Sea Basins, Norway	Sten-Andreas Grundvåg
Claudia Erhart	F	Germany	UiT	WP3	2020-2023	Biological effects of crude oil pollution in fish species from the Barents Sea	Jasmine Nahrgang
Dimitrios Ktenas	M	Greece	EU FP7 Marie Curie ITN	WP1&2	2013-2019	Quantification of the magnitude of net apparent erosion in the southwestern Barents Sea by using compaction trends in shales and sandstones – Implications for hydrocarbon exploration.	Erik Henriksen
Isabel Edmundson	F	United Kingdom	Wintershall DEA	WP1&2	2017-2020	Elucidating key controls on top seal, lateral seal and fault seal capacity in hydrocarbon traps: insights from the Norwegian Continental Shelf.	Atle Rotevatn
Malte Jochmann	M	Germany	UNIS/Store norske	WP1&2	2015-2020	The regional geometry and sedimentology of the lower Paleogene basin in Svalbard and North East Greenland	Snorre Olaussen
Mark Joseph Mulrooney	M	United Kingdom	UNIS	WP1&2	2013-2017	Faults affecting the Triassic Barents Shelf: Syn-kinematic deposition, deformation mechanisms and driving forces.	Alvar Braathen
Maximilian Weber	M	Germany	UiT	WP1&2	2020-2024	The formation and geological evolution of sedimentary basins in the Barents Sea - Svalbard region	Jan Sverre Laberg
Morgan Bender	F	USA	UiT	WP3	2016-2020	Toxicity of crude oil on sensitive life history stages of a key Arctic species.	Jasmine Nahrgang
Maayke Jacqueline Koevoets	F	The Netherlands	UNIS	WP1&2	2014-2018	The Palaeontology, Stratigraphy and Palaeo-environment of the Agardhfjellet Formation (Middle Jurassic-Lowermost Cretaceous) of Spitsbergen, Svalbard	Øyvind Hammer
Peter Betlem	M	South Africa	UNIS	WP1&2	2019-2023	Carbon Capture Storage.	Kim Senger
Rowan Romeyn	M	Australia	UiT	WP4	2018-2021	Cracking into cryoseismology.	Alfred Hanssen
Sigrun Kvendbø Hegstad	F	Norway	Aker BP	WP1&2	2017-2022	Geochemically enhanced correlation of Triassic successions in the Barents Sea area and implications for sediment provenance and palaeo-environmental reconstructions	Matthias Forwick
Stine Bjordal Olsen	F	Norway	UiT	WP1&2	2019-2023	A tectonostratigraphic model for the Cenozoic evolution of the northern Mid-Norwegian and the Lofoten-Vesterålen continental margin	Tom Arne Rydningen
Vilde Dimmen	F	Norway	VISTA	WP1&2	.	Geological and geophysical properties of fault zones in carbonate rocks: from outcrop analogues to seismic imaging (SW Barents Sea and analogues)	Atle Rotevatn

Master degrees

Name	Gender	Scientific area	Period	Thesis title	Main thesis advisor
Birkeland, Åshild	F	WP1&2	2020	A 3D seismic study of late Cenozoic deposits on the northern inner part of the mid-Norwegian continental shelf	Jan Sverre Laberg
Hansen, Arne	M	WP1&2	2020	The Miocene sedimentary environment on the northern part of the mid-Norwegian continental margin	Tom Arne Rydningen
Kristiansen, Ådne Frostad	M	WP1&2	2020	Upper Triassic to lower Cretaceous tectonostratigraphic development of the Barents Sea South East	Stig-Morten Knutsen
Lundegaard, Marius	M	WP1&2	2020	Late Cenozoic development of the mid-Norwegian continental margin – a study of the Naust Formation based on 3D-seismic data	Tom Arne Rydningen
Moen, John Einar Karlsen	M	WP1&2	2020	Gas migration and sealing modelling in the Haapet Dome area, Norwegian Barents Sea – analysis of seismic anomalies and water column data	Stig-Morten Knutsen
Rein, Sindre Arnesen	M	WP1&2	2020	The Mjølner Impact Crater in the central Barents Sea – a potential hydrocarbon system?	Stig-Morten Knutsen
Michon, Elisa	F	WP3	2020	Exposure of maturing Atlantic cod (<i>Gadus morhua</i>) females to a water-soluble fraction of crude oil and effects on early life stages development.	Claudia Erhart
Rein, Sindre Arnesen	M	WP1&2	2020	The Mjølner Impact Crater in the central Barents Sea – a potential hydrocarbon system?	Stig-Morten Knutsen
Skorgenes, Julia	F	WP1&2	2020	Sedimentology of Late Precambrian storm-influenced pro-deltaic successions: Varanger, eastern Finnmark'	Sten-Andreas Grundvåg
Amdal, Frank Andreas	M	WP1&2	2019	Cross-disciplinary investigation of gas seepage at Storbanken high and the Olga basin, The northern Barents Sea.	Andreia Plaza Faverola
Edvardsen, Egil	M	WP1&2	2019	The Bigganjárgga Tillite re-visited: a stratigraphical and sedimentological study.	Sten-Andreas Grundvåg
Jones, Connie	F	WP3	2019	Comparative effects of two temperatures [0 & 3 °C] on polar cod embryonic and larval development.	Jasmine Nahr-gang
Kiss, Akos	M	WP1&2	2019	Dynamically controlled hydrocarbon column heights in fault bounded traps of the Hammerfest Basin, SW Barents Sea. Fault valve theory applied to the Snøhvit field.	Amando Lasabuda
Martinsen, Birgitta Saue	F	WP1&2	2019	Late Cenozoic erosion in the SW Barents Sea, and its influence on salt movement.	Stig-Morten Knutsen
Poulsen, Johanne Schønning	F	WP1&2	2019	Seismic Sequence analysis and petroleum system indicators at the Oligocen-Miocene level in the southern North Sea.	Iver Martens
Strømme, Kristine	F	WP1&2	2019	3D-seismic interpretation of the glacial deposits in the outer Ingøydjupet area, SW Barents Sea.	Iver Martens
Teisrud, Ragnar	M	WP3	2019	Cardiotoxic Effects from the Water-Soluble Fraction of Crude Oil on an Arctic Keystone Species – Polar Cod [<i>Boreogadus saida</i>].	Jasmine Nahr-gang
Thorsen, Truls	M	WP1&2	2019	Salt movements in three provinces in the southwestern Barents Sea: development, timing, and implications of regional structural differences.	Stig-Morten Knutsen
Betlem, Peter	M	WP1&2	2018	3D Thermobaric Modelling of Central Spitsbergen Implications for Gas Hydrate Occurrence.	Kim Senger
Brennhaugen, Adam Alfred	M	WP1&2	2018	A combined 3D seismic and sedimentological study of the Lower Cretaceous succession in the northeastern part of the Nordkapp Basin.	Sten-Andreas Grundvåg
Engen, Thea	F	WP1&2	2018	A sedimentological study of the Lower Cretaceous Glitrefjellet Member, Svalbard.	Sten-Andreas Grundvåg
Finnesand, Sebastian	M	WP1&2	2018	The upper Paleozoic regional development of the Ottar basin from seismic 2D interpretation.	Stig-Morten Knutsen
Forsberg, Mariann	F	WP1&2 / WP5	2018	Geofaglig kunnskap og holdninger til norsk petroleumsnæring; Et casestudie av Alta/Gohta.	Alfred Hanssen
Furland, Susanne	F	WP4	2018	Effects of frozen and partly frozen surfaces on seismic data.	Tor Arne Johansen

Geicke, Astrid	F	WP1&2	2018	Sedimentary environments in the lower part of the Upper Triassic Snadd Formation in the SW Barents Sea analysed from 2D- and 3D-seismic data.	Tom Arne Rydningen
Gossa, Julia	F	WP3	2018	Behavioral effects of crude oil water soluble fraction on polar cod larvae.	Jasmine Nahr-gang
Hansen, Johanne	F	WP4	2018	Combining geophysical data with a mathematical model to describe vertical two-phase flow.	Alfred Hanssen
Heiberg, Vegard	M	WP1&2	2018	The regional Cretaceous development of the southeastern part of the Norwegian Barents Sea- from seismic interpretation.	Stig-Morten Knutsen
Hetland, Asbjørn	M	WP1&2	2018	Use of 2D-seismic data and available wells to investigate the source potential of the Palaeozoic interval in the Loppa High area, SW Barents Sea.	Iver Martens
Hinna, Camilla	F	WP3	2018	Geological and environmental uncertainty and risk assessment in the Arctic, how can these be integrated?	Roger Flage
Johnsen, Therese Mortensen	F	WP1&2	2018	Geometriske og kinematiske studier av post-kaledonske rift-margin forkastninger og bruddsett mellom Tjeldsundet og Bjarkøy, Sør-Troms.	Steffen Bergh
Larssen, Kristine	F	WP1&2	2018	Integrated characterization of the Upper Permian Kapp Starostin Formation in central Spitsbergen, Svalbard – from outcrop to geomodel.	Kim Senger
Laurent, Jennifer Malica.	F	WP3	2018	Biotransformation capacity of crude oil water soluble fraction on polar cod early life stages.	Jasmine Nahr-gang
Matveev, Aleksei	M	WP1&2	2018	The Cretaceous development of the Nordkapp Basin based on seismic interpretation	Stig-Morten Knutsen
Poole, Louise Kristiansen	F	WP1&2	2018	Sedimentology of the Paleogene succession at Calypsostranda, Svalbard.	William Hel-land-Hansen
Skjærpe, Karoline Thu	F	WP1&2	2018	Sedimentological facies analyses of Clinothem 8C (Eocene), Bat-fjellet Formation, Brogniartfjella, Svalbard.	William Hel-land-Hansen
Slettehaug, Hanne-Lise	F	WP1&2	2018	The regional upper Paleozoic development of the SE part of the Norwegian Barents Sea – from seismic interpretation.	Stig-Morten Knutsen
Tennvassås, Ingrid	F	WP1&2	2018	Characterisation of palaeosols in the Lower Cretaceous Helveti-afjellet Formation, Svalbard – palaeo-climatic implications.	Sten-Andreas Grundvåg
Tonstad, Sigurd	M	WP1&2	2018	The late Paleozoic development of the Ottar Basin from seismic 3D interpretation.	Stig-Morten Knutsen
Broze, Elliot	M	WP1&2	2017	The occurrence of flow transformations within sandy submarine fans: A case study from the Eocene on Spitsbergen.	Sten-Andreas Grundvåg
Eikermann, Isak Emil Skadsem	M	WP1&2	2017	Shallow stratigraphic cores NW of Bjørnøya, results and implications.	Stig-Morten Knutsen
Festøy, Marte Her-got	F	WP1&2	2017	Integrated characterization of igneous intrusions in Central Spitsbergen.	Kim Senger
Gotliebsen, Katrine	F	WP4	2017	Exploratory data analysis of flexural waves in Arctic fjord ice seismic data.	Alfred Hanssen
Kalac, Amra	F	WP1&2	2017	Cretaceous and Cenozoic tectono-stratigraphic evolution of the southern Lofoten and northern Vøring margins, offshore northern Norway.	Filippos Tsikalas
Krokmyrdal, Sucha-da	F	WP1&2	2017	Sedimentary environment and seismic anomalies of the upper Brygge and Kai formations on the northern part of the Mid-Norwegian Continental Shelf.	Jan Sverre Laberg
Martins, Gustavo de Aguiar	M	WP1&2	2017	Seismic interpretation and stratigraphy of the Paleogene in the Bjørnøya Basin, western Barents Sea.	Stig-Morten Knutsen
Toonen, Ruud	M	WP1&2	2017	Geological controlling parameters on seismic imaging of igneous intrusions on Svalbard.	Kim Senger
Yankina, Anna	F	WP1&2	2017	Petroleum systems of the Barents shelf: A regional well-based study of the Mesozoic.	Kim Senger
Bergø, Espen	M	WP1&2	2016	Analyses of Paleozoic and Mesozoic brittle fractures in West-Fin-nmark. Geometry, kinematics and relations to structures on the Finnmark Platform in the southwestern Barents Sea.	Steffen Bergh

Grimstad, Silje	F	WP1&2	2016	Salt structures and salt tectonics in the Central and NE segments of the Nordkapp Basin, Barents Sea.	Roy Helge Gabrielsen
Hagset, Andreas H.	M	WP4	2016	Seismic attributes, well correlation and geostatistical analysis for sequence variability prediction in the Sleipner area.	Alfred Hanssen
Hoang, Ha Thi Thanh	F	WP1&2	2016	Salt structures and salt tectonics in the western segment of the Nordkapp Basin, Barents Sea.	Roy Helge Gabrielsen
Høgseth, Gert Vidar	M	WP1&2	2016	The Cenozoic pre-glacial sedimentary environment of the SW Barents Sea continental margin – Lofoten Basin.	Jan Sverre Laber
Jensen, Kristian	M	WP4	2016	Modelling and Processing of flexural wave noise in sea ice.	Tor Arne Johansen
Johansen, Stian André	M	WP1&2	2016	Depositional environments of the Upper Triassic Snadd Formation on the Loppa High, SW Barents Sea.	Tom Arne Rydningen
Karlsen, Kristine Morsund	F	WP1&2	2016	Evolution of an Eocene prograding system in the Tromsø Basin, southwestern Barents Sea	Ivar Midtkandal
Karlsen, Nils Andreas	M	WP1&2	2016	AVO study of the Salina discovery on the Loppa High in the south-western Barents Sea.	Iver Martens
Lea, Halldis	F	WP1&2	2016	Analysis of Late Paleozoic-Mesozoic brittle faults and fractures in West-Finmark: geometry, kinematics, fault rocks and the relationship to offshore structures on the Finnmark Platform in the SW Barents Sea.	Steffen Bergh
Njå, Erika Rørvik	F	WP1&2	2016	The sequence stratigraphic development of the Late Permian Kapp Starostin Formation, central Spitsbergen.	Sten-Andreas Grundvåg
Prytz, Alexander	M	WP1&2	2016	The Use of Seismic Attributes and Well Data for Prediction of Reservoir Sand Definition in the Vøring Basin, Norwegian Sea.	Tom Arne Rydningen
Prytz, Richard	M	WP1&2	2016	Seabed depressions in the Ingøydjupet Through and their relation to buried canyons on the Loppa High, Barents Sea.	Tom Arne Rydningen
Wilhelmsen, Hanne C.R.	F	WP1&2	2016	Cretaceous tectono-stratigraphic evolution of the Ribban and northern Træna basins at the Lofoten margin, offshore northern Norway.	Jan Inge Faleide
Aghataghiyev, Elnur	M	WP4	2015	Evolution of Tromsø Basin in the light of salt tectonics.	Ståle Emil Johansen
Bakke, Svein H.	M	WP4	2015	Seismiske bølger i havis.	Tor Arne Johansen
Buriro, Aamir	M	WP4	2015	Seismic Interpretation and Characterization of the North Sea Chalk Group.	Ståle Emil Johansen
Enga, Jonas	M	WP1&2	2015	Paleosols in the Triassic De Geerdalen and Snadd formations.	Atle Mørk
Haraldsvik, Kristian Liland	M	WP1&2	2015	Analyse av mesozoiske forkastninger og asymmetriske landskap i et profil over Lofotryggen ved Leknes, Vestvågøy. Implikasjoner for dannelsen av roterte forkastningsblokker, riftrelaterte bassenger og nedforkastningen av Leknesgruppen.	Steffen Bergh
Jabbar, Abdul	M	WP1&2	2015	Reservoir Quality of Lower-Middle Jurassic sandstones within the Johan Castberg Field in the SW Barents Sea.	Jens Jahren
Jørgensen, Knut William	M	WP1&2	2015	Sedimentology of inter-channel deposits of the Aspelintoppen Formation, Brogniartfjella, Svalbard.	William Helling-Hansen
Khan, Asad	M	WP1&2	2015	Reservoir quality of the Stø and Nordmela Formations in well 7220/8-1, Johan Castberg Area in the SW Barents Sea.	Jens Jahren
Kongsgården, Andreas Gillebo	M	WP1&2	2015	Sedimentology of channel-deposits of the Aspelintoppen Formation, Brogniartfjella, Svalbard.	William Helling-Hansen
Lundekvam, Petter Andreas	M	WP1&2	2015	Land sokkel korrelasjon av sprø mesozoiske og paleozoiske forkastninger i et profil over Vestfjordbassenget, Vestvågøya og Ribbebassenget.	Steffen Bergh
Marheni, Lolita	F	WP1&2	2015	Sedimentation process and stratigraphic evolution of deep-water sediments in Sørvestsnaget Basin, Southwestern Barents Sea.	Maarten Felix
Mohammedyasin, Mohammed Seid	M	WP1&2	2015	Deep-seated faults and hydrocarbon leakage in the Snøhvit Gas Field, Hammerfest Basin, southwestern Barents Sea.	Stephen John Lippard
Norkus, Audrius	M	WP1&2	2015	Pre-Jurassic evolution of the Fingerdjupet Subbasin area, SW Barents Sea	Jan Inge Faleide

Panou, Nektaria	F	WP1&2	2015	Microscopic and organic geochemical characterization of the Lower Carnian black shale interval in the Northern Calcareous Alps.	Wolfram M. Kürschner
Prøis, Bjørn Margido	M	WP1&2	2015	Late Paleocene – earliest Eocene prograding system in the SW Barents Sea.	Ivar Midtkandal
Rallakis, Dimitrios	M	WP1&2	2015	Geochemical Comparison of Oils and Source Rocks from Barents Sea.	Dag A. Karlsen
Rønningen, Anders	M	WP1&2	2015	The first attempt to correlate the migrated bitumen from the Helgeland Basin cores to Devonian source rocks and oils from the UK Orcadian Basin – Is there a Devonian Orcadian type basin offshore Norway?	Dag A. Karlsen
Strand, Siri Anne Haugland	F	WP1&2	2015	Layer parallel shortening and cataclastic flow by fractures in the Permian Kapp Starostin Formation, Mediumfjellet, Spitsbergen.	Alvar Braathen
Babayev, Murad Fikrat	M	WP4	2014	Seismic Expression of Deep-Water Fan with an Example from Triassic in Southwestern Barents Sea.	Ståle Emil Johansen
Canales, Mauricio Reyes	M	WP4	2014	Seismic interpretation and evaluation of the Cenozoic uplift in the southwestern Barents Sea.	Ståle Emil Johansen
Christophersen, Gard	M	WP1&2	2014	Fracturing and weathering in Billefjorden through, an analogue to top basement reservoir.	Tom Arne Rydningen
Dahlberg, Maria Evensen	F	WP1&2	2014	Structural and stratigraphical evolution of the Fingerdjupet Sub-basin, SW Barents Sea.	Jan Inge Faleide
Dimitriou, Myrsini	F	WP1&2	2014	Lower Cretaceous Prograding Units in the eastern part of the SW Barents Sea.	Ivar Midtkandal
Harishidayat, Dicky	M	WP4	2014	Seismic sedimentology of Triassic channel complex in the Barents Sea.	Ståle Emil Johansen
Naurstad, Olav Aleksander	M	WP1&2	2014	Sedimentology of the Aspelintoppen Formation (Eocene-Oligocene), Brogniartfjella, Svalbard.	William Heland-Hansen
Zhang, Dechen	M	WP1&2	2014	Imaging reservoir quality of Knurr and Stø Formations in the Hammerfest Basin and RLFC, Norwegian Barents Sea.	Nazmul Haque Mondol

Appendix 3

List of Publications

Peer reviewed articles

In progress

Chivata Cardenas, I. (In review) A non-parametric approach to quantify uncertainty in geological models.

Chivata Cardenas, I., Aven, T., Flage, R. (In progress) Addressing challenges in uncertainty quantification. The case of geohazard assessments.

Chivata Cardenas, I., Flage, R. (In review) Providing a more informed specification of trigger factors in marine geohazard assessments – An example of mass movement processes.

Chivata Cardenas, I., Flage, R. (In review) Marine geohazards exposed: uncertainties involved. Under revision (minor revisions).

Chivata Cardenas, I., Flage, R. (In review) An efficient two-dimensional non-parametric approach to quantify stratigraphic uncertainty in geological models.

Gabrielsen, R.H., Roberts, D., Gjelsvik, T., Sygnabere, T.O., Hassaan, M., Faleide, J.I. (In review) Double-folding and thrust-front geometries associated with the Timanian and Caledonian orogenies in the Varanger Peninsula, Finnmark, North Norway. Submitted to *Journal of the Geological Society*.

Koehl, J.-B. P., Collombin, M., Taule, C., Christophersen, G., Allaart, L. and Noormets, R. (In review) Devonian collapse and segmentation of the Billefjorden Trough, and Eurekan inversion overprint and strain partitioning and decoupling along inherited WNW–ESE-striking faults. Submitted to *Norwegian Journal of Geology*.

Liu, Y.-W., Wanamaker Jr, A.D., Aciego, S.M., Searles, I., Hangstad, T.A., Carroll, M.L. (Accepted) Resistant calcification responses of *Arctica islandica* clams under ocean acidification conditions. Submitted to *Nature Scientific Reports*.

Olaussen, S., Grundvåg, S.-A., Senger, K., Anell, I., Braathen, A., Dallmann, W., Helland-Hansen, W., Jochmann, M., Johannessen, E.P., Mørk, A., Stemmerik, L. (In review) Svalbard Platform Tectono-Stratigraphic Element. Submitted to *The Geological Society Special Publication*.

Solbakk, T., Svånå, T. A., Fichler, C., Ringrose, P. (In review) Increasing reliability of seismic prediction of karst morphology, with examples from the Loppa High, Norwegian Continental Shelf. Submitted to *Petroleum Geoscience*.

Walker, E.Z., Wiedmann, I., Nikolopoulos, A., Skarðhamar, J., Renner, A.H.H. (In review) Pelagic ecosystem dynamics between late autumn and the post spring bloom in a sub-Arctic fjord. Submitted to *ELEMENTA: Science of the Anthropocene*.

2022

Birchall, T., Senger, K., Swarbrick R. (2022): Naturally Occurring Underpressure – A Global Review. *Petroleum Geoscience*, 2022(28,2), petgeo2021-051. DOI: 10.1144/petgeo2021-051.

Koehl, J.B.P, Magee, C., Anell, I. (2022): Impact of Timanian thrust systems on the late Neoproterozoic–Phanerozoic tectonic evolution of the Barents Sea and Svalbard. *Solid Earth*, 2022(13), pp. 85-115. DOI: 10.5194/se-13-85-2022..

Paulsen, R., Birchall, T., Senger, K., Grundvåg, S.A. (2022): Seal characterization and integrity in uplifted basins: Insights from the northern Barents Shelf. *Marine and Petroleum Geology*, 2021(139), 105588. DOI: 10.1016/j.marpetgeo.2022.105588.

Plaza-Faverola, A., Vadakkepuliymbatta, S., Singhroha, S., Hong, W.L., Waghorn, K.A., Lasabuda, A.P.E., Ferré, B., Bünz, S., Mienert, J. (2022): Gas Hydrate Related Bottom-Simulating Reflections Along the West-Svalbard Margin, Fram Strait. In: Mienert, J., Berndt, C., Tréhu, A.M., Camerlenghi, A., Liu, CS. (eds) *World Atlas of Submarine Gas Hydrates in Continental Margins*. Springer, Cham. 2022, pp. 225-235. ISBN 9783030811853. DOI:

10.1007/978-3-030-81186-0_18.

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Wesenslund, F., Grundvåg, S.-A., Sjøholt, V.E., Thiessen, O., Pedersen, J.H. (2022) Multi-elemental chemostratigraphy of Triassic mudstones in eastern Svalbard: Implications for source rock formation in front of the World's largest delta. *The Depositional Record*, 2022(00), pp. 1-36. DOI: 10.1002/dep2.182.

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Arlebrand, B.A., Augustsson, C., Escalona Varela, A., Grundvåg, S.A., Marin, D. (2021): Provenance, depositional setting and diagenesis as keys to reservoir quality of the Lower Cretaceous in the SW Barents Sea. *Marine and Petroleum Geology*, 2021(132), article 105217. DOI: 10.1016/j.marpetgeo.2021.105217.

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- Hassaan, M., Faleide, J.I., Gabrielsen, R.H., Tsikalas, F. (2021): Effects of basement structures and Carboniferous basin configuration on evaporite distribution and the development of salt structures in Nordkapp Basin, Barents Sea—Part I. *Basin Research*, 2021(33,4), pp. 2474-2499. DOI: 10.1111/bre.12565.
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