NGU REPORT 2015.032

7th International Conference on Arctic Margins - ICAM 2015

GEOLOGY FOR SOCIETY
SINCE 1858

GEOLOGICAL SURVEY OF NORWAY
- NGU -

NORGES GEOLOGISKE UNDERSØKELSE
- NGU -

REPORT

Geological Survey of Norway
P.O.Box 6315 Sluppen
NO-7491 TRONDHEIM
Tel.: 47 73 90 40 00

Report no.: 2015.032	**ISSN: 0800-3416 (print)** **ISSN: 2387-3515 (online)**	**Grading:** Open

Title:
7th International Conference on Arctic Margins - ICAM 2015

Authors: Morten Smelror (Editor)	**Client:**
County:	**Commune:**
Map-sheet name (M=1:250.000)	**Map-sheet no. and -name (M=1:50.000)**
Deposit name and grid-reference:	**Number of pages:** 143 **Price (NOK):** 250.- **Map enclosures:**

Fieldwork carried out:	**Date of report:** 26 May 2015	**Project no.:** 001230	**Person responsible:** Øystein Nordgulen

Summary:

This report presents the program and abstracts of scientific presentations given at the 7th International Conference on Arctic Margins (ICAM-VII 2015) held 2nd-5th June 2015, in Trondheim, Norway.

The International Conference on Arctic Margins (ICAM) is a forum for earth scientists who study the Arctic. ICAM was founded by the U.S. Department of the Interior Bureau of Ocean Energy Management in 1991 with the underlying themes of Arctic understanding and international cooperation in Arctic research. Since its very beginning ICAM has proved a successful arena to raise the geo-scientific knowledge of the Arctic and to foster cooperation and collaboration among Arctic researchers. ICAM is organized, hosted, and conducted by scientists for scientists, which makes it a unique forum. Prior to the conference in Trondheim 2015 six meetings have been held in Anchorage, Magadan, Celle, Dartmouth, Tromsø and Fairbanks.

ICAM VII 2015 included 56 oral presentations and 44 posters covering the following topics: New data on seafloor geology and deep structure of the Arctic Basin and adjacent areas; their implementation in international projects, with sub-session on planned field activities; Circum-Arctic onshore-offshore structural relations; Stratigraphy, paleo-environments and geological history of the Arctic basin and adjacent areas; Arctic Large Igneous Provinces and their geodynamic significance; Plate reconstructions and lithosphere evolution of the Arctic region; Glacial events and their geological consequences (with sub-session on origin of bottom sediments); and Arctic Gas Hydrates.

Keywords: Arctic	Geology	Geophysics
Arctic margins	Tectonics	Stratigraphy
LIP	Glacial geology	Gas hydrates

7TH INTERNATIONAL CONFERENCE ON ARCTIC MARGINS

ICAM 2015

The ICAM VII International Organizing Committee

Alexander Minakov (UiO), Andrey Morozov (Rosnedra), Astrid Lyså (NGU), Bernard Coakley (UAF), Carmen Gaina (UiO), Christian Marcussen (GEUS), Dennis Thurston (BOEM), Dieter Franke (BGR), Hans-Joachim Kümpel (BGR), Harald Brekke (NPD), James Clough (Alaska DGGS), Karin Andreassen (UiT), Morten Smelror (NGU), Odleiv Olesen (NGU), Oleg Petrov (VSEGEI), Ruediger Stein (AWI), Sergey Sokolov (RAS), Thomas Funck (GEUS), Valery Kaminsky (VNIIOkeangeologia), Victoria Pease (Stockholm University) and Wilfried Jokat (AWI)

List of Presentations:

N. Alexandropoulou, K. Andreassen, M. Winsborrow, J.I. Faleide & J.P. Nystuen: **Late Cenozoic evolution of the western Barents Sea-Svalbard continental margin. Case study: Upper Bjørnøya Fan, western Barents Sea margin** 11

K. Andreassen, L.R. Bjarnadóttir, M.C.M. Winsborrow, H. Patton & A. Hubbard: **Patterns of past ice-sheet flow in the Barents Sea**.. 12

J.E. Arndt, W. Jokat & B. Dorschel: **New insights on the glacial history of North-East Greenland from swath bathymetric data** 13

E.V. Artyushkov, P.A. Chekhovich & E.I. Petrov: **Mechanism of crustal subsidence in deep Arctic basins** 14

K. Asch & H.-J. Kümpel: **A Project Proposal: Compilation of a new Digital International Quaternary Map of the Arctic (IQUAMAR)** 15

S. Baranwal, J. Knies & S. Sauer: **Foraminiferal communities of hydrocarbon seeps from the continental shelf offshore Vesterålen, Northern Norway** 17

V.K. Bellec, R. Bøe, L. Plassen, N. Baeten, H. Olsen, D. Ottesen, L.R. Bjarnadóttir, A. Lepland, T. Thorsnes, M. Dolan & S. Elvenes**: Sediment maps of the Norwegian and Barents seas** 19

BGS Marine Geoscience (presented by D. Dove): **British Geological Survey remotely operated sea bed rockdrills and vibrocorers: new advances to meet the needs of the scientific community** 20

O.K. Bogolepova & A.P. Gubanov: ***Gloeocapsomorpha prisca* in Early Silurian source rocks of the northern East Siberia** 21

O.K. Bogolepova, A. Carter & A.P. Gubanov: **Pilot apatite fission-track study of the Furongian sandstones from Severnaya Zemlya, Russian Arctic** 22

S.E. Box & T.E. Moore: **Deformational history of Alaska** 23

K. Brumley, M. Grove, K.E. Meisling & L.A. Mayer: **U-Pb detrial zircon geochronology of dredged metasediments from the Northwind Ridge, Arctic Ocean: Is this Chukchi Borderland part of Crokerland** 24

C.F. Castro, T. Funck & J.R. Hopper: **The crustal structure of the Amundsen Basin in the Arctic Ocean derived from seismic refraction data** 27

A.A. Chernykh, V.Yu. Glebovsky, A.V. Egorova, A.G. Redko & R.A. Sukhanov: **Tectonic structure and evolution of the Alpha-Mendeleev Fracture Zone** 28

D. Chian, G.N. Oakey, H.R. Jackson, D.R. Hutchinson, N. Lebedeva-Ivanova, J. Shimeld, Q. Li, D.S. Mosher & R.W. Saltus: **Crustal Structure of the Canada Basin: new constraints from seismic reflection and refraction data** 29

B. Coakley, R. Forsberg, J. Beale, R. Gabbert & S. Kenyon: **New data support updating of the Arctic Gravity Project grid; Version 3.0** 30

W.K. Dallmann & P.I. Myhre: **Geoscience Atlas of Svalbard** 31

L.A. Daragan-Sushchova, L.R. Grinko, N.A. Petrovskaya & Yu.I. Daragan-Sushchov: **To substantiation of the stratigraphy of key seismic horizons on the East-Arctic Shelf and in the area of Central Arctic uplifts** 32

M. Dolezych & L. Reinhardt: ***Protopiceoxylon yukonense* spec. nov. – an extinct conifer from the Northern Yukon / Mackenzie Delta area** 34

M.S. Doronina, A.M. Nikishin, N.A. Vasilyeva, A.I. Leybenko, T.S. Basalaeva & N.A. Kukina: **Geological evolution of the Norwegian Barents Sea South-East** 36

D. Dove, L. Polyak & B. Coakley: **Efforts to constrain extent and dynamics of past glaciation on the Chukchi margin and adjacent areas** 37

V.B. Ershova, A.V. Prokopiev, H. Lorenz, N.N. Sobolev, A.K. Khudoley, E.O. Petrov, S. Estrada, S. Sergeev, A. Larionov & T.B. Thomsen: **De Long Islands: provenance, paleogeography and geodynamic model** 38

S. Estrada, D. Damaske, F. Henjes-Kunst, G. Oakey, B. Schreckenberger, K. Eckelmann & U. Linnemann: **Onshore extension of the Alpha Ridge into the Yelverton Bay area? Evidence from aeromagnetic and geochronological data** 39

J. Evangelatos, D.C. Mosher & T. Funck: **Tectonic significance of seismic reflection and refraction data from Makarov Basin, Arctic Ocean** 40

J.I. Faleide, A. Mahajan, R.H. Gabrielsen, A.J. Breivik, S. Planke & R. Myklebust: **Basement and Late Paleozoic basin configurations in the western and central Barents Sea** 41

W. Fjeldskaar & A. Amantov: **Post-glacial uplift in the Barents Sea – determination of Earth rheology and implications for petroleum systems** 42

D. Franke, K. Piepjohn, C. Gaedicke, C. Brandes, B. Mouly, N. Sobelev, T. Tolmacheva, E. Weigelt & W. Jokat: **Sedimentary succession around the New Siberian Islands: onshore to offshore relation** 43

J.M. Frederick & B.A. Buffett: **Is submarine groundwater discharge a control on Arctic permafrost-associated gas hydrate formation on the Beaufort Shelf?** 44

T. Funck, J. Gerlings, J.R. Hopper, C.F. Castro, C. Marcussen, T. Nielsen & A. Døssing: **The East Greenland Ridge: Geophysical mapping and geological sampling reveal a highly segmented continental sliver** 45

C. Gaina, R.J. Watson & J. Cirbus: **Late Mesozoic - Cenozoic plate boundaries in the North Atlantic – Arctic: Quantitative reconstructions using Hellinger criterion in GPlates** 46

D.G. Gee, A.N. Larionov, H. Lorenz & A. Simonetti: **Mesoproterozoic crystalline basement, intruded by Timanian granites, beneath the Pechora Basin and within the foreland and fold-and-thurst belt of Arctic Urals** 48

W.H. Geissler, A.C. Gebhardt, F. Gross, J. Wollenburg, L. Jensen, M.C. Schmidt-Aursch & S. Krastel: **Slope stability, gas hydrates, and methane seepage at the shelf north of Svalbard** 50

W.H. Geissler, J. Knies, T. Nielsen, C. Gaina, J. Matthiessen, A.C. Gebhardt, V. Damm, M. Forwick, B. Hjelstuen, J. Hopper, K. Husum, J.S. Laberg, W. Kürschner, C. Morig, M. Schreck, A. Tripati, C. Vogt, M. Rebesco, S.-Il Nam, A. Carlson, S. De Schepper, R. Lucchi, R. Mattingsdal, W. Jokat & R. Stein: **The Opening of the Arctic-Atlantic Gateway: Tectonic, Oceanographic and Climatic Dynamics - an IODP Initiative** 51

L. Gernigon, A. Blischke, A. Nasuti & M. Sand: **Conjugate volcanic rifted margins, sea-floor spreading and microcontinent: Insights from new high-resolution aeromagnetic surveys in the Norway Basin** 53

S. Gradmann, M. Keiding, O. Olesen & Y. Maystrenko: **3D Stress and Strain Modeling in Nordland, Northwestern Norway** 54

T.B. Grant & R.B. Larsen: **The Reinfjord Ultramafic complex, Seiland Igneous Province, Northern Norway** 55

A.P. Gubanov & B.L. Nikitenko: **Jurassic biostratigraphy of Eastern Taimyr, Arctic Siberia** ... 56

A.P. Gubanov & W.D. Mooney: **World Basement Geological Map - a new platform for global reconstructions** 57

E. Halvorsen: **Magma flow and stress induced magnetic fabric inferred from AMS analysis. A Case study in Early Cretaceous sills from the Diabasodden suite (HALIP), Svalbard** 58

I. Ilhan & B. Coakley: **Structure and stratigraphy of the Northwind Basin and southern Chukchi Borderland from multi-channel seismic (MCS) reflection data: implications for regional geology and tectonics** 59

N.M. Ivanova, N.V. Amelin, M.A. Veretennikova, L. Miles, I.V. Belyaev & D.G. Gee: **The East-Barents Mega-Depression and its relationship to adjacent tectonic elements** 60

W. Jokat: **Crustal structure off NE Greenland – a review** 62

Y.B. Kazmin, H. Brekke, E.I. Petrov, A.M. Nikishin, L.I. Lobkovskiy & V.A. Poselov: **Evolution of the Amerasian Basin – a Tectonic Model** 63

M. Keiding, S. Gradmann, O. Olesen, Y. Maystrenko & the NEONOR2 working group: **Neotectonics in Nordland, NEONOR2 – Implications for petroleum exploration** 65

P.K. Kepezhinskas, G.M.D. Eriksen & N.P. Kepezhinskas: **Ultramafic to mafic magmas in Norwegian Arctic: geochemical evidence for the multiplicity of mantle sources** 67

A.K. Khudoley, V.E Verzhbitsky, D.A. Zastrozhnov & V.B. Ershova: **Mesozoic tectonic events in the Eastern Taimyr Fold and Thrust Belt and adjoining Yenisey-Khatanga Depression** 68

C.G. Kingsbury, R.E. Ernst, B.L. Cousens, M.-C. Williamson & Y. Xia: **High Arctic LIP in Canada: Nd isotopic evidence for the role of crustal assimilation** 69

S.A. Klotsko, N.W. Driscoll & L. Keigwin: **Sedimentological and stratigraphic evidence for a multiple floods along the Beaufort Margin, Arctic Ocean** 70

J.B. Koehl, S.G. Bergh, K. Indrevær & T. Henningsen: **Onshore-offshore tectonic relationships in Troms and Finnmark, North Norway** 71

J.S. Laberg & T.A. Rydningen: **On the quantification of late Cenozoic glacial erosion of northern Norwegian – southwestern Barents Sea continental margin (69-74°N)** 72

T.R. Lakeman, A.J. Pieńkowski, F.C. Nixon, M.F.A. Furze, S. Blasco & J.T. Andrews**: Age and origin of multiple ice-rafted debris horizons in the Canadian Beaufort Sea: implications for Arctic Ocean stratigraphy and paleoclimate** 73

E. Larsen, W. Fjeldskaar, O. Fredin, A. Lyså & D. Ottesen: **Asynchronous Last Glacial Maximum of the Fennoscandian ice sheet** 74

R.O. Lease, D.W. Houseknecht & A.R.C. Kylander-Clark: **Colville Basin response to Arctic tectonics and climate: 3rd and higher order Aptian-Albian depositional sequences** 75

N. Lebedeva-Ivanova, C. Gaina, A. Minakov & S. Kashubin: **A crustal thickness model of the Arctic Region from 3D gravity inversion** 76

G.V. Ledneva, V.L. Pease & B.A. Bazylev: **The late Triassic volcanic and subvolcanic rocks of the Vel'may terrane (Chukchi Peninsula) and their geodynamic setting** 78

M.A. Levitan, T.A. Antonova, T.N. Gelvi & W. Jokat: **Triassic-Pliocene sedimentation history in the Circum-Arctic belt: A quantitative approach and possible influence for the Arctic Ocean sedimentation** 80

M.V. Luchitskaya, S.D. Sokolov, S.A. Sergeev, A.B. Kotov, L.M. Natapov, E.A. Belousova & S.M. Katkov: **Neoproterozoic and Late Paleozoic granitoids of Wrangel Island and North Chukotka** 82

E.R. Lundin, A.G. Doré, A. Gibbons, T. Sømme, B.O. Tørudbakken & B. Hendriks: **Opening of the Arctic oceanic basins – constraining the model, and some implications** 84

E.O. Malysheva, E.M. Volfovich, N.A. Vasilyeva, M.S. Doronina, A.I. Leybenko & N.A. Kukina: **Paleogeographic reconstructions in Western Barents Sea, Stø formation (J1-J2)** 85

G.M. Manby & N. Lyberis: **The North Greenland dyke swarm within the Greenland-Svalbard convergence zone** 87

E.L. Miller, T.A. Dumitru, M.J. Grove, E. Gottlieb, K. Meisling & V.V. Akinin: **Re-interpretation of the structural geology of Wrangel Island based on the onshore geology of Chukota and offshore deep crustal seismic data** 88

A.V. Moiseev, S.D. Sokolov, M.I. Tuchkova & V.E. Verzhbitsky: **Early Carboniferous (?) volcanic complex of the Wrangel Island** 90

D.C. Mosher, D. Hutchinson, L.A. Mayer, C. Marcussen & J. Verhoef: **Geoscience for extended continental shelf mapping in the Arctic Ocean** 92

A. Mørk & B.A. Lundschien: **The Triassic Svalbard Hydrocarbon Play Model; A prospective model for the Barents Shelf** 94

F. Niessen, R. Stein, L. Jensen, M. Schreck, J. Matthiessen, W.M. Jokat, J.K. Hong & S.-Il Nam: **Pleistocene ice-grounding events along the East Siberian margin and on the Lomonosov Ridge: Implications for circum-arctic ice shelves in the Arctic Ocean?** 96

G.N. Oakey & R.W. Saltus: **Sever Spur - Chukchi Plateau: Conjugate Margins?** 97

V.V. Obmetko, N.A. Malyshev, T.M. Streltsov, V.E. Verzhbitskiy, A.A. Borodulin, Yu.V. Reydik & B.I. Ikhsanov: **Results of the Arctic Shelf Exploration Works performed by Rosneft in 2012–2014** 99

G. Odden, A. Minakov & J. Schweitzer: **The lower crust and upper mantle beneath Svalbard and the Western Barents Sea: evidence from combined active-source and array seismology........** 101

O. Olesen, M. Brönner, E. Dalsegg, O. Fredin, J.S Rønning & T. Solbakk: **The strandflat - a Mesozoic weathered paleosurface exhumed and eroded in the Pleistocene?** 103

P.T. Osmundsen, A. Braathen & H. Maher: **Structural framework at the NE Atlantic-Arctic margin junction: the Devonian Keiserhjelmen Detachment, Northern Svalbard** 104

G. Panieri, A. Lepland, C. Graves, A. Schneider, C. Consolaro, W. Hong, R. James & J. Mienert: **Fossil bioarchives to discover and track methane releases in the Arctic** 105

Z. Pastore, C. Fichler & S. McEnroe: **Potential field modelling of the Seiland Igneous Province in the geodynamic framework of the northern Baltican margin** 107

I. Pathirana & J. Knies: **Holocene primary productivity variability and sea ice coverage in the western Barents Sea** 108

H. Patton, K. Andreassen, M.C.M. Winsborrow, A. Auriac & A. Hubbard: **Numerically modelling extensive glaciation of the Eurasian Arctic** 109

V. Pease & I. Nobre Silva: **Age and geochemistry of Cretaceous basalts from Axel Heiberg, Canada** 110

O. Petrov, M. Smelror, A. Morozov, N. Sobolev, G. Grikurov, S. Shokalsky, I. Pospelov, S. Kashubin & E. Petrov: **Structural-tectonic zoning of the Arctic** 111

K. Piepjohn, W. von Gosen, F. Tessensohn & L. Reinhardt: **The Eurekan deformation in the Arctic – architecture and kinematics of a strange foldbelt** 113

A. Plaza-Faverola, S. Vadakkepuliyambatta, K. Waghorn, J. Johnson, J. Mienert & S. Bünz: **Seismic characterization of a > 100 km long hydrate province close to an oceanic ridge-transform fault complex in Fram Strait, Arctic Ocean** 115

L. Polyak, D. Dove, S. Kim, S.-Il Nam, F. Niessen & B. Coakley: **A complex pattern of marine glaciations on the Amerasian Arctic margins** 116

A. Portnov, S. Vadakkepulyambatta, J. Mienert & A. Hubbard: **Arctic methane storage and release across a formerly glaciated polar margin** 117

V.A. Poselov, V.V. Butsenko, S.M. Zholondz & A.A Kireev: **Seismic stratigraphy of sedimentary cover in Central Arctic Uplifts Complex, Amerasia Basin** 118

A.V. Prokopiev, V.B. Ershova, O.A. Anfinson, A.K. Khudoley, D.A. Vasiliev & D.F. Stocki: **Mesozoic-Cenozoic Tectonic History of New Siberian Islands** 120

T.F. Redfield & E.R. Lundin: **Wiping the Arctic Windshield: On plate kinematics, hyperextension, and Alpha-Mendeleev magmatism** 122

L. Reinhardt, K. Piepjohn, W. von Gosen & S. Estrada: **Early Cenozoic Eurekan deformation: Attempts to refine the dating of deformation phases** 123

Yu.V. Reydik, N.A. Malyshev & V.V. Obmetko: **Hydrocarbon potential of the Russian Western Arctic: New data and the results of exploration in the Pechora and Barents seas** 124

D. Roberts, A. Nasuti & L. Gernigon: **Blind mafic dykes of Ediacaran, Devonian and Carboniferous age revealed by high-resolution aeromagnetic data, Finnmark Caledonides, North Norway** 126

V. Schlindwein & F. Schmid: **Contrasting spreading processes at Gakkel Ridge across 3°E boundary shaped the Arctic Ocean lithosphere** 127

M.C. Schmidt-Aursch & W. Jokat: **Tectonics and magmatism of the western Gakkel Ridge** .. 128

G. Shephard & C. Gaina**: Reconstructing extinct and current Arctic oceans from surface and mantle constraints** 129

J. Shimeld, Q. Li, D. Chian, N. Lebedeva-Ivanova, R. Jackson, D. Mosher & D. Hutchinson: **Spatial trends of seismic velocity within the sedimentary succession of the Canada Basin and southern Alpha-Mendeleev Ridge: Evidence for accelerated porosity reduction?** 130

E.V. Shipilov: **On the strike slip zone between Chukotka and Arctic Alaska and the possible mechanism of the disclosure of the Canadian Basin** 131

A. Shulgin & R. Mjelde: **Crustal structure of the South Barents Sea shelf** 133

N.N. Sobolev, L.A. Daragan-Suscheva & E.O Petrov: **New data on structural and tectonic zoning and evolution history of the Northeast Arctic** 134

C. Tegner, N.H. Stolbov, H. Svensen, E.L. Brown & S. Planke: **Cretaceous magmatism of Svalbard and Franz Josef Land: Petrogenesis of the High Arctic Large Igneous Province** 136

E.V. Vatrushkina, S.A. Sergeev & S.D. Sokolov: **Composition and geochronology of the Cretaceous volcanic formations, Central Chukotka** 137

V.E. Verzhbitskiy, N.A. Malyshev, V.V. Obmetko, A.A. Borodulin & I. Ikhsanov: **Geology and hydrocarbon potential of the East Siberian - Chukchi Sea region** 139

E. Weigelt & W. Jokat: **Seismostratigraphy of the Eastern Makarov Basin and adjacent Lomonosov Ridge and Mendeleev Ridge** 140

M. Winsborrow, K. Andreassen, A. Hubbard, A. Plaza-Faverola & E. Gudlaugsson: **Gas hydrate regulation of ice stream flow** 141

X. Zhang, V. Pease, J. Skogseid & C. Wohlgemuth-Ueberwasser: **U-Pb detrital zircon provenance investigations of late Paleozoic to Mesozoic sandstones from Taimyr Peninsula, Russia, and their tectonic implications** 142

K.J. Zieba & M. Felix: **How to assess glacial sedimentary conditions in the light of missing local data?** 143

Abstracts

Late Cenozoic evolution of the western Barents Sea - Svalbard continental margin. Case study: Upper Bjørnøya Fan, western Barents Sea margin

Alexandropoulou, N.[1], Andreassen, K.[1], Winsborrow, M.[1], Faleide, J.I.[2] & Nystuen, J.P.[2]

[1]CAGE - Centre for Arctic Gas Hydrate, Environment and Climate, Department of Geology, UiT The Arctic University of Norway, Tromsø, Norway; [2]University of Oslo, Department of Geosciences, Faculty of Mathematics and Natural Sciences

Both pre-glacial and glacial history is reflected in the present day topography of the Barents Sea region. One of the most striking topographic features is the series of large depositional fans located at the mouth of cross-shelf troughs (trough-mouth fans) along the western Barents Sea-Svalbard margin. The fans are depocenters dominated by debris flows accumulated in front of ice streams draining former large ice sheets (Vorren & Laberg 1997). As such, they represent an excellent source of information on past glacial fluctuations.

Within the Plio-Pleistocene sedimentary succession along western Barents Sea-Svalbard margin, three main sediment packages (GI-GIII) and seven regionally correlatable reflectors (R7-R1) were identified almost 20 years ago (Faleide et al. 1996). Since then a large number of high-resolution seismic datasets have been acquired, providing the opportunity for more detailed studies. We use an extensive 2D and 3D seismic dataset to update and improve the existing Plio-Pleistocene chronostratigraphy. In this poster, we present a case study from Bjørnøya Fan, by far the largest fan along this margin, recording a ~2.7 million year history of ice sheet dynamics in the Barents Sea.

In this study, we interpret the main sediment packages and reflectors of the glacial sediments forming the Bjørnøya Fan, with a focus on refining and expanding our understanding of the chronological and environmental framework for their deposition. In doing so, we test the hypothesis that individual seismic sequences in the Bjørnøya Fan represent ice advance-retreat-readvance cycles.

Patterns of past ice-sheet flow in the Barents Sea

Andreassen, K.[1], Bjarnadóttir, L.R.[2], Winsborrow, M.C.M.[1], Patton, H.[1] & Hubbard, A.[1]

[1]CAGE - Centre for Arctic Gas Hydrate, Environment and Climate, Department of Geology, UiT - The Arctic University of Norway, Tromsø, Norway; [2]Geological Survey of Norway (NGU), Trondheim, Norway

The Barents Sea continental shelf was covered by grounded ice reaching the shelf breaks in the west and north during the Late Weichselian Glacial Maximum. Improved understanding of process dynamics and patterns during the retreat of the former Barents Sea Ice Sheet has relevance far beyond the regional scale, as this palaeo-ice sheet offers a good geological analogue to the contemporary West Antarctic Ice Sheet. Initial ice sheet retreat along its western margin is well established, while the retreat patterns in the interior parts of the ice sheet remain less known. Here we present geophysical data from the central and northern Barents Sea, including geomorphological mapping of the seafloor and buried surfaces as well as analyses of seismic stratigraphy, based on multibeam swath bathymetry, 2D and 3D seismic data. The results significantly advance our understanding of important process dynamics related to the retreat of a marine-based ice sheet. In particular, they reveal clear changes in location of main ice divides and domes, with ice flow becoming gradually more topographically controlled as deglaciation progressed. Major troughs were characterised by episodic retreat and reoccurring cycles of fast and slow ice flow, sometimes leading to stagnation and ice shelf formation, whereas ice retreated more slowly from adjacent bank areas. Empirical results will be compared with new results from numerical ice-sheet modelling output, providing potential insight into the drivers governing the complex flow patterns observed across the Barents Sea continental shelf.

New insights on the glacial history of North-East Greenland from swath bathymetric data

Arndt, J.A., Jokat, W. & Dorschel, B.

Alfred Wegener Institute, Bremerhaven, Germany

The present-day shape of the Greenland ice sheet represents its extent during an interglacial. Information on its past dynamic during glacials is preserved as submarine glacial features on the Greenland continental shelves. However, large areas of the continental shelves are unmapped or only poorly covered by bathymetric soundings. Hence, little is known on the extent and retreat of the ice after the Last Glacial Maximum (LGM) here. This is also the case for the North-East Greenland continental shelf. Here, the East Greenland Current is continuously exporting Arctic sea ice. In addition, in the Arctic winter large areas of landfast ice are developing at the coast and on shoals of the continental shelf that only seldom break up. These conditions make this area only hardly accessible to research vessels. Nevertheless, two studies based on single track lines of high resolution multibeam bathymetric data showed that Westwind Trough was covered by a fast flowing ice stream reaching at least to the middle shelf. Radiocarbon dating even suggested that probably the LGM ice extended to the shelf edge, but direct marine evidence was missing.

We have investigated newly acquired and re-processed swath bathymetric data and sub-bottom profiler data from 19 cruises of RV Polarstern from 1985 until 2014 for glacial seafloor features. These features shed light on the past ice sheet configuration and LGM retreat. Amongst others, our study gives first marine evidence for ice stream activity in Norske Trough and in general a more intense ice streaming activity on the shelf. In addition, our data indicates that possibly a small separate ice sheet was present offshore the modern day Greenland coast.

Mechanism of crustal subsidence in deep Arctic basins

Artyushkov, E. V.[1], Chekhovich, P.A.[1,2] & Petrov, E.I.[3]

[1]Institut of Physics of the Earth, Moscow, Russian Federation; [2]The Earth Science Museum at Moscow State University, Russian Federation; [3]The Federal Subsoil Resources Management Agency «ROSNEDRA», Moscow, Russian Federation

The East Barents and North Chukchi basins, 18-20 km deep, are underlain by strongly attenuated crystalline crust. This layer is characterized by a high density and P-wave velocities typical of oceanic crust. However the subsidence history was quite different in them from that of oceanic crust. Thus, the East Barents Basin evolved for several hundreds of millions years and one half of the deposits was formed in it ≥ 100 m.y. after the start of the subsidence when the subsidence of oceanic crust would be already over. Furthermore, the basins are 3-5 km deeper than would be expected if the isostatic compensation occurred at the Moho boundary. This indicates the existence of a layer of dense eclogites, ~20 km thick, under the Moho. These basic rocks which pertain to the crust by their composition ensure a large additional subsidence of this layer. The occurrence of high density rocks under the Moho is confirmed by a joint analysis of the gravity and seismic reflection profiling data. In a presence of only moderate stretching at the basement, gabbro to eclogite transformation appears to be the main cause of formation of the basins.

Similarly, as can be seen in the last profiles by W. Jokat, only minor stretching occurred at the basement of the Lomonosov Ridge. This implies that its predominantly water loaded subsidence by 1.0-2.5 km in the Miocene also resulted from the transformation of gabbroids in the crust into denser garnet granulites and eclogites.

Some authors suppose the existence of a large transform fault separating the Lomonosov Ridge and Podvodnikov Basin from the adjacent Asian shelf. Such a fault cannot be seen in long seismic profiles crossing these structures that were carried out in 2014. This indicates that the Lomonosov Ridge is welded to the Asian shelf and the divergent boundary between the Eurasian and North American plates continues from the Gakkel Ridge into the Moma rift zone beneath the Northeastern Asia.

Supported by RFBR grant 15-05-08539

A Project Proposal: Compilation of a new Digital International Quaternary Map of the Arctic (IQUAMAR)

Asch, K. & Kümpel, H.-J.

Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Stilleweg 2, 30655 Hannover, Germany

The Arctic has been a focus of geological interest for the adjacent countries for many years, including with respect to its supposed potential for hydrocarbon and mineral resources. By now, map compilations such as the Geological Map of the Arctic 1 : 5 000 000 (GSC, VSEGEI, VNIIOkeangeologia, USGS, SGU, NGU and GEUS, 2009) have concentrated on the Pre-Quaternary geology including geological structures, faults, contacts, spreading ridges etc.

At present, BGR is leading the review of the International Quaternary Map of Europe (IQUAME 2500) and its transformation into a geographical information system (GIS). The comprehensive modi operandi, procedures and guidelines being developed can be brought in the creation of a so far missing Quaternary geological map of the Arctic. Such a map would, for the first time, summarize the actual status quo of research on Quaternary geology in the Arctic in form of a digitally available synthesis. Subjects of the map would include:

- The geological boundaries and classifications of the Quaternary rocks both unconsolidated sediments and bedrock as well as young volcanic extrusions,
- the extension and boundaries of permafrost,
- the last glacial maxima,
- active faults,
- submarine exhalations of gas hydrates (cold seeps),
- geomorphology/landforms,
- submarine currents and their impact on the ocean floor etc.

The projected “IQUAMAR” is thought to be a geoinformation system that would allow future generations of geologists to select specific information and easily create or develop new maps for various subjects and purposes, e.g.:

- hazards due to marine earthquakes and the necessity of coastal protection using the information about submarine sediments, active faults, young volcanism, mud volcanoes, cold seeps;
- dredging conditions for the building of pipelines (permafrost occurrence/distribution/boundaries and depth, sedimental grade of consolidation);
- visualization of palaeo-climate (sea level rise, relocation of the coastline, peat deposits, glacial regression, loess distribution, soil development, transfer of ecosystems, biodiversity, epi-, endo- and ecto-benthos);
- recommendation maps for sand and gravel excavations, peat extraction, heavy metal from placer deposits;
- base for decision makers for measures to conserve the circumpolar biodiversity and diversity of species (e.g. Northern seas fishing).

The endeavor is already being supported by the International Arctic Science Committee (IASC). For the Alfred Wegener Institute for Polar and Marine Research (AWI), like for other research institutions, the IQUAMAR would support process-oriented studies of the palaeo-environment (e.g. concerning the temporal and spatial interaction of permafrost with glacial regions).

Clearly, data availability presents a major challenge: The Arctic is not as thoroughly explored as e.g. Western or Central Europe – the Arctic Ocean shows numerous „white patches“, where no mapping campaign has ever been realized: So far only few ship expeditions with geophysical explorations (seismic, hydro acoustic) and sampling campaigns have taken place (e.g. the IODP campaign at the Lomonossov Ridge). In addition, though VSEGEI, USGS and GSC already showed interest in the participation, the free data release is still an issue. Further challenges include the typical issues any international mapping project needs to solve: Discrepancies of geological units and classification at national boundaries, differing scales and willingness to cooperate.

This presentation will show the potential contents of the projected IQUAMAR GIS, give an overview about the challenges and give an outlook on future applications and opportunities linked to such a compilation.

References:

BGR and UNESCO (1962-2005): International Quaternary Map of Europe. BGR. Hannover

Harrison, J C; St-Onge, M R; Petrov, O V; Strelnikov, S I; Lopatin, B G; Wilson, F H; Tella, S; Paul, D; Lynds, T; Shokalsky, S P; Hults, C K; Bergman, S; Jepsen, H F; Solli, A (2011). Geological Map of the Arctic. Natural Resources Canada. Ottawa

Foraminiferal communities of hydrocarbon seeps from the continental shelf offshore Vesterålen, Northern Norway

Baranwal, S.[1], Knies, J.[1, 2] & Sauer, S.[1, 2]

[1]Centre for Arctic Gas Hydrate, Environment and Climate, University of Tromsø, NO-9037 Tromsø, Norway; [2]Department of Geological Survey of Norway, (NGU), 7491 Trondheim, Norway (E-mail: soma.baranwal@ngu.no)

A video survey conducted in the Hola area, offshore Vesterålen, northern Norway, has revealed active gas venting, bacterial mats, carbonate crusts and cold-water coral reefs. The present study investigated total (unstained) benthic foraminiferal assemblages from Hola-Vesterålen around 68°55 N 14°17 E, at around 220 m water depth. A major NE-SW fault runs along the area where ice removal after the last ice age is believed to have re-activated passage ways for the release of hydrocarbons from deeper formations. The CTD recorded temperatures of ˜7˚C and higher dissolved methane concentrations along the bottom of the water column. Following Whiticar's (1999) model, the methane source was found to be from an early mature thermogenic source with some contribution of microbial methanogenesis as well. Fifty-six (1 cm) sediment samples were collected with 5 cm spacing from the top to the bottom of gravity core GC-51 (310 cm long) for micropaleontological analyses. The radio carbon dating estimates the age of the bottom sediment of core GC-51 to be at ˜37 Ka B.P. Several intervals of the sediment downcore are poor in planktonic foraminifera content, whereas benthic foraminifera occur throughout the whole core.

The benthic foraminiferal assemblage from the surface sediment 0-1cm (>100 µm) reveals fauna characteristic of coral mounds (*Discanomalina coronata*) with high current velocities (e.g., *Cibicides lobatulus*) and high nutrient flux. However, *D. coronata* disappears completely downcore in GC-51 and *C. lobatulus* reduces in abundance downcore. Core top samples with low diversities also contain deformed individuals of *C. lobatulus* (3.4-6.5 %), similar to those reported from a gigantic oil spill or for environments polluted with heavy metals. However, it is an attached form and prefers hard substrates. Thus, the variability in the shape of the test in this species is primarily caused by the nature of the substratum. We do not find deformities in any other species.

The stable carbon isotopic results from Hola-Vesterålen ranges between -0.2 and 0.34 ‰ with most values around -1 ‰. Distinct negative δ13C peaks (*Cassidulina reniforme*) occur at 5.79 ka (-2.01 ‰; 27 cm) and 10.49 ka (-2.69 ‰; 77 cm) directly above the present sulphate-methane transition zone (SMTZ, ~90 cm). Towards the base of the core (260-270 cm), lighter values (-1.63‰, -1.86‰) occur above the glacial diamicton characterized by reworked AMS14C datings (31.18 and 32.35 ka). The lighter δ13C values around the present SMTZ and above may be primary signals of episodic past seepage events. Secondary overgrowth of calcite with lower δ13C occurred at variable depths of the SMTZ as a result of abundant isotopically light dissolved inorganic carbon produced during anaerobic oxidation of methane. An important sedimentary event is evident at ˜11 Ka B.P. with drastic lowering of >100 µm fraction downcore and corresponding change in benthic assemblage and a negative δ13C peak.

This work was partly supported by the Research Council of Norway through its Centres of Excellence funding scheme, project number 223259.

References:

Whiticar, M.J., 1999. Carbon and hydrogen isotope systematics of bacterial formation and oxidation of methane. Chemical Geology, 161(1–3): 291-314.

Sediment maps of the Norwegian and Barents seas

Bellec, V.K., Bøe, R., Plassen, L., Baeten, N., Olsen, H., Ottesen, D., Bjarnadóttir, L.R., Lepland, A., Thorsnes, T., Dolan, M. & Elvenes, S.

Geological Survey of Norway, Trondheim. (E-mail: Valerie.Bellec@ngu.no)

The Norwegian seabed mapping programme MAREANO (www.mareano.no) has mapped more than 140 000 km^2 of the Norwegian offshore areas. MAREANO has acquired multibeam bathymetry and backscatter, seabed samples, videos and high resolution shallow seismic data. These data provide the basis for the mapping of the seafloor in terms of geology, sedimentary processes and habitats.

Seabed sediment maps (scale 1:100 000) of the Norwegian offshore area have been produced between 62°N and 73°N. Other derived products show sedimentary environments, genesis of sediments, landscapes and landforms and bioclastic sediments (mainly from coral reefs). All these products are available on www.mareano.no.

The sediment maps are based on multibeam echosounder data of variable quality and origin. Olex single beam data were used in parts of the Mørebankene area. Multibeam backscatter data, which provide information on the hardness and roughness of the seabed, were mostly acquired simultaneously with the bathymetry data, except for some of the old multibeam surveys. Observations from video transect data guided the interpretation of the backscatter data with regard to sediment classes. The final sediment maps are to a large degree based on interpreted backscatter data.

The general pattern of distribution for different sediment grain size classes is nicely portrayed in MAREANO's seabed sediment maps; Firstly, the sediments of the continental shelf tend to be finer in glacial troughs and coarser on shallow banks. Secondly, coarse sediments are found on the upper continental slope (gravelly sand and sandy gravel). Thirdly, downslope, the sediments become finer and consist mainly of muddy sandy gravel and gravelly sandy mud. Finally, the deep-sea plains covered in our study area are mainly characterized by slide blocks and slide deposits partly covered by mud.

British Geological Survey remotely operated sea bed rockdrills and vibrocorers: new advances to meet the needs of the scientific community

BGS Marine Geoscience (presented by Dayton Dove[1])

[1]British Geological Survey (BGS), Edinburgh, United Kingdom (dayt@bgs.ac.uk)

The British Geological Survey (BGS) have developed a number of coring and drilling systems for use in science projects in the UK and internationally. These include 3m and 6m vibrocoring systems; a 5m combined rockdrill and vibrocorer system; an oriented drill designed specifically to recover samples for use in palaeomagnetic studies; and a 55m rockdrill (RockDrill2).

The BGS have developed a 55m rockdrill (RockDrill2), a remotely operated sampling system capable of coring up to 55 m below sea floor in water depths up to 4000 m. The rockdrill can be operated via its own launch and recovery system and can be outfitted with additional sensors such as gas flow meters, which have been designed by the BGS for assessing volume of gas hydrate, and down-hole logging tools. The 55m rockdrill has recently been used to sample hydrate-entrained sediments in the Sea of Japan. The maximum coring depth achieved was 32 m below sea floor and the system can operate for more than 50 hours on a single deployment. The BGS system will be used in conjunction with the Bremen University (MARUM) MeBo sea-floor rockdrill on future International Ocean Discovery Program (IODP) expeditions.

The BGS have also developed an autonomous, battery-operated vibrocoring system compatible with both the 3m and 6m vibrocorers, which can be used in water depths up to 6000 m. Use of a battery system negates the use of an umbilical power cable to operate the vibrocorer, which instead can be deployed using the vessels A-frame and winch. The autonomous battery system comprises six 48V 19Ah batteries connected in series to give 288 V power source, a microprocessor and real-time clock. Data from the sensors are recorded with a time-stamp, giving diagnostic information that can be downloaded once the system is returned to the deck. The vibrocorer is operated via a pre-set program which is set up before deployment. The new system not only allows vibrocoring in greater water depths, but can also be used on smaller vessels where deck space is limited as a separate winch and umbilical is not required. The autonomous system was used for the first time in June 2014 on-board the R\V Belgica to acquire samples from 20 sites in the Dangeard and Explorer canyon heads, off the southwest of England in 430 m water depth.

Gloeocapsomorpha prisca in Early Silurian source rocks of the northern East Siberia

Bogolepova, O.K.[1] & Gubanov, A.P.[2]

[1]CASP, University of Cambridge, West Building, 181A Huntingdon Road, Cambridge, CB3 0DH, UK (olga.bogolepova@casp.cam.ac.uk); [2]SCANDIZ, Grönsångarvägen 22, Skokloster, 746 95, Sweden

Organic-rich shales in the Early Silurian Pravy Atyrdyakh Formation of north-western Anabar, East Siberia, show optical and chemical characteristics that are very similar to those of the Ordovician oil shales (e.g. Estonian kukersites), whose organic matter is dominated by *Gloecapsomorpha prisca*-derived alginite.

Gloeocapsomorpha prisca was a major contributor to kerogens sourcing most Ordovician oils. In spite of extensive studies, to date, no agreement has been made concerning the nature and the ecology of this organism, and the mechanism for accumulation of beds rich in *G. prisca*. Foster *et al*. (1989) suggested they must have been mat-forming cyanobacteria. *G. prisca* was widespread in low latitude tropical epicontinental seas during the Ordovician time. There are very few records of *G. prisca* occurring in post-Ordovician sediments, e.g. as young as Late Devonian (Fowler *et al*. 2004). The presence of *G. prisca* as a main contributor to the Rhuddanian Pravy Atyrdyakh potential source rocks and not to any other Silurian source rocks in the East Siberian Basin adds more information about the post-Ordovician history of this organism. After the Ordovician-Silurian extinction event, and the appearance of the major groups of phytoplankton, this cyanophyte survived in shallow water, near-shore and lacustrine environments that are generally not considered good to source rock development.

References:

Foster, C.B., Reed, J.D. & Wicander, R. 1989. *Gloeocapsomorpha prisca* Zalessky, 1917: A new study. Part I: Taxonomy, geochemistry, and paleoecology. Geobios, 22 (6), 735-759.

Fowler, M.G., Stasiuk, L.D., Hearn, M. & Obermajer, M. 2004. Evidence for *Gloeocapsomorpha prisca* in Late Devonian source rocks from southern Alberta, Canada. Organic Geochemistry, 35, 425-441.

Pilot apatite fission-track study of the Furongian sandstones from Severnaya Zemlya, Russian Arctic

Bogolepova, O.K.[1], Carter, A.[2] & Gubanov, A.P.[3]

[1]CASP, University of Cambridge, West Building, 181A Huntingdon Road, Cambridge, CB3 0DH, UK (E-mail: olga.bogolepova@casp.cam.ac.uk); [2]Department of Earth and Planetary Sciences, Birkbeck, University of London, London, WC1E 7HX, UK ; [3]SCANDIZ, Grönsångarvägen 22, Skokloster, 746 95, Sweden

Sandstones, collected from the Late Cambrian (Furongian) Kurchavaya Formation exposed in the south-east of October Revolution Island of the Severnaya Zemlya Archipelago were subjected to apatite fission track analysis to determine their low temperature (<110°C) thermal histories. Apatite yields were generally poor but one sample yielded a Late Devonian central age with surprisingly long (> 14µm) mean track lengths indicative of rapid cooling followed by long—term residence at shallow crustal levels. This is confirmed by the fission track thermal history model that shows rapid cooling to <50° between 360-390 Ma and no significant reburial thereafter, i.e. the sampled rock remained at or below a depth of c. 2 km since the Late Devonian. Whether this sample is representative of the region is no yet known. If so it would imply that the Uralian and Cimmerian deformations recognized on Novaya Zemlya and Taimyr (Scott & Carter 2009, unpublished CASP report) did not affect this part of Severnaya Zemlya. More AFT work is required, especially from the Bol'shevik Island of Severnaya Zemlya to test if this is the case.

References:

Scott, R.A. & Carter, A. 2009. Apatite fission track data from southern Novaya Zemlya and northeastern Taimyr. CASP 2008-2010 Arctic Research & Database Project, Module 8, 1-21.

Deformational history of Alaska

Box, S.E.[1] & Moore, T.E.[2]

[1]United States Geological Survey, Spokane, WA, USA (E-mail: sbox@usgs.gov); [2]United States Geological Survey, Menlo Park, CA, USA

The structural architecture of Alaska is the product of a complex history of deformation that occurred along both the Cordilleran and Arctic margins of North America through interactions with ancient and modern ocean plates and with continental elements derived from Laurentia, Siberia and Baltica. To analyze these events, we use geological constraints to assign areal shortening deformation (and penetrative extensional deformation) to 13 time intervals and map their distributions in Alaska. Episodes of brittle normal and strike-slip faulting are noted but not mapped.

We interpret the new maps to indicate that the geology of Alaska can be divided into three domains with differing histories of deformation. The northern domain north of the Cenozoic right-slip Tintina and Kaltag faults was involved in a progressive oceanic arc-continent collision that produced the Early Cretaceous Brookian orogeny whose high-pressure metamorphic core experienced a subsequent mid-Cretaceous extensional overprint. Many authors interpret fan-like opening of the oceanic Canada Basin to have rifted the orogen from the Canadian margin, producing the bent trend of the orogeny, either during or after the collisional event.

The second domain lies south of the Cenozoic right-slip Denali Fault in southern Alaska and includes a long-lived oceanic magmatic arc terrane and its paired accretionary prism. The Peninsular and Wrangellia arc terranes were amalgamated by Middle or Late Jurassic tectonic events. The Chugach forearc preserves a discontinuous record of accretion since the Early Jurassic, interrupted by episodes of subduction erosion, Paleocene spreading ridge subduction and Neogene subduction of the Yakutat terrane.

The third domain, situated between the first two domains and roughly bounded by the Denali and Tintina faults, includes the large Farewell (Baltic origin) terrane and both allochthonous and para-autochthonous components of the Yukon-Tanana (Laurentian origin) metamorphic terrane. These terranes display unrelated(?) episodes of Permian collisional deformation (Browns Fork and Klondike orogenies); a later episode of Middle Jurassic penetrative deformation affected only the composite Yukon-Tanana terrane. We have not identified a shared deformation between these two terranes that might mark their juxtaposition by collisional processes. Instead, their first linkage is marked by detritus derived primarily from the Yukon-Tanana terrane deposited in deep Late Cretaceous sedimentary basins atop the adjacent Farewell terrane. Similar early Late Cretaceous linkages stitch the northern and central domains. Late Late Cretaceous folding and thrusting across much of Alaska south of the Brooks Range is driven by the collision of the Peninsular-Wrangellia terrane with the remainder of Alaska. Early Cenozoic shortening is mild across much of the state but is significant in the Brooks Range, while Late Cenozoic shortening is significant in southern Alaska inboard of the underthrusting Yakutat terrane at the Pacific margin subduction zone.

U-Pb detrital zircon geochronology of dredged metasediments from the Northwind Ridge, Arctic Ocean: Is the Chukchi Borderland part of Crockerland

Brumley, K.[1], Grove, M.[2], Meisling, K.E.[2] & Mayer, L.A.[3]

[1]Fugro GeoConsulting, Houston, TX, USA (E-mail: kbrumley@fugro.com); [2]Geological Sciences, Stanford University, Stanford, CA, USA (E-mail: mjgrove@stanford.edu; kmeisling@comcast.net); [3]Center for Coastal and Ocean Mapping, University of New Hampshire, Durham, NH, USA (E-mail: larry@ccom.unh.edu)

Detrital zircon studies from the circum-Arctic have attempted to answer questions about the complicated tectonic history of the Arctic region by comparing information collected from land around the Arctic margins. Correlation of these data sets is complicated partly by the formation of the Arctic Ocean that has separated these regions by broad drowned continental shelves and the submerged continental fragments within the Arctic Ocean itself. Prior to 2008, published information was sparse on *in situ* geologic samples from the bathymetric features within the Arctic Ocean that could provide ground truth as to their geologic nature. As part of the U.S. Extended Continental Shelf project, seventeen dredges were collected between 2008-2012 aboard the USCGC Healy (cruise numbers HLY0805, HLY0905, HLY1202; Mayer & Armstrong 2008, 2009, 2012) to answer first order questions about the geology of the bathymetric highs bordering the Canada Basin. Most of these dredges sampled submarine outcrops, and these samples of *in situ* rock, provide important information for tectonic reconstruction models of the Arctic Ocean. Here we present lithological descriptions and detrital zircon U-Pb age data from dredged meta-sedimentary rock samples from a site (DR7) on the northern edge of the Chukchi Borderland.

The Chukchi Borderland, a prominent bathymetric feature within the Arctic Ocean, has been interpreted as an undeformed continental remnant correlated to either the Franklinian carbonate shelf margin of the Canadian Arctic Islands or to the resedimented carbonates of the Franklinian Basin. Both the Franklinian and the Sverdrup Basins in the Canadian Arctic received periodic sediment input from an "exotic" northerly source rather than from the intermittently exposed Sverdrup Rim which was composed of uplifted Franklinian rocks (Miller et al. 2006; Lane 2007; Colpron & Nelson 2009, 2011; Beranek et al. 2010). This northerly sediment source is inferred to have been an arc-related terrane (Anfinson et al. 2012) that Embry (1988, 1992, 2009) and Lane (2007) proposed to consist of a large landmass located north of the basin. This northerly landmass has been referred to as "Crockerland" and it has been suggested that its accretion against Laurentia was responsible for Paleozoic deformation in the region. The lithology and U-Pb zircon age distributions measured from the dredged metasedimentary rocks of DR7 in the Chukchi Borderland are very similar in age to zircons analyzed from dredged basement samples from another dredge site in the Borderland (HLY0905-DS5). The immature, first-cycle character of the DR7 lithic sandstones suggest that they were probably directly eroded from Chukchi Borderland basement rocks (Figure 1). The existence of these basement rocks and derivative sediment indicate that the Chukchi Borderland is highly unlikely to be a tectonically displaced fragment from the Laurentian passive margin as was previously thought. We propose, instead, that the Chukchi Borderland was a magmatically active terrane during the latest Neoproterozoic and Late Ordovician-Silurian and experienced subsequent mylonitic deformation. In our model, the immature arc-derived metasediments from DR7 are evidence that the Chukchi Borderland was a detrital source for sediments attributed to Crockerland (Figure 1).

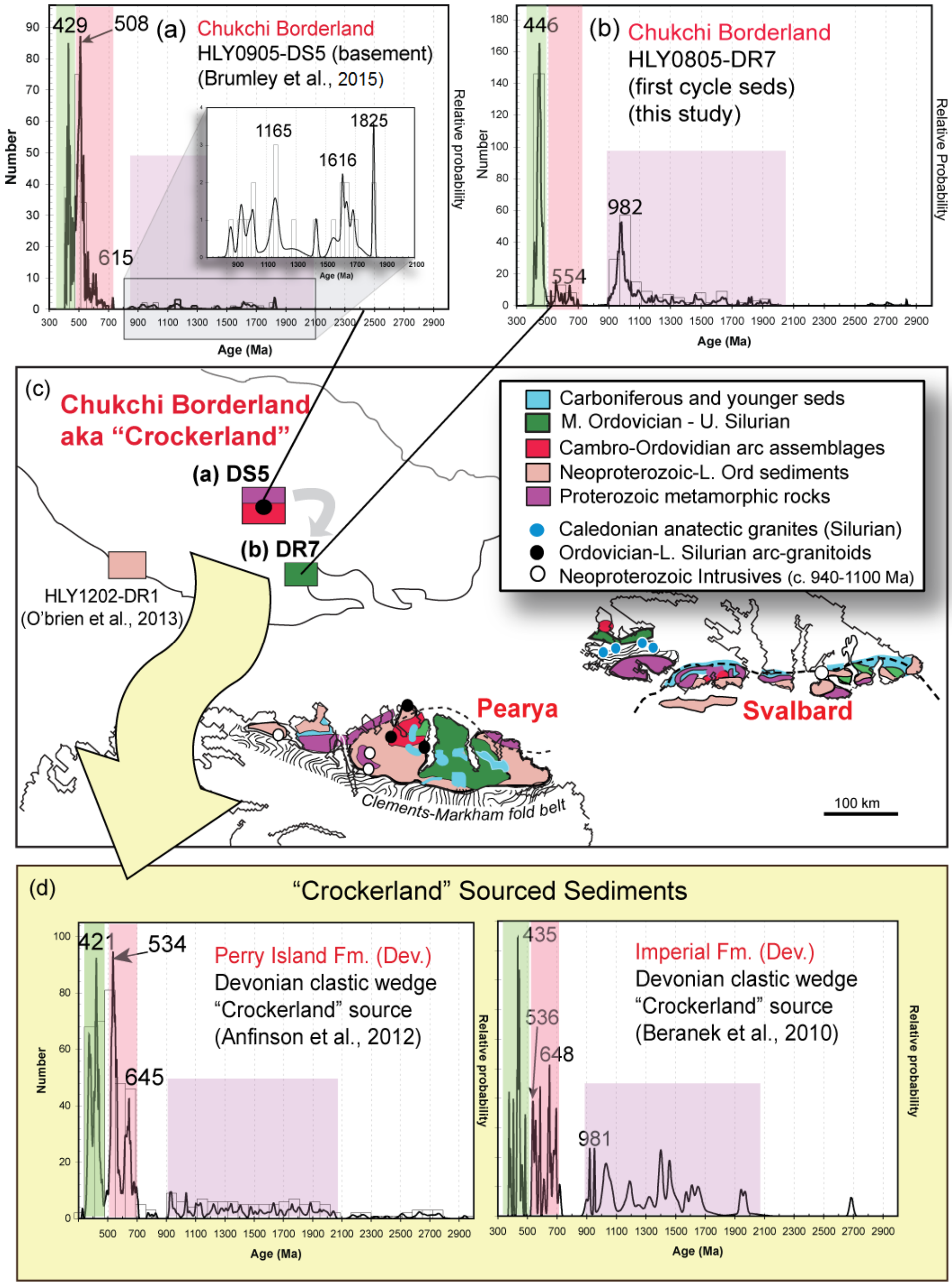


Figure 1 (a): Probability density curve of all zircons collected from crystalline basement sampled from HLY0905-DS5 dredge (all amphibolite grade metamorphic): 420-465 Ma ages (429 Ma peak) are from K-spar augen gneisses, 480-530 Ma (508 peak) ages are from metamorphic zircon in amphibolites and zircon overgrowths in gneisses, 580-680 Ma ages are from feldspathic gneisses. The older Proterozoic ages are from inherited zircon cores (Brumley et al., 2015) **(b) Probability density curve of all DR7 zircons from metamorphosed immature sediments from this study. Colorbars correspond to age ranges found in detrital zircon data sets assumed to be the fingerprint for "Crockerland"**.(c) Generalized geologic maps of Pearya (modified from Trettin 1998) and western Svalbard (modified from Dallmann et al. 2002) showing correlative rocks types of dredged rock samples from the Chukchi Borderland that correspond to (a,b). Small grey arrow illustrates that the basement rocks from DS5 were probably the source rocks for the sediments of DR7. Large yellow arrow illustrates that Chukchi Borderland could have been a source region for Franklinian Basin sediments (d) assumed to have been from Crockerland (360-470, 500–700, 900-2100 and rare 2550-3000 Ma).

The crustal structure of the Amundsen Basin in the Arctic Ocean derived from seismic refraction data

Castro, C.F.[1], Funck, T.[2] & Hopper, J.R.[2]

[1]Niels Bohr Institute, University of Copenhagen, Juliane Maries Vej 30, 2100 Copenhagen, Denmark (E-mail: cfc@geus.dk); [2]Geological Survey of Denmark and Greenland (GEUS), Øster Voldgade 10, 1350 Copenhagen K, Denmark

From 2007 to 2012, three expeditions (LOMROG I through III) were carried out to acquire marine seismic refraction data in the Amundsen Basin and on the Lomonosov Ridge in the Arctic Ocean. Previous geophysical investigations indicate that the Amundsen Basin is characterized by irregular magmatic seafloor generation as evidenced by alternating peridotite and basalt dredge samples along the ultra-slow spreading Gakkel Ridge. We therefore seek to (i) map the crustal character and thickness in the Amundsen Basin, and (ii) in particular check for the presence of exhumed mantle in the basin.

The data of the LOMROG expeditions consist of 1028 km of seismic reflection data supplemented by sonobuoys to obtain information on the velocity structure. In the Amundsen Basin, a total of 72 sonobuoys were deployed along 25 lines. The length of these lines varied between 6 and 135 km. The seismic energy produced by the airgun cluster (volume between 605 and 1040 cu. in.) could be recorded up to offsets of 25 km. The energy was sufficient to detect mantle refractions on some of the sonobuoy records. P-wave velocity models of the sediments, the underlying crust and the mantle were then obtained by forward modeling of the travel times using raytracing software (RAYINVR). The coincident seismic reflection data were used to guide the velocity modeling down to the basement.

We present preliminary results showing variable crust in the Amundsen Basin. Profile 3-14 is located 600 km north of Greenland and is parallel to the Gakkel Ridge at a distance of 220 km close to Chron C21. The velocity model of the 40-km-long line indicates five sedimentary layers with velocities ranging from 1.6 to 3.0 km/s and a maximum thickness of 2.1 km. The underlying crust displays lateral variations in its velocity structure and three distinct domains are recognized. In the south, a 0.7-km-thick upper layer with velocities between 3.90–4.3 km/s and a 2.2-km-thick lower layer with velocities between 4.80–5.80 km/s are observed. These layers are interpreted to correspond to oceanic layers 2A and 2B. No layer 3 could be identified. In the center of the line, the crust is modeled as a single 3-km-thick layer with velocities of 5.2–5.9 km/s. The base of this layer is characterized by a reflection and velocities underneath are 6.9 km/s, which is interpreted as partially serpentinized mantle. In the north, the upper crust is 2.5 km thick with velocities of 4.3–5.6 km/s, while the lower crust (6.0–6.4 km/s) is up to 1.6 km thick but thins toward the center of the line. The lower crustal velocities are lower than those found in typical oceanic crust but are compatible with a fractured layer 3.

Tectonic structure and evolution of the Alpha-Mendeleev Fracture Zone

Chernykh, A.A.[1,2], Glebovsky, V.Yu.[1], Egorova, A.V. [1,2], Redko, A.G. [1] & Sukhanov, R.A.[1]

[1]«VNIIOkeangeologia named after I.S. Gramberg », St.-Petersburg, Russia; [2]Saint Petersburg State University, Russia

The existence of fracture zone between the Alpha and Mendeleev Ridges (AMFZ) and its complex tectonic structure were already revealed mainly by comprehensive analysis of potential field data (Chernykh et al. 2014). In addition to well known horsts and grabens oriented mainly in N-S direction, some new evidences for shear deformations in AMFZ were found. It was proposed that the Alpha-Mendeleev Ridge existed earlier as a single continental structure, was separated later by this shear zone on two individual ridges which moved from each other forming the system of NW-SE sinistral strike/oblique-slip faults.

In the presented study, we focus on the analysis of seismic reflection data available in the expected AMFZ to find additional evidences for proposed tectonic movements and understanding their kinematics. It is found that most of signs for significant tectonic activity on seismic cross-sections are concentrated in this fracture zone. Seismic profiles across the zone have revealed: a positive/negative flower structures, different thickness of the same stratigraphic layers on both sides of faults and different (normal/reverse) kinematics of faults. The thickness of sediments in grabens reaches up to 3 sec TWT. We suppose that AMFZ was formed mainly under transtensional conditions, in spite of presence here some compressional structures. Amount of the displacement along AMFZ could be estimated as up to 400 km.

Results of preliminary interpretation show that the AMFZ was formed due to the movement of the Mendeleev Ridge together with Chukchi Rise in S-E direction after separation from the Alpha Ridge. If it is so, the Podvodnikov, Mendeleev and perhaps Makarov basins were formed at the same time. The opening of the Canadian Basin at its proposed second stage (Grantz et al. 2010) could be initiator of these tectonic processes. Some more details and speculations concerning the evolution of the AMFZ and adjacent structures will be offered in presentation.

Crustal Structure of the Canada Basin: new constraints from seismic reflection and refraction data

Chian, D.[1], Oakey, G.N.[2], Jackson, H.R.[2], Hutchinson, D.R.[3], Lebedeva-Ivanova, N.[4], Shimeld, J.[2], Li, Q.[2], Mosher, D.S. & Saltus, R.W.[5]

[1]Chian Consulting, Dartmouth, NS, B2Y 4A2; [2]Geological Survey of Canada, Dartmouth, NS, B2Y 4A2; [3]U.S. Geological Survey, Woods Hole, MA 02543; [4]University of Oslo, Oslo, Norway, 0316; [5]U.S. Geological Survey, Denver, CO, 80225

Seismic velocities determined from modeling 85 regionally distributed expendable sonobuoys in the Canada Basin have been used to discriminate between oceanic, transitional and continental crust. Crustal type was primarily based on objective assignments of diagnostic velocities – oceanic from the presence of layer 3 velocities (6.7-7.2 km/s); transitional from the presence of a lower-most, high velocity layer (7.2-7.7 km/s), and continental for velocities typical of continental crust (≤6.6 km/s). The wide-angle refraction models are co-incident with seismic reflection profiles which show different characteristics of acoustic basement for the different crustal domains. The top of oceanic crust is generally a weak reflection with a high-relief blocky character, and rare deeper reflections. The top of transitional crust is a low-relief, bright reflection with numerous subparallel bright reflections that extend as much as .5 km deeper. The areas of continental crust show grabens possibly associated with rifting. Oceanic crust is identified only within central Canada Basin and forms a polygon approximately 320-350 km wide (east-west) by ~500 km (north-south). The northern segment of the Canada Basin Gravity Low (CBGL) bisects the oceanic crustal domain, as would be expected from the axis of a spreading center. Two distinctive magnetic lineations are observed equidistant from the CBGL and correspond with the outer limit of the oceanic crust. Since offsets were recorded only up to ~40 km, mantle arrivals were identified at only a few sonobuoy stations. Mantle arrivals show oceanic crust is thinner (4 - 7 km), than typical oceanic crust (~7.2 km). The southern segment of the CBGL, where it trends toward the Mackenzie Delta/fan, is associated with transitional velocities that are interpreted to represent serpentinized peridotite (mantle). Further north, near Alpha Ridge and along Northwind Ridge, transitional crust is interpreted to be underplated or intruded material related to the emplacement of the High Arctic Large Igneous Province. In southwestern Canada basin (offshore Alaska) crustal velocities are consistent with thinned continental crust with no evidence of serpentinization or underplating. These results have implications for plate reconstruction models, which now must close a smaller area of oceanic crust and must also account for finite extension in the transitional and continental crustal domains.

New data support updating of the Arctic Gravity Project grid; Version 3.0

Coakley, B.[1], Forsberg, R.[2], Beale, J.[3], Gabbert, R.[3] & Kenyon, S.[4]

[1]University of Alaska Fairbanks, Fairbanks, AK 99775 USA (E-mail: bcoakley@gi.alaska.edu); [2]Geodynamics Department, National Space Institute, Lyngby, Denmark; [3]National Geospatial-Intelligence Agency, Arnold, MO, USA; [4]S2 Analytical Solutions, Herndon, VA, USA

The Arctic Gravity Project (AGP) grid achieves excellent, near-isotropic coverage over of the earth north of 64˚N by combining land, satellite, airborne, submarine, surface ship and ice set-out measurements of gravity anomalies. Since the release of the V 2.0 grid in 2008, there has been extensive icebreaker activity across the Amerasia Basin due to mapping of the circum-Arctic nation's Extended Continental Shelves (ECS). This has resulted in an expansion of the available high-resolution surface ship gravity anomaly data.

In addition to the new ECS data sets, gravity anomaly data has been collected from other vessels; notably the Korean Icebreaker Araon, the Japanese icebreaker Mirai and the German icebreaker Polarstern. Also the GRAV-D project of the US National Geodetic Survey has flown airborne surveys over much of Alaska. These data will be Included in the new AGP grid, which will result in a much improved product when version 3.0 is released in 2015.

To make use of these measurements, it is often necessary to compile them into a continuous spatial representation. Compilation is complicated by differences in survey parameters, gravimeter sensitivity and reduction methods. Gravity anomalies measured during independent surveys often require rescaling to be incorporated into a single grid.

Cross-over errors are the classic means to assess repeatability of track measurements. Prior to the introduction of near-universal GPS positioning, positional uncertainty was evaluated by cross-over analysis. GPS positions can be treated as more or less true, enabling evaluation of differences due to contrasting sensitivity, reference and reduction techniques. For the most part, cross-over errors for racks of gravity anomaly data collected since 2008 are less than 0.5 mGals, supporting the compilation of these data with only slight adjustments.

Geoscience Atlas of Svalbard

Dallmann, W.K. & Myhre, P.I.

Norwegian Polar Institute, Tromsø (E-mail: dallmann@npolar.no; myhre@npolar.no)

The Geoscience Atlas of Svalbard (2015) was recently published by the Norwegian Polar Institute, and provides information about geosciences in Svalbard to a broad group of potential users. Data from many geoscientific disciplines are collected in one book and presented in thematic maps, photographs and charts with concise explanations. Target groups are researchers, students, teachers, administration as well as scientific interested tourists and the public. The disciplines covered are

- physical geography
- ocean and sea ice
- geomorphology and Quarternary geology
- glaciers
- historical geology
- bedrock geology
- tectonics and structural geology
- geophysics
- geochemistry of superficial deposits
- georesources
- infrastructure and management (brief overview)

The book contains contributions from 32 authors, with many more contributing photos from Svalbard. Approximately 170 maps and 400 photos and other illustrations are included, and a new bedrock map series in 1:250 000 scale is published as part of the book. This series is also available as digital maps on Svalbardkartet.npolar.no.

References:

Dallmann W.K. (Ed) 2015: Geoscience Atlas of Svalbard. Norsk Polarinstitutt Rapportserie; 148. Tromsø. 292 pp.

To substantiation of the stratigraphy of key seismic horizons on the East-Arctic Shelf and in the area of Central Arctic Uplifts

Daragan-Sushchova, L.A.[1], Grinko, L.R.[2], Petrovskaya, N.A.[3] & Daragan-Sushchov, Yu.I.[4]

[1]FSUE “A.P. Karpinsky Russian Geological Research Institute”, Saint-Petersburg, Russia; [2]FSUE “A.P. Karpinsky Russian Geological Research Institute”, Saint-Petersburg, Russia; [3]“Dalmorneftegeophysica” JSC,Yuzhno-Sakhalinsk, Russia; [4]FSUE VNIIOkeanologia Saint-Petersburg, Russia

The progress in geological and geophysical studies of the Central Arctic uplifts area has revealed the basic problems in subdivision of quasi-synchronous seismic-stratigraphic sequences (QSSS), correlation of reflection horizon (RH) and its age determination. The stratigraphic correlation of RH within the deep-water part of the AO (Arctic Ocean) is still quite unclear due to the absence of geological markers. General approach for stratigraphy of the AO sedimentary cover is based on the wave field’s characteristics and RH tracing.

An additional characteristic which is considered while correlation of quasi-synchronous seismic sequences (QSSS) is the distribution of layer velocity along the seismic section which are surely not the attributes of own stratigraphy but carry the important information about physical peculiarities of the studied formation.

Profile CDP A7, located in the connection zone of the Lomonosov Ridge and the Russian Shelf, is an evident illustration of seismic stratigraphy correlation possibilities. Sedimentary cover QSSS and RH are traced continuously over nearly 800 km along the shelf and northwards through the continental slope along the ridge and partially slope part of the Lomonosov Ridge starting almost from Kotelniy Island of the Novosibirsk grabens and horsts system. In the sedimentary cover of the profile a series of seismic sequences and RH were identified and results will be presented.

The example of uncertainty in determination of section stratigraphic fullness on the shelf is a seismic section of the North-Chukchi Trough.

To solve the problem of correlation and age determination of RH, in our study we combine the wave field of American seismic profile D84-33, kindly given to us by French company «Total», to data from the wells Burger and Popcorn-1. And then, the stratigraphic correlation from the American profile D84-33 was imposed onto a composite profile starting from the nearest seismic profile SC 90-08m in the Russian sector of the Chukchi Sea, which is located 32 km from D84-33. After that, the position of key seismic horizons was transferred on the profile Arc12-01. In the cross-section point the correlation was transferred onto profile Arc12-03. The transfer will be illustrated. Analyzing the west part of the Arc12-03 profile and comparing it with the wave field of the North-Chukchi trough ES10z23m**,** ES10z02_1, one can suggest their similarity. We have made an attempt to compare the western part of the profile Arc12-03 with the profile A-7 in the area where there is a maximal thickness of sedimentary cover. These wave fields are partially correlated (in the upper part). But the structures of these wave fields evidently differ in dynamics and kinematics, especially in dynamic characteristics (QSSS quantity, its characteristics). Thus the general thickness of sedimentary cover in the deepest part is almost equal. It means we may suppose that the area of variously aged basement shall be aligned somewhere along the Podvodnikov Basin (probably, the Geophysics Spur). In the published studies about the seismic profile 89-01 (LARGE), such border had been identified since 2001 (Drachev et al. 2001; Vinogradov et al. 2004).

The specific regional studies should be based on accurate continuous tracing of RH and QSSS and their dynamic and kinematic characteristics over the lateral and through a section.

Protopiceoxylon yukonense spec. nov. – an extinct conifer from the Northern Yukon / Mackenzie Delta area

Dolezych, M.[1] & Reinhardt, L.[2]

[1]Senckenberg Naturhistorische Sammlungen Dresden, Königsbrücker Landstr. 159, 01109 Dresden, Germany (E-mail: Martina.Dolezych@senckenberg.de); [2]Federal Institute for Geosciences and Natural Resources (BGR), Stilleweg 2, 30655 Hannover, Germany

Pinaceaeous fossil woods are well known from Upper Cretaceous/Cenozoic times in the Northern Hemisphere. However, specimens from the Northern Yukon / Mackenzie Delta area are only little investigated and no fossil woods older than Middle Pliocene (Wheeler & Arnette 1994) have been described so far.

During the expedition CASE 15*a fossil wood remain of para-autochthonous origin was found in Paleocene sediments of the Moose Channel Formation (TMC) in the Big Fish River area nearby the Yukon / Northwest Territories boundary. The fossil wood was recovered from overall medium to coarse sandstones including conglomerate layers of supposed fluvial-deltaic origin with minor shale intercalations. This contribution summarizes the current knowledge primarily on taxonomy and paleoecology of the pinaceaeous wood specimen.

The fossil wood specimen turned out to be without a relationship to extant taxa: *Protopiceoxylon yukonense* spec. nov. as a taxon of the fossil wood genus *Protopiceoxylon* Gothan 1907 belongs to the extinct genus of Protopinaceae Kraeusel 1949. The holo- and paratypes of the generotypus *Protopiceoxylon extinctum* Gothan 1907 from the King Charles Land (Gothan 1907) as well as from Spitsbergen (Gothan 1910), preserved in the Natural Historical Museum at Berlin, were available for this investigation. The fossil conifer wood *Protopiceoxylon* is characterized by extinct major anatomical differences that are intermediate between the extinct *Protopiceoxylon* and the extant *Piceoxylon* manifest within the radial bordered pits, which are protopinoid in the first mentioned taxon and abietioid in the other discussed taxon. Most other features demonstrate a close relationship between both fossil taxa. *Protopiceoxylon*, a plant with heterobathmic structure, was convergent in its evolutionary line with *Piceoxylon*.

The described pinaceaeous wood has a potential for the palaeoecological reconstruction, inter alia as this fossil represents a constituent of vegetation growing under condition at high latitude (e.g., continous daylight in arctic summer vs. darkness for months during arctic winters).

The 15th geological expedition of the* ***CASE* *research program (****CASE*** *=* ***C****ircum-****A****rctic* ***S****tructural* ***E****vents) of the German Federal Institute for Geosciences and Natural Resources (BGR) was a joint project with the Geological Survey of Yukon (YGS), the Université Pierre et Marie Curie, Paris, and the Royal Ontario Museum,Toronto.*

References:

Gothan, W., 1907. Die fossilen Hölzer von König-Karls-Land. Kungl. Svenska Vetenskapsakad. Handl. XLII, 10, 1-44.

Gothan, W., 1910. Die fossilen Holzreste von Spitzbergen. Kungl. Svenska Vetenskapsakad. Handl. XLV, 8, 1-56.

Kräusel, R., 1949. Die fossilen Koniferenhölzer (unter Ausschluss von *Araucarioxylon* Kraus). Palaeontographica B, 89, 83-203.

Wheeler, E.A. & Arnette, C.G., 1994. Identification of Neogene woods from Alaska-Yukon. Quaternary International 22/23, 91-102.

Geological evolution of the Norwegian Barents Sea South-East

Doronina, M.S.[1], Nikishin, A.M.[1], Vasilyeva, N.A.[1], Leybenko, A.I.[1], Basalaeva, T.S.[1] & Kukina, N.A.[2]

[1]Department of geological modeling and database RN-Exploration LLC, Moscow, Russia (E-mail: m_doronina@rn-exp.rosneft.ru); [2]RN Nordic Oil AS, Oslo, Norway

Nordkapp and the Tiddlybanken rift basins are located within south-eastern part of the Norwegian Barents Sea shelf at the base of sedimentary cover as well as several uplifts in the area of the Fedinsky High. The basement structure has not been sufficiently explored yet. It is assumed that the basement of the area is composed of different geological terrains with Caledonides in the west and Timanides (Vendian-Cambrian age) in the east. Salt tectonics is typical for the area of studies, activated in several periods during Triassic – Quaternary time. Geological evolution in the South-East of the Norwegian Barents Sea could be subdivided into seven stages:

1. Visean-Bashkirian rifting phase is likely to occur in transtensional environment accompanied by deposition of evaporites.
2. Moscovian-Permian phase represents a post-rift subsidence with carbonate platform development and sedimentation of evaporites.
3. Triassic phase is a period of regional subsidence with formation of a large-scale clastic clinoforms. During the Middle-Late Triassic active salt movements took place, possibly related to Novaya Zemlya compression and orogeny processes. Syn-compressional deformations took place in the area of Fedinsky High in the Late Triassic. It was also the beginning of rift basins inversion.
4. Jurassic phase is a period of slow thermal subsidence with clays and sandstones deposition;
5. Cretaceous phase is a period of relatively rapid subsidence caused by a high rate of sediments input from the north. In the Late Jurassic/Early Cretaceous transition as well as in the Neocomian time in the area of the Fedinsky High a syn-compression growth was reactivated. The Neocomian time is also characterized as a period of transpressional deformations in the eastern part and transtensional grabens formation in the western part of the area.
6. In post-Cretaceous period, possibly in the Paleocene-Oligocene, regional compression deformations took place and many of the highs were involved in syn-compression uplift.
7. Phase of rapid salt movements and various salt tectonics occurred in the Late Cenozoic (Neogene-Quaternary), intensified due to glacial-related processes during the Quaternary period.

Efforts to constrain extent and dynamics of past glaciation on the Chukchi margin and adjacent areas

Dove, D.[1], Polyak, L.[2] & Coakley, B.[3]

[1]British Geological Survey, West Mains Rd, Edinburgh, EH9-1JG, UK; [2]Byrd Polar Research Center, Ohio State University, 1090 Carmack Rd., Columbus, OH 43210, USA; [3]University of Alaska Fairbanks, 900 Yukon Drive, Fairbanks, AK 99775

Recent mapping efforts have reignited the discussion of the past presence and extent of grounded glacial ice on the East Siberian (Niesen et al. 2013) and Chukchi (Dove et al. 2014) continental margins. Swath bathymetry and shallow sub-bottom profiler data provide insights into the dynamics, extent, and relative event chronology of past glaciation, which has been shown to have widely impacted the outer continental shelf, adjacent slopes, as well as several outlying ridges beyond the shelf break. Bathymetry data frequently reveal glacigenic landforms at seabed across the region, down to 900 m water depth, though obscured in shallower water to the south by iceberg scouring. Sub-bottom data reveal multiple till units, shelf-edge glacigenic wedges, glacigenic debris flows, as well as erosional surfaces. Studies over the last 20 years have documented occurrences of similar features relying on opportunistically collected datasets, but scarcity of data have hindered paleo-ice sheet reconstructions . Influenced by the findings from terrestrial-based research (largely suggesting large ice masses could not be present in the Chukchi region), these studies largely related these features to ice impinging only from the Laurentide ice sheet, with possible small ice cap(s) on the Chukchi Plateau. Despite the resulting uncertainty with the southern extent of glaciation, recently acquired data indicate a widespread grounded-ice presence on the northern Chukchi and East Siberian shelves, which makes the region an important, previously underestimated component of the Arctic paleo-ice sheet system.

Despite these recent advances, data remain sparse and insufficiently dense in regions which would further elucidate the glacial history of the region. We will discuss potential survey approaches, in terms of acoustic equipment types and geographical areas, which should help researchers to better understand past glacial dynamics in the region. Seabed geomorphology has become the most reliable tool for mapping the extent and pattern of past glaciation, but is limited (e.g. cross-cutting landforms) in terms of providing chronological information, as well as being skewed towards most recent events. The relative effectiveness of this method is significantly improved through acquisition of extensive, continuous bathymetry datasets (vs. corridors of data). Seismic stratigraphy provides further relative chronology via depth profiles but presents challenges when extrapolating between broadly-spaced survey lines, compounded by the difficulty in dating key horizons in high latitudes (e.g. Polyak et al. 2007). High-resolution, sub-bottom profilers have become regularly-employed tool to link bathymetric features with the shallow sub-surface, but in many cases deeper penetrating seismic data are required to characterize large-scale erosional forms and the full thickness of glacial deposits.

De Long Islands: provenance, paleogeography and geodynamic model

Ershova, V.B.[1], Prokopiev, A.V.[3], Lorenz, H.[4], Sobolev, N.N.[1], Khudoley, A.K.[1,2], Petrov, E.O.[1], Estrada, S.[5], Sergeev, S.[1], Larionov, A.[1] & Thomsen, T.B.[6]

[1]All Russian Geological Institute, Sredniy prospect 74, Saint Petersburg, Russia, 199106; [2]Institute of Earth Science, St. Petersburg State University, Universitetskaya nab. 7/9, St. Petersburg, Russia, 199034 (E-mail: ershovavictoria@gmail.com); [3]Diamond and Precious Metal Geology Institute, Siberian Branch, Russian Academy of Sciences, Lenin prospect 39, Yakutsk, Russia, 677980; [4]Uppsala University, Department of Earth Sciences, Villavägen 16, 752 36 Uppsala, Sweden; [5]Federal Institute for Geosciences and Natural Resources (BGR), Stilleweg 2, 30655 Hannover, Germany; [6]Geological Survey of Denmark and Greenland (GEUS), Department of Petrology and Economic Geology, Øster Voldgade 10, 1350 Copenhagen, Denmark

The De Long islands are located in the eastern Russian High Arctic and provide an important window into the geology of this area and are a key for understanding the Early Paleozoic history of the Amerasian Arctic. De Long Islands comprise Jeannette, Henrietta, Bennett, Zhokhov and Vil'kitskiy islands. Four of them (Jeanette, Henrietta, Bennett and Zhokhov islands) were studied using structural data, petrographic and geochemical analyses and U-Pb zircon age dating. No outcrops of basement rocks are known in the whole New Siberian Islands archipelago. The age of the basement beneath the De Long Islands we have estimated by dating assimilated material in the sills and dikes and igneous xenoliths from the Late Cenozoic stratovolcano on Zhokhov Island. Thus, the combined data from xenocrysts and xenoliths suggests the Late Neoproterozoic age of the basement beneath the De Long Islands.

The sedimentary environment and lithologies suggest that Henrietta and Jeannette Islands Lower Paleozoic sediments deposited in the island arc or continental arc environments. The sedimentary facies of the Cambrian-Ordovician deposits of Bennett Island are clearly indicative of deposition in a shallow marine shelf environment.

The results of U-Pb dating of detrital zircons from the sediments of the Jeanette, Henrietta and Bennett Islands show close similarities with magmatics known from Timanian and Grenville-Sveconorwegian orogens, and Baltic Shield. The results of our study suggest that the De Long Islands represent a Lower Paleozoic active continental margin developed on basement of Timanian age. Sedimentary petrography, facies and composition of the Lower Paleozoic successions of Henrietta and Jeannette islands suggest a depositional environment comparable to that of a continental arc - back-arc system. The more mature shallow marine Cambrian-Ordovician sediments of Bennett Island were deposited further towards the craton interior. Similarities in the detrital zircon age distributions suggest a common Early Paleozoic history for Severnaya Zemlya, the New Siberian Islands, and the Arctic Alaska-Chukotka and Alexander terranes.

This research was supported by RFBR grants 13-05-00700, 13-05-00943, 15-35-20591, DPMGI SB RAS VIII.66.1.4, Project N 53 (program of Russian Academy of Sciences N 44P).

Onshore extension of the Alpha Ridge into the Yelverton Bay area? Evidence from aeromagnetic and geochronological data

Estrada, S.[1], Damaske, D.[1], Henjes-Kunst, F.[1], Oakey, G.[2], Schreckenberger, B.[1], Eckelmann, K.[3] & Linnemann, U.[3]

[1]Federal Institute for Geosciences and Natural Resources (BGR), Stilleweg 2, 30655 Hannover, Germany (E-mail: solveig.estrada@bgr.de); [2] Geological Survey of Canada (GSC Atlantic), Dartmouth, NS, Canada; [3]Senckenberg Naturhistorische Sammlungen Dresden, Germany

Onshore geological work combined with an onshore/offshore aeromagnetic survey was carried out during joint expeditions of the German BGR and the Canadian GSC to understand the structural architecture of the North American passive continental margin. The joint helicopter-borne magnetic survey in 2008 covered the coastal area of Ellesmere Island to the east of the previous Canadian survey over Axel Heiberg Island and adjacent marine areas in 1991. A prominent feature of the combined magnetic anomaly map is a broad magnetic high over Yelverton Bay that also covers a small strip in the neighbouring coastal area and that is most likely caused by deep-seated thick igneous units without onshore outcrops. The Yelverton Bay High can be traced to the large Alpha-Mendeleev Ridge magnetic domain, interpreted as a LIP (Saltus et al. 2011). A chain of small positive anomalies crossing the Wootton Peninsula and forming the southeastern margin of the Yelverton Bay High can be correlated with Late Cretaceous alkaline intrusive and extrusive suites, the Wootton Intrusive Complex (WIC) and the Hansen Point Volcanic Complex (HPVC), that were formerly radiometrically dated at ca. 92 and 80 Ma, respectively.

Rhyodacite forms larger parts of the HPVC outcrops southwest and east of Yelverton Bay. It differs from the alkaline felsic WIC and HPVC rocks by lower epsilon Nd(t) and higher Sr(t) isotope values indicating crustal influence. LA-ICP-MS U-Pb zircon dating of two rhyodacite samples from southwest of Yelverton Bay yielded an age of ca. 100 Ma (97 ±1 and 102 ±1 Ma). The rhyodacite is probably an extrusive equivalent of granitic plutons magnetically reflected as part of the Yelverton Bay High that can be traced to the large Alpha-Mendeleev Ridge magnetic domain. Thus, the zircon age for the rhyodacite may provide an estimate of the formation age of the Canadian terminus of the Alpha Ridge as part of the High Arctic Large Igneous Province (HALIP).

Tectonic significance of seismic reflection and refraction data from Makarov Basin, Arctic Ocean

Evangelatos, J.[1], Mosher D.C.[2] & Funck, T.[3]

[1]Department of Earth Sciences, Dalhousie University, Halifax, Nova Scotia, Canada (E-mail: j.evan@dal.ca); [2]Geological Survey of Canada (Atlantic), Dartmouth, Nova Scotia, Canada; [3]Geological Survey of Denmark and Greenland (GEUS), Copenhagen, Denmark

Understanding the geological history of Makarov Basin, central Arctic Ocean, is key to deciphering the tectonic model for the formation of the early Arctic Ocean that now forms Amerasia Basin. For this purpose, the study relies on coincident multi-channel seismic reflection (MCS) data and seismic refraction data from sonobuoy records acquired in 2011 during a joint Canada–US expedition to Amerasia Basin. The transect spans almost 400 km from Alpha Ridge, across Makarov Basin, to the top of Lomonosov Ridge.

Seismic refraction data from sonobuoy records are used to construct a 2D model of P-wave velocities for Makarov Basin. The crustal structure of Makarov Basin is broadly divided into three parts: 1) sedimentary layers (1.8–4.2 km/s), 2) volcanics (4.2–5.3 km/s), and 3) igneous crust (including the lower, middle and upper crust). The thickness of the igneous crust of Makarov Basin is constrained by shipborne gravimetry and varies from 12 km near Alpha Ridge to 6 km in the centre of the basin. The MCS profile shows a thickening of the sedimentary cover from 0.6 s two-way travel time (0.5 km) on the flank of Alpha Ridge to over 2 s (4 km) adjacent to Lomonosov Ridge. Basin stratigraphy is composed of two broad groups: 1) sediments present in the deepest part of the basin near Lomonosov Ridge that were sourced from the Barents Shelf and Lomonosov Ridge prior to the opening of Eurasia Basin, and 2) shallow sediments preserved basin-wide that are dominated by seismic facies interpreted as pelagic to hemipelagic successions, suggesting a change in sediment source after opening of Eurasia Basin. Stratigraphic correlation from Makarov Basin to Alpha Ridge suggests that the sedimentary drape on Alpha Ridge is mostly Cenozoic and that this section was not emergent.

The crustal structure of Makarov Basin supports previous studies that show a decrease in crustal thickness from Podvodnikov Basin, near the Siberian Shelf, towards the centre of Makarov Basin. Sedimentary P-wave velocities in Makarov Basin are similar to values from Canada Basin adjacent to Alpha Ridge, implying similar compaction histories and/or mineralogy. Stratigraphic dating of the oldest sediments imposes an upper limit of early Late Cretaceous on the age of Makarov Basin. In conclusion, the results are consistent with existing tectonic models that predict Cretaceous seafloor spreading orthogonal to Lomonosov Ridge in northern Amerasia Basin, requiring the flank of Lomonosov Ridge to be a transform or transtensional margin.

Basement and Late Paleozoic basin configurations in the western and central Barents Sea

Faleide, J.I.[1], Mahajan, A.[1], Gabrielsen, R.H.[1], Breivik, A.J.[1], Planke, S.[2,1] & Myklebust, R.[3]

[1]Department of Geosciences, University of Oslo, Oslo, Norway; [2]VBPR, Oslo, Norway; [3]TGS, Asker, Norway

Most of the western Barents Sea is underlain by a Caledonian basement but there are uncertainties related to how far east the Caledonian deformation front reaches. Magnetic data indicate that the main Caledonian structures turn to a NNW orientation just off the coast of northern Norway and continue northwards to Svalbard. The Late Paleozoic basin configurations consist of three different generations characterized by different extent and orientations. The oldest is interpreted to be of Devonian age and related to collapse of the Caledonian Orogen, partly by extensional reactivation of frontal thrusts of the main orogen. Thick units of non-magnetic sediments were deposited in front of the orogen as reflected by seismic data and estimated depths to magnetic basement. The Carboniferous rift structures are, on the other hand, better revealed by seismic and gravity data. New high-quality long-offset seismic data show a horst and graben basin relief with a dominant NE to NNE trend, which also gives rise to lateral density variations reflected by the gravity anomalies. In some areas these structures cut through the underlying structural grain while in other areas they seem to reactivate the pre-existing grain. The Carboniferous horst and graben basin configuration had impact on the depositional systems and facies distribution within the overlying Carboniferous-Permian succession dominated by carbonates and evaporites. The rift structures and associated evaporites also played a role in the later reactivation and formation of contractional structures. The new seismic data also reveal increasing evidence of an important Late Permian rift phase mainly affecting the deep sedimentary basins of the SW Barents Sea.

Post-glacial uplift in the Barents Sea – determination of Earth rheology and implications for petroleum systems

Fjeldskaar, W.[1] & Amantov, A.[2]

[1]Tectonor, Stavanger, Norway; [2]VSEGEI, St. Petersburg, Russia

The Arctic has probably experienced more than 30 glacial/interglacial periods in Quaternary. Repeated ice loading and erosion over the last millions of years has significantly influenced the temperature history of the sediments in Arctic, and associated hydrocarbon maturation in potential source rocks. In addition, repeated loading of glaciers leads to isostatic response of the lithosphere, which can be significant and fast vertical movements of the Earth's surface.

Most of the information about the glacial impact on the Earth is from the deglaciation period after the last glaciation (Holocene). In this study we have used Holocene sea level data from Svalbard, Franz Joseph Land, Novaya Zemlya and Finnmark to constrain the modeling of the Barents Sea.

Glaciers act as loads on the Earth's surface. When a load is applied to the Earth's surface, part of the applied load will be supported by the elastic rigidity of the lithosphere, and part by buoyant forces of the asthenosphere. The glacial isostatic rebound over the last thousands of years has potential to reveal the Earth's dynamic rheology.

The deglaciation history after the last glacial maximum (last 20 000 years) is relatively well known by dated end moraines. The ice thickness is, however, less known and is based on glacial modelling. The method we have used to compute ice-sheet thicknesses consists of: 1) Estimation of an ice-sheet based on viscoplastic flow as we know from present ice-sheets, 2) Modifications due to sub-glacial topography, 3) Corrections due to possible ice-streams and sub-ice lithology.

The Earth's response to glaciers is calculated by using a layered viscous model (mantle) overlain by an elastic lithosphere. The sea level data from Svalbard, Franz Joseph Land, Novaya Zemlya and Finnmark are used to constrain the isostatic modeling. The Finnmark data are based on age dated deposits in isolation basins (Romundset et al., 2011); for the other areas the data are more uncertain, as they are based on age dated driftwood and whalebones (Forman et al. 2004).

Best fit with the observed sea level data is achieved with a 30-40 km elastic lithosphere for Finnmark, and a thicker lithosphere (60-80 km) for Svalbard, Franz Joseph Land and Novaya Zemlya. The asthenosphere viscosity for Finnmark is 1.8×10^{19} Pa s and somewhat lower for the other locations.

Glacial isostasy will lead to tilting of potential reservoirs in the western Barents Sea. The tilts could exceed 4 m/km, dipping towards east during the glaciations. This could lead to changes in migration pathways for oil and gas.

Sedimentary successions around the New Siberian Islands: onshore to offshore relation

Franke, D.[1], Piepjohn, K.[1], Gaedicke, C.[1], Brandes, C.[2], Mouly, B.[3], Sobelev, N.[4], Tolmacheva, T.[4], Weigelt, E.[5] & Jokat, W.[5]

[1]BGR –Federal Institute for Geosciences and Natural Resources, Hannover, Germany; [2]Institut für Geologie, Leibniz Universität Hannover, Germany; [3]TOTAL, Paris, France; [4]VSEGEI - A.P. Karpinsky Russian Geological Research Institute (VSEGEI), Saint-Petersburg, Russia
[5]AWI - Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany

Since no deep wells have been drilled on the shelves surrounding the New Siberian Islands, the precise age and nature of the sedimentary successions remains uncertain. Interpretations base on evolution scenarios for the shelf areas. Either it is proposed that the basement of the rift basins of the Laptev Shelf is a continuation of the Siberian craton, or that the basement is made up of the continuation of the Mesozoic fold belts situated around the Siberian craton. Authors proposing that the sedimentary basins on the shelf are filled by Mesozoic or even Paleozoic sediments argue that portions of the New Siberian Islands are underlain by equivalents of the Siberian craton and that Taimyr may be considered as an integral part of Siberia. On the other hand the Laptev Sea is surrounded by fold belts where considerable deformation is expected of any proposed earlier sedimentary basins. After several major phases of compression affecting the Laptev Shelf at different angles, persistence of earlier sedimentary basins seems doubtful.

Here we discuss the concepts for interpreting a regional stratigraphic scheme, present correlation from the geology of the New Siberian Islands to offshore based on multichannel reflection seismic data. Further, we cross-correlate to the ACEX lithostratigraphy and discuss the seismostratigraphy within the Arctic Ocean adjacent to the East Siberian Shelf. Key marker horizons in the offshore data are linked to major hiatuses in the onshore region to better constrain the timing of rifting. Onshore the breakup unconformity, related to the earliest opening of the Eurasia Basin is likely amalgamated with the rift-onset unconformity, indicating a major erosional phase. Offshore, the breakup unconformity seals the wedge-shaped rift deposits in the half-grabens and represents merely a depositional hiatus. Well information is available close by the Lena delta in the form of sketched stratigraphy ranging from Proterozoic to Cretaceous. This information can be reconciled on a cross section despite a gap of approximately 25 km, providing a tentative age for a regional unconformity sitting on top of an acoustic basement.

Is submarine groundwater discharge a control on Arctic permafrost-associated gas hydrate formation on the Beaufort Shelf?

Frederick, J.M.[1] & Buffett, B.A.[2]

[1]Division of Hydrologic Sciences, Desert Research Institute, Reno, Nevada, USA (E-mail: jenn@dri.edu); [2]Department of Earth & Planetary Sciences, University of California, Berkeley, California, USA

Methane hydrate is an ice-like solid that can sequester large quantities of methane gas in marine sediments along most continental margins where thermodynamic conditions permit its formation. Along the circum-Arctic shelf, relict permafrost-associated methane hydrate deposits formed when non-glaciated portions of the shelf experienced sub-aerial exposure during ocean transgressions. Gas hydrate stability and the permeability of circum-Arctic shelf sediments to gas migration is closely linked with relict submarine permafrost. Heat flow observations on the Alaskan North Slope and Canadian Beaufort Shelf suggest the movement of groundwater offshore, but direct observations of groundwater flow do not exist. Submarine groundwater discharge, an offshore flow of fresh terrestrial water, can affect the temperature and salinity field in shelf sediments, and may be an important factor in submarine permafrost and gas hydrate evolution on the Arctic continental shelf. Submarine groundwater discharge may also enhance the transport of organic matter for methanogenesis within marine sediments. Because it is buoyancy-driven, the velocity field contains regions with a vertical (upward) component as groundwater flows offshore. This combination of factors makes submarine groundwater discharge a potential mechanism controlling permafrost-associated gas hydrate evolution on the Arctic continental shelf.

In this study, we quantitatively investigate the feasibility of submarine groundwater discharge as a control on permafrost-associated gas hydrate formation on the Arctic continental shelf, using the Canadian Beaufort Shelf as an example. We have developed a shelf-scale, two-dimensional numerical model based on the finite volume method for two-phase flow of pore fluid and methane gas within Arctic shelf sediments. The model tracks the evolution of the pressure, temperature, salinity, methane gas, methane hydrate, and permafrost fields given imposed boundary conditions, with latent heat of water ice and hydrate formation included. The permeability structure of the sediments is coupled to changes in the permafrost and gas hydrate deposits, and the model can be run over several glacial cycles. Model development and preliminary results will be presented.

The East Greenland Ridge: Geophysical mapping and geological sampling reveal a highly segmented continental sliver

Funck, T.[1], Gerlings, J.[1], Hopper, J.R.[1], Castro, C.F.[2], Marcussen, C.[1], Nielsen, T.[1], Døssing, A.[3] & Mørk, F.[1]

[1]Geological Survey of Denmark and Greenland (GEUS), Øster Voldgade 10, 1350 Copenhagen K, Denmark (E-mail: tf@geus.dk); [2]Niels Bohr Institute, University of Copenhagen, Juliane Maries Vej 30, 2100 Copenhagen K, Denmark; [3]DTU Space, Technical University of Denmark, Diplomvej, Building 371, 2800 Kgs. Lyngby, Denmark

From 2002 to 2012, the continental shelf project of the Kingdom of Denmark carried out a comprehensive geophysical and geological mapping program along the East Greenland Ridge (EGR). The ridge is a 320-km-long and 35-km-wide feature that protrudes from the North-East Greenland shelf into the deep ocean. The EGR is situated along the Greenland Fracture Zone and separates the Boreas Basin in the north from the Greenland Basin in the south. Initially, the EGR was considered to have an oceanic affinity. However, as more detailed information became available, a continental origin of the ridge was suggested.

As part of the mapping program, the ridge was almost completely covered by swath bathymetric data that reveal two main overstepping ridge segments and several minor ridge crests. The two main segments have a 10° difference in strike. This is suggested to relate to a reorientation of the lithospheric stress field around Chron C22 time.

A total of six seismic refraction and coincident reflection lines were acquired along and across the EGR. Velocity models were obtained from raytracing modeling and indicate that the two main ridge segments are characterized by velocities of 5.2-5.7 km/s and 6.3-6.8 km/s in the upper and lower crust, respectively. The inner segment of the EGR is characterized by a variable crustal thickness of 2 to 5 km, while the outer segment has a more constant thickness around 7 km. Partially serpentinized mantle is interpreted beneath the inner segment of the EGR. In the Greenland Basin, 6 to 7 km thick oceanic crust is encountered, which thins to 3 km adjacent to the ridge. The southernmost Boreas Basin to the north of the EGR is characterized by faulting and basement ridges. Crustal velocities are around 6.3 km/s and the total crustal thickness is in general between 1 and 3 km. The basement along the EGR and the southern Boreas Basin are covered with a 1 to 3 km thick layer with velocities ranging from 4.1 to 4.5 km/s. This layer is absent in the Greenland Basin, indicating that the layer predates the oceanic crust there. Dredge samples from the outer segment of the EGR were analyzed in a high-pressure testing facility. The results indicate that velocities of 4.1 to 4.5 km/s are best explained with the recovered sandstone samples. The sandstones could not be dated but some sandy mudstones from the same dredge revealed a Late Triassic (Carnian) age (223-237 Ma) based on palynological screening. This age is consistent with the seismic interpretations, indicating a continental affinity of the EGR.

Late Mesozoic - Cenozoic plate boundaries in the North Atlantic – Arctic: Quantitative reconstructions using Hellinger criterion in GPlates

Gaina, C.[1], Watson, R.J.[2] & Cirbus, J.[3]

[1]Centre for Earth Evolution and Dynamics, Department of Geosciences, University of Oslo, Norway, (E-mail: Carmen.gaina@geo.uio.no); [2]Geological Survey of Norway, Trondheim, Norway; [3]Norconsult, Trondheim, Norway

Cretaceous extension that resulted in the formation of several sedimentary basins along the North American and western and southwestern Greenland margin was followed by seafloor spreading in the Labrador Sea and Baffin Bay. Controversy regarding the timing of the oldest oceanic crust in these basins spanned more than 25 years and it is still not resolved due to the complexity of the margins and non-uniqueness of potential field data interpretation.

Here we revisit the geophysical data (in particular the magnetic and gravity data) available for the Labrador Sea and Baffin Bay in order to identify the age of oceanic crust and infer new parameters that can be used for quantitative kinematic reconstructions. We identify chrons 20 to 29 for the central part of the basin. For the crust formed near the extinct spreading ridge we have modelled chrons 19 to 15 assuming an ultraslow spreading rate. Oceanic crust older than chron 29 is uncertain and may be part of a transitional crust that possibly contains other type of crust or exhumed mantle. The new magnetic anomaly identifications were inverted using the Hellinger (1981) criterion of fit. In this method the magnetic data are regarded as points on two conjugate isochrons consisting of great circle segments. This method has been extensively used for kinematic reconstructions since Royer & Chang (1991) first implemented it for quantitative plate tectonics, and is now available as a new interactive tool in the open-source software GPlates (www.gplates.org).

The GPlates Hellinger tool lets the user interactively generate a best-fit rotation pole to a series of segmented magnetic picks. The fitting and determination of uncertainties are based on the FORTRAN program hellinger1 (Chang 1988; Hellinger 1981; Hanna & Chang 1990; Royer & Chang 1991). Input data can be viewed and adjusted both tabularly and graphically, and the best fit can be viewed and tested on the GPlates globe.

The new set of rotations and their uncertainties are combined with a regional model and used to infer the plate boundaries during the formation of Labrador Sea and Baffin Bay. Challenges for establishing the continuation of these plate boundaries the Arctic domain are also discussed.

References:

Chang, T. 1988. Estimating the relative rotation of two tectonic plates from boundary crossings. J. Am. Stat. Assoc. 83, 1178-1183.

Hellinger, S. J. 1981. The uncertainties of finite rotations in plate tectonics. *J* Geophys Res, 86, 9312-9318.

Hanna, M.S & T. Chang 1990. On graphically representing the confidence region for an unknown rotation in three dimensions. Computers & Geosciences 16, 163-194.

Royer, J. Y. & T. Chang 1991. Evidence for Relative Motions between the Indian and Australian Plates during the Last 20 My from Plate Tectonic Reconstructions - Implications for the Deformation of the Indo-Australian Plate. J Geophys Res, 96(B7), 11779-11802.

Mesoproterozoic crystalline basement, intruded by Timanian granites, beneath the Pechora Basin and within the foreland and fold-and-thurst belt of Arctic Urals

Gee, D.G.[1], Larionov, A. N.[2], Lorenz, H.[1] & Simonetti, A.[3]

[1]Department of Earth Sciences, Uppsala University, Villavägen 16, 752 36 Uppsala, Sweden; [2]A. P. Karpinsky Russian Geological Research Institute (VSEGEI), Centre of Isotopic Research, 74, Sredny prospect,199106, St Petersburg, Russia; [3]University of Notre Dame, USA

Within the Lapinskaya Antiform, east of Inta, in the northern Urals, the deepest structural levels of the foreland fold-and-thrust belt expose amphibolite facies and higher grade para- and orthogneisses, overlain by Neoproterozoic (Riphean) mica schists and phyllites (turbidites) and unconformably overlying Lower Ordovician (locally Upper Cambrian) conglomerates, quartzites and carbonates. This entire succession, passing up into the mid to Late Paleozoic, comprises the footwall to Uralian blueschists and eclogites, themselves overthrust by ophiolites. Quartzite formations occur within the mica schist succession and at the base. Detrital zircon studies have shown that these quartzites, at three different levels, have zircon populations that are dominated by Timanian signatures (c. 550-700 Ma), implying that the Lapinskaya Antiform is an imbricate stack, repeating the Paleozoic and Neoproterozoic successions at least three times.

Granites in the Lapinskaya Antiform intrude the Riphean mica schists and underlying gneisses, but not the quartzites. Their ages range from 580 to 600 Ma (Larionov in Gee et al. 2007). The paragneisses have zircons with dominantly Mesoproterozoic ages, ranging from latest Paleoproterozoic to Early Tonian; rims are of Timanian age (c 630 Ma). Two enigmatic zircons have Cambrian ages.

To the west of Inta, granites have been located by deep drilling in the basement beneath the Paleozoic successions of the Pechora Basin. Six of these granites yielded ages of 550-570 Ma, one c. 620 Ma and another c. 380 Ma, all by the single zircon Pb-evaporation method. The more easterly located intrusions also yielded Meoproterozoic to Tonian ages (Gee et al. 2000). Subsequent SIMS dating by one of us (A.N.L) of the zircons from one of these intrusions (Kharyaga), confirmed the Timanian age of 560 Ma and also the presence of Mesoproterozoic cores as old as 1550 Ma.

This evidence from beneath the Pechora Basin and the Uralian margin of Baltica, taken together with the fragments of Mesoproterozoic basement (Korago et al. 2004) on Novaya Zemlya and related detrital zircon data (Lorenz et al. 2012, 2013), suggest that much of the basement within the Timanides and northwards into the high Arctic beneath the Barents Shelf comprises reworked Sveconorwegian-Grenvillian crystalline crust. Clearly, the small fragments of Mesoproterozoic crystalline crust that are exposed in the Urals, on Novaya Zemlya and on Svalbard deserve comprehensive investigation.

References:

Gee, D.G., Belyakova, L., Pease V., Larionov, A. N. & Dovshikova L, 2000. New Single Zircon (Pb-Evaporation) Ages from Vendian Intrusions in the Basement beneath the Pechora Basin, Northeastern Baltica. Polarforschung 68, 161-170.

Gee, D.G., Larionov, A.N., Belyakova, L. & Pystin, A.M. 2007. Timanian deformation, metamorphism and granite intrusion in the Sub-Polar Urals. In H. Brekke, S. Henriksen, & G. Haugdal (Eds.), *The Arctic Conference Days 2007,* 75–6. International Conference on Arctic Margins (ICAM) NGF, Tromsø: Norway.

Korago, E. A., Kovaleva, G.N., Lopatin, B.G. & Orgo, V.V. 2004. The Precambrian rocks of Novaya Zemlya. In D. G. Gee & V. Pease(Eds.), *The Neoproterozoic Timanide Orogen of Eastern Baltica.* Geological Society of London, Memoir 30, 135–43.

Lorenz, H., Gee, D.G., Larionov, A.N. & Majka, J. 2012. The Grenville–Sveconorwegian orogen in the high Arctic. Geological Magazine 149, 875-891. doi:10.1017/S0016756811001130.

Lorenz, H., Gee, D.G., Korago, E., Kovaleva, G., McClelland, W.C., Gilotti, J. & Frei, D. 2013. Detrital zircon geochronology of Palaeozoic Novaya Zemlya–a key to understanding the basement of the Barents Shelf. Terra Nova 25, 496-503. DOI: 10.1111/ter.12064

Slope stability, gas hydrates, and methane seepage at the shelf north of Svalbard

Geissler, W.H.[1], Gebhardt, A.C.[1], Gross, F.[2,3], Wollenburg, J.[1], Jensen, L.[1], Schmidt-Aursch, M.C.[1] & Krastel, S.[3]

[1]Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany (E-mail: Wolfram.Geissler@awi.de); [2]GEOMAR Helmholtz-Zentrum für Ozeanforschung, Kiel, Germany; [3]Christian-Albrechts-Universität, Kiel, Germany

The Arctic changes rapidly in response to global warming and is expected to change even faster in the future (IPCC 2001, 2007, 2013). Large areas of the shelves and continental slopes bordering the Arctic Ocean are characterized by permafrost and the presence of gas hydrates. Future global warming and potential hydrate dissociation in the Arctic Ocean challenge the slope stability of these areas. This may lead to slope failures. The first, and so far only reported, large-scale slope failure in the Arctic Ocean is the Hinlopen/Yermak Megaslide, which is located in front of the Hinlopen glacial trough north of Svalbard.

During cruise MSM31 onboard the German R/V MARIA S. MERIAN we investigated this giant slope failure and the deeper structure of the Sophia Basin in detail to elucidate the potential causes of the main and following failure events as well as to test existing hypotheses on the generation of this giant submarine landslide. We studied the megaslide and the adjacent so far not failed shelf areas by means of multibeam swath bathymetry, Parasound sediment echo sounder, low- and high-resolution multichannel seismic reflection profiling. The seismic data image bottom-simulating reflectors beneath not failed areas of the slope, as well as a buried gas escape pipe. On the shelf, shallower than the gas hydrate stability zone, we observed widespread gas seepage as flares in the Parasound echo sounder data. These flares rise from a seafloor highly disturbed by iceberg scouring. Therefore, we could not identify pockmarks in the multibeam data. At one location, we sampled a flare by means of a CTD probe close to the seafloor and proofed that the emanating gas has a high methane concentration.

The new data indicate that the existence of gas and gas hydrates beneath the shelf north of Svalbard was one key factor causing slope instability in the past and may also cause further slope failures in the future.

The Opening of the Arctic-Atlantic Gateway: Tectonic, Oceanographic and Climatic Dynamics - an IODP Initiative

Geissler, W.H.[1], Knies, J.[2,3], Nielsen, T.[4], Gaina, C.[5], Matthiessen, J.[1], Gebhardt, A.C.[1], Damm, V.[6], Forwick, M.[7], Hjelstuen, B.[8], Hopper, J.[4], Husum, K.[9], Laberg, J.S.[7], Kürschner, W.[5], Morigi, C.[4,10], Schreck, M.[11], Tripati, A.[12], Vogt, C.[13], Rebesco, M.[14], Nam, S.-Il[11], Carlson, A.[15], De Schepper, S.[16], Lucchi, R.[14], Mattingsdal, R.[17], Jokat,W.[1] & Stein, R.[1]

[1]Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, D-27568 Bremerhaven, Germany (E-mail: Wolfram.Geissler@awi.de); [2]Geological Survey of Norway, NO-7491 Trondheim, Norway; [3]Centre for Arctic Gas Hydrate, Environment and Climate, University of Tromsø, NO-9037 Tromsø, Norway; [4]Geological Survey of Denmark and Greenland, 1350 København, Denmark; [5]Center for Earth Evolution and Dynamics Co5, Department of Geosciences, University of Oslo, NO-0316 Oslo, Norway; [6]Bundesanstalt für Geowissenschaften und Rohstoffe, D-30655 Hannover, Germany; [7]Department of Geology, University of Tromsø, NO-9037 Tromsø, Norway; [8]Department of Earth Science, University of Bergen, NO-5007 Bergen, Norway; [9]Norwegian Polar Institute, NO-9296 Tromsø, Norway; [10]Department of Geosciences, University of Pisa, 56126 Pisa, Italy; [11]Korea Polar Research Institute (Arctic Research Centre), 406-840 Incheon, Republic of Korea; [12]Department of Earth, Planetary, and Space Sciences, University of California, Los Angeles, California, USA, 90095; [13]Crystallography, Geosciences, University of Bremen, D-28334 Bremen, Germany; [14]OGS, 34010 Sgonico (TS) Italy; [15]College of Earth, Ocean, and Atmospheric Sciences, Oregon State University; [16]Uni Climate, Uni Research AS and Bjerknes Centre for Climate Research, NO-5007 Bergen, Norway; [17]Norwegian Petroleum Directorate, NO-4003 Stavanger, Norway

The modern polar cryosphere reflects an extreme climate state with profound temperature gradients towards high-latitudes. It developed in association with stepwise Cenozoic cooling, beginning with ephemeral glaciations and the appearance of sea ice in the late Middle Eocene. The polar ocean gateways played a pivotal role in changing the polar and global climate, along with declining greenhouse gas levels. The opening of the Drake Passage finalized the oceanographic isolation of Antarctica, some 40 Ma ago. The Arctic Ocean was an isolated basin until the Early Miocene when rifting and subsequent sea-floor spreading started between Greenland and Svalbard, initiating the opening of the Fram Strait / Arctic-Atlantic Gateway (AAG). Although this gateway is known to be important in Earth's past and modern climate, little is known about its Cenozoic development. However, the opening history and AAG's consecutive widening and deepening must have had a strong impact on circulation and water mass exchange between the Arctic Ocean and the North Atlantic. To study the AAG's complete history, ocean drilling at two primary sites and one alternate site located between 73°N and 78°N in the Boreas Basin and along the East Greenland continental margin are proposed. These sites will provide unprecedented sedimentary records that will unveil (1) the history of shallow-water exchange between the Arctic Ocean and the North Atlantic, and (2) the development of the AAG to a deep-water connection and its influence on the global climate system. The specific overarching goals of our proposal are to study: (1) the influence of distinct tectonic events in the development of the AAG and the formation of deep water passage on the North Atlantic and Arctic paleoceanography, and (2) the role of the AAG in the climate transition from the Paleogene greenhouse to the Neogene icehouse for the long-term (~50 Ma) climate history of the northern North Atlantic.

Getting a continuous record of the Cenozoic sedimentary succession that recorded the evolution of the Arctic-North Atlantic horizontal and vertical motions, and land and water connections will also help better understanding the post-breakup evolution of the NE Atlantic conjugate margins and associated sedimentary basins.

Conjugate volcanic rifted margins, sea-floor spreading and microcontinent: Insights from new high-resolution aeromagnetic surveys in the Norway Basin

Gernigon, L.[1], Blischke, A.[2], Nasuti, A.[1] & Sand, M.[3]

[1]Continental Shelf Geophysics, Geological Survey of Norway (NGU), Leiv Eirikssons vei 39, Trondheim, Norway; [2]Íslenskar orkurannsóknir / Iceland GeoSurvey (ISOR), Department of Energy Technology, Rangarvellir, P.O. Box 30, 602 Akureyri, Iceland; [3]Norwegian Petroleum Directorate (NPD), Professor Olav Hanssens vei 10, P.O. Box 600, 4003 Stavanger, Norway

We have acquired and processed more than 88.000 km of new aeromagnetic data that cover the entire oceanic Norway Basin located between the Møre volcanic rifted margin (MVRM) and the Jan Mayen microcontinent (JMMC). The new compilation allows us to revisit the crustal structure of the conjugate volcanic (rifted) margins and the spreading evolution of the Norway Basin from the Early Eocene breakup time to the Late Oligocene when the Aegir Ridge became extinct. The volcanic margins (sensu stricto) that formed before the opening of the Norway Basin have been disconnected with the previous Jurassic-Mid Cretaceous episode of crustal thinning. The significant amount of breakup magmatism (SDRs), the large amount of pre-breakup sag sedimentation, and the presence of large continental crustal rafts and marginal plateau without the systematic occurrence of underlying and/or exhumed serpentinised terranes, make the MVRM appear to be quite different from (Iberian type) magma-poor margins. We also show evidence of relationships between the margin architecture, the breakup magmatism distribution along the sharp continent-oceanic transitions, and the subsequent oceanic segmentation. The Norway Basin is now fully covered by high-resolution magnetic data form and shows a more complex system of asymmetric oceanic segments locally affected by episodic ridge jumps. The new aeromagnetic compilation also confirms that a fan-shaped spreading evolution of the Norway Basin was clearly active before the cessation of seafloor spreading and extinction of the Aegir Ridge. An important Mid Eocene kinematic event at around magnetic chron C21r can be recognized in the Norway Basin. This event coincides with the onset of diking and increased rift activity (and possible oceanic accretion?) between the proto-JMMC and the East Greenland margin. It led to a second phase of breakup and microcontinent formation in the Norwegian-Greenland Sea ~26 Myrs later in the Oligocene.

3D Stress and Strain Modeling in Nordland, Northwestern Norway

Gradmann, S., Keiding, M., Olesen, O. & Maystrenko, Y.

Geological Survey of Norway NGU, Trondheim, Norway

The Nordland area in NW Norway is one of the tectonically most active areas in Fennoscandia. It exhibits patterns of extension, which are in contradiction to the first-order regional stress pattern which reflects compression from ridge-push. The regional stress field stems from the interaction of ridge push and GIA (glacial isostatic adjustment); the local stress field mainly results from gravitational stresses as well as the flexural effects of sediment erosion and offshore re-deposition. Whereas the first three effects are fairly well constrained, the latter is only poorly known and is the focus of this study.

A number of data sets are collected within the project: Seismicity is monitored by a 2-year local seismic network. Surface deformation is recorded by a dense GPS network and DInSAR satellites. In-situ stresses are measured in a couple of relevant boreholes.

We develop 3D finite element numerical models of crustal scale, using existing geometric constraints from previous geophysical studies. Internal body forces (e.g. variations in topography and crustal thickness) already yield significant deviatoric stresses, which are often omitted in stress models. We apply the far-field stress fields (GIA, ridge-push, sediment redistribution) as effective force boundary conditions to the sides or base of the model. This way, we can account for all stress sources at once, but can also vary them separately in order to examine their relative contributions to the observed stress and strain rate fields.

We constrain a best-fit model using the different seismological and geodetic data sets collected and compiled within the project. Major faults are included as pre-existing weakness zones. Their effects on stress localization are studied in connection to observed clusters of enhanced seismic activity.

The Reinfjord Ultramafic complex, Seiland Igneous Province, Northern Norway

Grant, T.B. & Larsen, R.B.

NTNU, Trondheim, Norway. (E-mail: thomas.grant@ntnu.no)

The Seiland Igneous Province (SIP), Northern Norway consists of >5,000 km^3 of mafic, ultramafic, silicic and alkaline melts. These were intruded into the lower continental crust (25-30 km depth) within just 10 Ma (570-560 Ma). The SIP may therefore represent the deep plumbing system of a large igneous province, making the region an excellent location in which to study the ascent, emplacement and modification of dense ultramafic melts from the mantle into the lower crust. Here, we report field and geochemical data on the Reinfjord ultramafic intrusion.

The ultramafic melts in the Reinfjord intrusion were emplaced into partially solidified, layered gabbro-norite as three separate series. The first two series, the lower and upper layered series (LLS + ULS), are composed of rhythmically modally layered olivine – clinopyroxene cumulates and are separated by a thin gabbro screen. The final phase, the central series (CS), is a cryptically layered dunite-poikilitic wehrlite cumulate that occupies the central region of the intrusion. The CS intruded into a partially crystallized crystal mush of the ULS. As this melt was saturated with olivine it reacted with the pyroxene dominated ULS to form discordant replacive dunites. Contamination of the ultramafic magmas by the gabbro is localized to <150 m wide marginal zones that consist of coarse grained pyroxenites, leucogabbro xenoliths and plagioclase bearing ultramafic rocks.

The CS formed two reef deposits of 5 and 7 m's thickness, respectively, 20 m's apart and with 1-2 % sulphide. The lower deposit (5 m) is a PGE-reef with 0.64 g/t Pt+Pd+Au, 0.15 g/t Os, and 0.27% Ni. The upper Cu-Ni reef has 0.38% Ni and 0.12% Cu and traces of PGE. PGE analysis of sulphide bearing portions of the ultramafic rocks yielded a conspicuous trough shaped PGE-pattern with positive Os, Rh, Pt and Pd anomalies but negative Ir and Ru values, which may be indicative of melts derived from the deeper parts of the mantle close to the C-M boundary.

Jurassic biostratigraphy of Eastern Taimyr, Arctic Siberia

Gubanov, A.P.[1,2] & Nikitenko, B.L.[3]

[1]SCANDIZ, Skokloster, Sweden (E-mail: alexander.gubanov@scandiz.se); [2]CASP, University of Cambridge, Cambridge, UK; [3]Trofimuk Institute of Petroleum Geology and Geophysics, Novosibirsk, Russia

During the fieldwork 2010, Jurassic outcrops along the Chernokhrebetnaya River in southeast Taimyr have been examined. The section is build up by marine weakly lithified clastic sediment ranging from organic-rich clays to sandstones yielding occasional thin layers and concretions of limestone. The entire Jurassic succession is ~1.5 km thick. The well exposed middle and upper Jurassic strata were sampled for palaeontology. This study allows fine biostratigraphic zonation and correlation based on foraminifers and ostracodes.

The location of the studied section between the Anabar-Lena and the Yenisei-Khatanga depressions is important for better understanding of both basins formation during the Jurassic time as well as more accurate interpretation of onshore and offshore seismic data.

World Basement Geological Map - a new platform for global reconstructions

Gubanov, A.P.[1] & Mooney, W.D.[2]

[1]SCANDIZ, Skokloster, Sweden (E-mail: alexander.gubanov@scandiz.se); [2]USGS, Menlo Park, USA

Geological maps display the surface geology of the Earth, and since a large portion of the surface is covered by sedimentary rocks, the deeper features of the continental crust are overshadowed. Due to the large number of small details and lack of large-scale geological features in places, these maps are difficult to use for reconstruction of large-scale lithospheric events or interpretation and interpolation of global geophysical data.

Here we present simplified crustal basement geological map of the world where the sedimentary cover was removed to expose a collage of rocks of different ages. It shows four Precambrian age units, Achaean (3.8-2.5 Ga), Paleoproterozoic (2.5-1.6 Ga), Mesoproterozoic (1.6-1.0 Ga), and Neoproterozoic (1.0-0. 54 Ga) and three Phanerozoic units: Early Paleozoic (543-400 Ma), Late Paleozoic (400-250 Ma), and Mesozoic-Cenozoic (250-0 Ma). The map reveals the history of continental growth where large blocks of continental crust were accreted around Achaean cratons and a large area of older crust was heavily reworked during continent-continent collisions.

The map provides context for an evaluation of global and continental scale models of crustal evolution as well as background for specialists in earth sciences who are addressing issues on a global scale. Of particular interest is to use our Global Map as a platform for investigation of the basement control on the formation and development of sedimentary/hydrocarbon basins by combining geophysical, geodynamic and paleogeographic data.

Magma flow and stress induced magnetic fabric inferred from AMS analysis. A Case study in Early Cretaceous sills from the Diabasodden suite (HALIP), Svalbard

Halvorsen, E.[1,2]

[1]Department of geosciences, University of Bergen; [2]The Centre for earth evolution and dynamics, University of Oslo

The effects of different petrological processes on the magnetic fabric of sills from the Diabasodden suite outcropping in eastern and central Svalbard were studied by means of the AMS technique. Magnetite is believed to be the main carrier of the magnetic fabric in the sills and crystallized late, after the main rock-forming minerals. The sills exhibit two different paleomagnetic directions that are suggested to represent the primary Early Cretaceous magnetization and a complete overprint in the Cenozoic.

The anisotropy of magnetic susceptibility (AMS) is an indicator of the strain experienced by a rock changing the orientation or shape of the magnetic grains so that the susceptibility becomes anisotropic. Igneous rocks forming sills can display a magnetic anisotropy derived from the viscous flow, and AMS measurements can thus be used to study their emplacement mechanisms.

Magnetic data from sills sampled in eastern Svalbard indicate a mean susceptibility of about 10^{-2} SI and a mean anisotropy (P) degree of about 1.03. The magnetic foliation plan is horizontal and parallel to the sill margins. The maximum (K1) and intermediate (K2) susceptibility directions are even distributed in the foliation plan. The minimum direction (K3) is well defined and vertical.

Magnetic data from sills sampled in central Svalbard show two patterns of fabric. The first group of samples exhibit very poor directional consistency. The susceptibility is about 10^{-3} Si and the magnetic fabric is of medium to low anisotropy ($P < 1.02$). The second group of samples exhibit well defined nearly horizontal K1 directions trending east - west. The K2 and K3 directions are distributed in the vertical plan trending north – south. The susceptibility is about 10^{-2} Si and the magnetic fabric is of higher anisotropy ($P = 1.04$).

The magnetic fabric measured in the samples from eastern Svalbard is believed to represent fabric caused by magma flow. During the ascent, emplacement and post-emplacement deformation of igneous rocks, two or more phases of deformation that overprint each other are often depicted. These overprints, when magnetic minerals are present, are recorded in magnetic fabric. It is suggested that the fabric found in the second group of samples from central Svalbard represent fabric related to regional stresses during the West Spitsbergen fold and thrust belt.

Structure and stratigraphy of the Northwind Basin and southern Chukchi Borderland from multi-channel seismic (MCS) reflection data: implications for regional geology and tectonics

Ilhan, I. & Coakley, B.

University of Alaska Fairbanks, Fairbanks, AK 99775 USA (E-mail: iilhan@alaska.edu)

Approximately 5300 km of MCS reflection profiles were acquired across the transition from the Chukchi Shelf (CS) to the Chukchi Borderland (CBL) with a tuned air-gun array (total volume: 1830 cubic inches) and a 5,75 km streamer. These data are being used to establish tectonic and stratigraphic relationship between the CS and CBL, and to indirectly test the hypotheses for the opening of the Amerasia Basin. These data reveal the basin-infill stratigraphy and structure of the Northwind Basin (NB) and the southern CBL.

The CBL is continental crust that has been segmented by N-S trending grabens. The bathymetry, MCS and potential field data are consistent with extensional deformation. The MCS data reveal the basement structure, its orientation relative to the CS and the basin stratigraphy. Four major border fault systems have been recognized based on their hanging-wall and footwall offset relationships. These border faults systems show variations in their dip directions, strikes, and amount of displacement. Two of the border fault systems of opposing dip form the full-graben structure of the NB between the Chukchi Plateau (CP) and Northwind Ridge (NR).

The syn-rift sequence is distinguished by stacking of internally divergent reflector packages with an overall wedge-shape basin geometry along the border fault systems of the NB. Comparison of the syn-rift sequence among the border fault systems suggests the rift traits differ in the underlying basin grabens in the southern CBL. This is supported by the change of strikes of the border fault systems. The early post-rift sequence shows bi-directional onlap and variations with its overall basin geometry: wedge-shape or thickening in the basin synclines. This unit overlies the post-rift unconformity, which marks the end of rift stage. The bi-directional onlap suggests axial infill from southerly sources. The thickening of the early post-rift sequence in the central basin is due to differential compaction of the underlying sediments. The late post-rift sequence is tabular and affected by only minor faulting.

The post-rift sediment thickness varies dramatically between the North Chukchi Basin (NCB) and NB. While the NCB contains over 5.5 sec. of two-way travel time sediment, the NB has 2 sec. of sediment reflecting south-sourced sediment transport direction and time-transgressive deposition that was controlled by the structural highs. In particular, the limited syn-rift sequence appears to be associated with the high-relief faults suggesting that the footwall was exposed and shedding local sediments into the basin during rifting. The bulk of the basin infill appears to be post-rift; derived from the strong progradational sequences observed on the shelf. It appears that the basin was starved during much of its history, while the depositional shelf edge prograded across the CS, postponing the arrival of sediments to fill the basin.

The East - Barents Megadepression and its relationship to adjacent tectonic elements

Ivanova, N.M.[1], Amelin, N.V.[1], Veretennikova, M.A.[1], Miles L.[1], Belyaev I.V.[2] & Gee, D.G.[3]

[1]Geology without limits, Regional Geophysical Exploration LLC, Russia Shukhova st.,14, Moscow, Russia 115162; [2]Russian Geological Research Institute (VSEGEI), Saint-Petersburg, Russian Federation 74, Sredny prospect, St. Petersburg, Russia, 199106; [3]Uppsala University, Sweden, Department of Earth Science, Villavagen 16, Uppsala, SE-752 36, Sweden

In 2012-2013, the Scientific Association "Geology without Limits" conducted a regional 2D seismic survey of the central and eastern parts of the Barents Shelf and northern parts of the Kara Shelf.

The new seismic data, recorded to 18 seconds (TWT), enables an assessment of the full crustal structure of the vast sedimentary basin – the East - Barents Megadepression (EBM). The latter spreads over a wide area beneath the central and northern parts of the Barents Sea, northwards to the St. Anna Trough. The boundaries of the megadepression are strongly influenced by large NE - trending fault zones. The very thick sedimentary cover (14-20 km) was deposited on basement blocks of Baikalian (Timanian) and probably Grenvillian-Sveconorwegian age, with Caledonian orogeny influencing western parts of the Barents Shelf and Uralian thrusting in Novaya Zemlya.

The EBM includes three large sedimentary basins: the South Barents Basin, North Barents Megatrough and St. Anna Trough. Western peripheral parts of the EBM are complicated by NW-trending faults, defining the West Kola, Demidovskiy, Malyginskiy and Knipovich graben. To the northeast from the North Barents Basin, two similar structures are distinguished, the largest being the North Novozemelskiy Graben. All these graben are transversal structures with respect to the EBM.

The EBM is surrounded by platform areas, where Paleozoic carbonate and terrigenous sediments dominate the sedimentary cover: to the west – the Svalbard (west Barents) Shelf; to the south and southeast – the Pechora Syneclise; to the east and northeast – the North Kara Syneclise. Geological and geophysical data show that the North Kara Syneclise (terrane) was not an independent 'plate' or microcontinent in the Palaeozoic, but an essential part of Baltica.

The sedimentary succession of the EBM is composed mainly of Upper Paleozoic and Mesozoic terrigenous deposits. The lower part of the sedimentary cover, the Devonian and Carboniferous succession is characterized by high velocities of 5.8-6.2 km s-1 and its thickness riches up to 5-7 km in the deepest part of the megadepression. Basalts and mafic sills are present in the Devonian succession. The Upper Permian to Lower Cretaceous clastic deposits form the main part of the sedimentary cover with the largest thickness in the Upper Permian and Triassic units (8-10 km). The Upper Permian sequence is characterized by clinoform structures, dipping northeastward on the southern flank and westward on the eastern flank of the EBM. The Triassic is represented by rhythmical alternation of sand and shale deposits of great thickness (4-7 km). Mafic sills and stocks occur in the Upper Permian and Triassic section within the EBM. This last cycle of rifting in Permian to Triassic time was accompanied by intensive regional sagging, accompanying accumulation of the greatest thicknesses in the sedimentary cover of the East-Barents Megadepression.

Crustal structure off NE Greenland – a review

Jokat, W.

Alfred Wegener Institute Helmholtz Centre for Polar Research, Bremerhaven, Germany

The complex structure of the North-East Greenland margin is the consequence of two rifting events: the initial separation of Greenland and Scandinavia around 56 Ma, and the dispersal of the Jan Mayen microcontinent from Greenland around 33 Ma. The latter event might have been driven by the arrival of the Iceland Plume beneath the east coast of Greenland. The boundary between these two rifting events is the Jan Mayen Fracture Zone. While seismic lines north of this pronounced topographic structure document the crustal variations in detail, this is not the case south of it. The data show no indications that the lower crust hosts a large, high velocity body as has been found north of the fracture zone. A 500 km long seismic transect, which starts in Kong Oscar Fjord, provides a detailed view of the crustal structure just south of the Jan Mayen Fracture Zone. The transect includes parts of the Caledonian crust of Greenland, and crosses the present-day shelf and the oceanic crust formed since the separation of the Jan Mayen microcontinent. The seismic refraction line shows a constant ~9 km thick oceanic between the extended continental margin and the mid-ocean ridge. Indications for a 3 km thick high-velocity lower crustal body are observed within the continent-ocean transition zone. While such high velocity crust is ubiquitous beneath the shelf to the north of the fracture zone, to the south it only occurs beneath Mesozoic basins that have been attributed to extensional collapse of the Caledonian orogeny in East Greenland. In line with earlier interpretations of high velocities in the lower crust of extended continental margins, we suggest that Kong Oscar Fjord is underlain by the products of excess magma production that were focused along the Jan Mayen Fracture Zone during the breakup of the Jan Mayen microcontinent from Greenland.

In strong contrast north of the Jan Mayen Fracture Zone only thin oceanic crust is present. While the Greenland Basin has crustal thicknesses up to 4 km and formed during slow to ultraslow spreading rates, all geophysical data north of the Greenland Ridge indicate a formation of the Boreas Basin at ultraslow spreading rates. These observations indicate that a possible thermal mantle anomaly, which caused/fed the East Greenland continental flood had a limited size and was located close to the Kong Oscar/Kajser Franz Josef fjords.

In summary, the existing crustal data support models in which the Jan Mayen Fracture Zone plays an important role for the regional magmatism off East Greenland.

Evolution of the Amerasian Basin – a Tectonic Model

Kazmin, Y.B.[1], Brekke, H.[2], Petrov, E.I.[3], Nikishin, A.M.[4], Lobkovskiy, L.I.[5] & Poselov, V.A.[6]

[1]Russian Ministry of Natural Resources and Environment, Moscow, Russia; [2]Norwegian Petroleum Directorate, Stavanger, Norway; [3]Russian Agency for Mineral resources, Moscow, Russia; [4]Moscow State University, Moscow, Russia; [5]Russian Academy of Sciences, Moscow, Russia; [6]VNIIOkeangeologia, St. Petersburg, Russia

There has been a revolutionary increase in the amount and variety of geoscientific data from the Arctic Basin during the last decade, which provide much better constraints than before on the tectonic history of the Amerasian Basin. This means that previously proposed models for the formation of the Amerasian Basin must be reconsidered, including the much referred to models of rotational opening involving simple sinistral strike slip along the Amerasian flank of Lomonosov Ridge accompanied by full seafloor spreading in the Canada Basin.

The ACEX 2004 drilling confirmed that the Lomonosov Ridge is of continental origin and constituted the edge of the shallow continental shelf adjacent to the Amerasian Basin during the Cretaceous. The new multibeam bathymetry and the multichannel seismic show that the Amerasian flank of the Lomonosov Ridge consist of rotated fault blocks resulting from mainly extensional faulting and not by pure strike slip. If sinistral strike slip tectonics were an essential part of the opening of the basin, the strike slip zone would have to be located elsewhere. The area between the Lomonosov Ridge and the Canada Basin is a complex of submarine basins and highs, in which most of the basement is hidden under volumes of magmatic rocks. This complex, which includes the Lomonosov Ridge, is elevated relative to the basins on each side (i.e. the Canada Basin and the Eurasian Basin) and include features like the Alpha Ridge, the Mendeleev Rise, the Chukchi Plateau, and the Chukchi, Podvodnikov and Makarov basins. It is a commonly accepted view that the magmatism was caused by hot spot activity associated by an underlying mantle plume, forming what is commonly referred to as the High Arctic Large Igneous Province (HALIP). Age dating of magmatic rock samples from this complex now show that these rocks were probably emplaced in two main episodes in the Cretaceous; the first at 130 – 120 Ma and the second at 100 – 80 M. Analyses show that the first episode represents volcanism with a chemical signature similar to Deccan Traps and continental plateau basalts, while the second episode was probably dominated by alkaline basalt volcanism. This is all evidence that the magmatic complex was intruded into and extruded onto pre-existing continental crust. The HALIP is a regional feature that extends into the shallow shelf areas adjacent to the Arctic Ocean. Recent publications present evidence for a dike swarm of the first magmatic episode, dated at 125 – 120 Ma, extending from the southern part of the Alpha Ridge, cutting the Lomonosov Ridge, and continuing into the Franz Josef Land and Svalbard Archipelagos. This strongly indicates that the basement to the Alpha Ridge and other parts of the magmatic complex is older than the first magmatic episode. Recent publications now also show, based on new refraction seismic, oceanic crust is restricted to an area centred within the middle of Canada Basin surrounded by highly attenuated transitional and continental crust. It is now evident that such attenuated continental crust is also underlying the complex of basins and highs between the Canada and Eurasian basins.

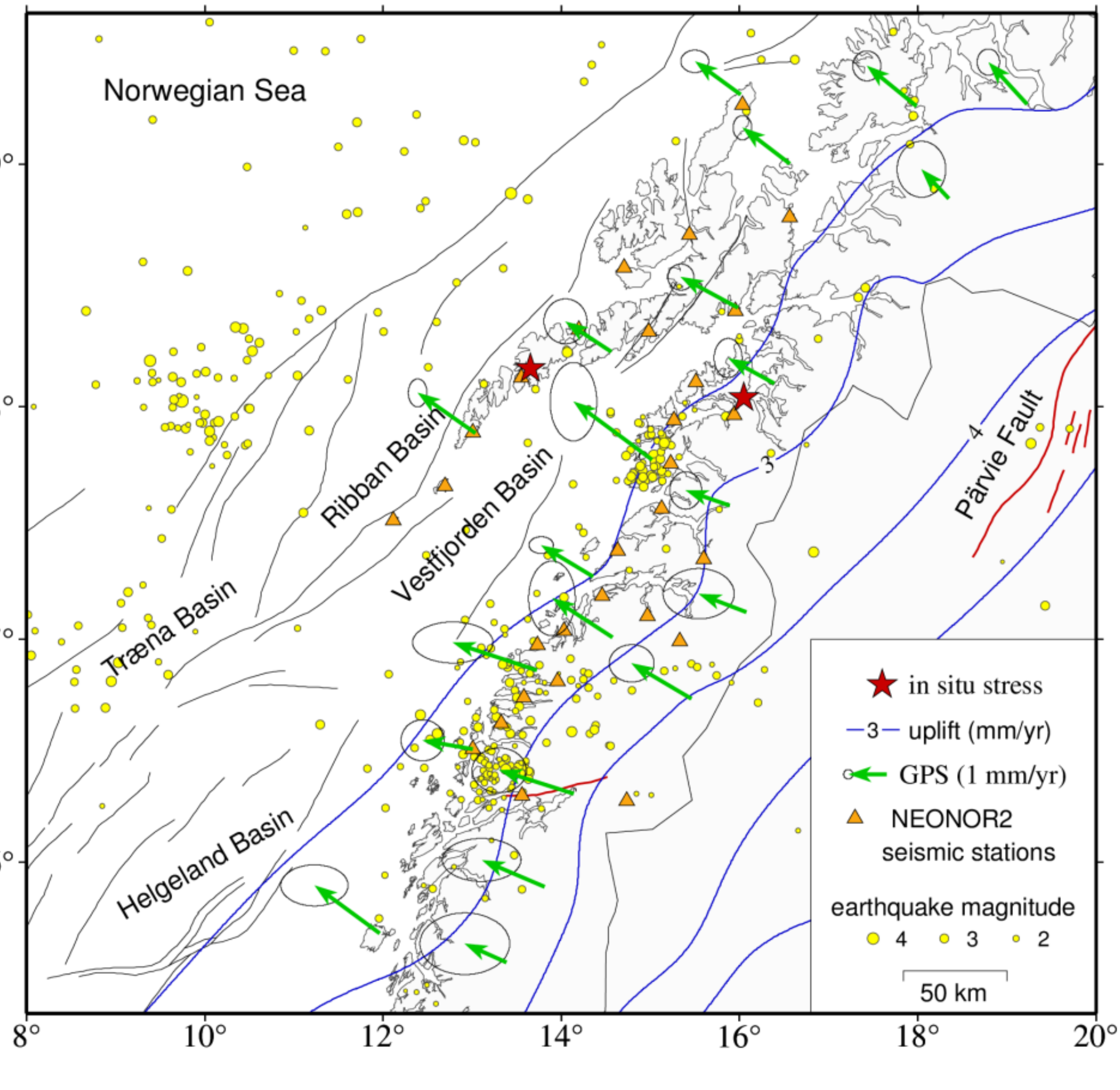
Based on the evidence and interpretations above, we present a two-stage model for the tectonic development of the Amerasian Basin. The first stage is the extension, stretching and eventual opening of the Canada Basin, mainly in a rotational mode with sinistral strike slip in the northern end (however, not along the Lomonosov Ridge). The second stage involved the first magmatic episode in Early Cretaceous and the rotation of the stress field into extension perpendicular to the initial strike slip direction. This gave extension perpendicular to shelf edge in the north, which at the time was constituted by the Lomonosov Ridge. This extension regime lasted through the Cretaceous giving intermittent phases of block faulting, partly overprinted by the second magmatic episode. The second magmatic episode, together with the Late Cretaceous plate tectonic movements involving Greenland, may have been the precursor to the final breakup and the earliest Cenozoic onset of seafloor spreading in the Eurasian Basin. Space for the opening of the Amerasian Basin in the Cretaceous was probably accommodated in the margin of the Pacific Ocean.

Neotectonics in Nordland, NEONOR2 – Implications for petroleum exploration

Keiding, M., Gradmann, S., Olesen, O., Maystrenko, Y. & the NEONOR2 working group

Geological Survey of Norway, Trondheim, Norway (marie.keiding@ngu.no)

Large petroleum reservoirs may be present in the area offshore Nordland. However, a potential problem for exploration relates to the considerable Pleistocene uplift and erosion in the area, which may have affected the petroleum generating mechanisms and reservoir integrity, similar to what has been observed in the Barents Sea. With this project, we intend to investigate the regional stress and strain dynamics in Nordland and offshore areas and the implications for petroleum exploration. We will use a detailed monitoring of seismicity, geodetic observations of surface deformation and in-situ stress measurements to map the present-day strain rate and stress field, and link the findings to tectonics, exhumation and isostatic processes during the Pleistocene through numerical modelling.



A network of 26 temporary seismic stations in Nordland has been installed, and initial recordings confirm a relatively high level of seismicity, mainly located along the coast of Nordland and in the offshore areas. Focal mechanisms will be estimated for the recorded events, when possible, and used to obtain important information about the present-day stress field. The surface deformation is monitored by a network of permanent GPS stations as well as differential SAR interferometry from a new satellite launched by the European Space Agency in 2014. As an initial approach, the available GPS and seismological data have been used to derive strain rate fields at the surface and at seismogenic depths. The stress field in Norway is made up by the interaction of a number of different stress generating mechanisms, notably ridge push, sediment redistribution, glacio-isostatic adjustment, topography and density contrasts in the crust. The influence of these different mechanisms in Nordland and offshore areas will be investigated through 3D finite-element modelling. Finally, the thermal history of the offshore basins will be assessed through 3D thermal modelling.

Ultramafic to mafic magmas in Norwegian Arctic: geochemical evidence for the multiplicity of mantle sources

Kepezhinskas, P.K.[1], Eriksen, G.M.D.[1] & Kepezhinskas, N.P.[2]

[1]Kimberlitt AS, Tollbugata 24, Oslo, Norway; [2]University of Florida, Gainesville, Florida, USA

Geology of Eastern Finnmark province (Norwegian Arctic) is dominated by diverse Archean crystalline basement complexes superimposed with Proterozoic greenstone belts. Isotopic dating of detrital zircons from basement gneisses in the Kirkenes area establishes presence of Early Archean (3.69 Ga) crustal component as well as three major episodes of crustal growth at 3.2 Ga, 2.7-2.9 Ga and 2.5 Ga. Precambrian terranes are intruded by ultramafic-mafic dikes and sills that range in composition from mica picrites and ultramafic-mafic lamprophyres to high-Mg basalts and low-Ti subalkaline basalts. Geochemical characteristics of these rocks fall into three principal groups: 1) enriched compositions with high Nd, Nb, Hf, Zr and Th concentrations and elevated La/Th and Nb/Th coupled with low La/Nb, Ba/Nb and U/Nb ratios; 2) compositions depleted in Th, Hf and Nb together with low LREE/HFSE (such as La/Nb) and LILE/HFSE (such as Ba/Nb and U/Nb) ratios; 3) transitional group clearly identified by marked depletions in Ti, Nb and Ta contents coupled with enrichment in Th and U and other large-ion lithophile elements (LILE). These geochemical characteristics are interpreted within the framework of two principal source models: 1) derivation of parental ultramafic-mafic melts from multiple mantle sources (depleted to enriched) inherited from Archaean lithospheric tectonics and 2) a single primitive mantle source which underwent several depletion and enrichment episodes, at least partially associated with subduction zone processes. Subduction modification of depleted lithospheric mantle was assisted by accretion of subducted sediment to depleted mantle source at Proterozoic or Early Paleozoic convergent margin. Alkaline ultramafic rocks such as lamprophyres and mica picrites (transitional kimberlites) display geochemical characteristics supportive of their origin within stability field of diamond in a deep mantle beneath Norwegian Arctic margin which, together with other lithospheric characteristics, suggests its high potential for hosting economic diamond mineralization.

Mesozoic tectonic events in the Eastern Taimyr Fold and Thrust Belt and adjoining Yenisey-Khatanga Depression

Khudoley, A.K.[1], Verzhbitsky, V.E.[2], Zastrozhnov, D.A.[3] & Ershova, V.B.[1]

[1]St. Petersburg State University, University Emb. 7/9, St. Petersburg, 199034, Russian Federation (E-mail: akhudoley@gmail.com); [2]Shirshov Institute of Oceanology RAS, Moscow, 117997, Russian Federation; [3]University of Oslo, The Centre for Earth Evolution and Dynamics (CEED), Sem Sælands vei 2A, 0371, Oslo, Norway

The Taimyr Fold and Thrust Belt (FTB) was formed after several tectonic events occurred in Neoproterozoic, Late Paleozoic and Mesozoic. In its modern structure, three domains are recognized: the Southern, Central and Northern zones. Southern zone of the Taimyr FTB is a deformed margin of the Siberian Craton, Central zone consists of terranes of different origin, and Northern zone consist of the Kara microcontinent.

Neoproterozoic and Late Paleozoic (Hercynian) tectonic events were accompanied by intense faulting and folding and granite intrusion and are clearly recognized in the Northern and Central zones. Southern zone containing mainly Upper Paleozoic and Mesozoic rocks was deformed in Mesozoic. However, recent apatite fission track studies show wide distribution of Mesozoic orogeny throughout the study area. The following tectonic events are identified.

205-175 Ma (latest Triassic – Early Jurassic). The most widespread event recognized throughout the east Taimyr FTB and in the adjacent areas of the Yenisey-Khatanga depression. The event is documented by apatite dating from both Permian-Triassic rocks and the Jurassic-Neogene sandstones unconformably overlapping Neoproterozoic and Paleozoic rock units in the Central and Northern zones. In the Southern zone of the Taimyr FTB and adjacent areas of the Yenisey-Khatanga depression this event corresponds to low-angle unconformity separating the uppermost Triassic and Jurassic rocks from older units. Intensity of deformation decreases southward.

120-85 Ma (Aptian – Coniacian). This event was the most intense in the southernmost part of the Taimyr FTB and in the adjacent areas of the Yenisey-Khatanga depression, whereas in the Central and Northern zones it is only locally recognized. It supports our observation that Triassic and Jurassic rocks were deformed in the same stress field. Most likely, compressional structures documented in the southernmost Taymyr FTB and to the south of it were formed during this event.

65-55 Ma (Paleocene). This event is locally recognized in different parts of the study area, and it does not clearly correlate with any specific structures in the study area. Probably, it corresponds to reactivation of normal faults related to the rifting and opening of the Laptev Sea sedimentary basin.

Supported by TGS, RFBR grants 13-05-00943, 15-35-20591, SPbSU project 3.38.137.2014

High Arctic LIP in Canada: Nd isotopic evidence for the role of crustal assimilation

Kingsbury, C.G.[1], Ernst, R.E.[1], Cousens, B.L.[1], Williamson, M.-C.[2] & Xia, Y.[1]

[1]Ottawa Carleton Geoscience Centre, Carleton University; 1125 Colonel By Drive, Ottawa, ON, K1S 5B6, Canada (E-mail: Cole_Kingsbury@carleton.ca); [2]NRCan – Geological Survey of Canada; 601 Booth Street, Ottawa, ON, K1A 0E8, Canada

The geology, tectonic configuration and evolution of the Cretaceous Arctic margins in many respects represents the last major uncertainty in our understanding of how Pangea rifted apart. A key element to solving this puzzle is understanding the voluminous and extensive constituent mafic dyke swarms, sill provinces and lava flows of the c. 90 – 130 Ma High Arctic large igneous province (HALIP) in Arctic Canada, Norway (Svalbard) and Russia's western Arctic along with offshore regions (Alpha-Mendeleev Ridge).

Herein, we report on new Sm-Nd isotopic data from intrusions and lava flows which were emplaced within or over the Early Cretaceous Isachsen Formation on Canada's Axel Heiberg Island in order to (1) constrain the chemistry of magmatic source(s) and (2) assess whether these rocks show evidence for crustal assimilation, a process that is important in generating orthomagmatic Ni-Cu-PGE deposits. We then compare these data with previous Nd isotopic analyses from Isachsen Formation (4 samples) and the Late Cretaceous Strand Fiord Formation continental flood basalts (4 samples) (Estrada and Henjes-Kunst, 2004).

Our 10 new Sm-Nd isotopic analysis from sills, dykes and a lava flow from South Fiord on western Axel Heiberg Island reveal that basaltic rocks have $\varepsilon Nd(T)$ between +1.2 and +4.5. This indicates that Nd isotopic compositions are more depleted than chondritic values and in tandem with trace element geochemical data, suggest that a major component of the melt is consistent with an E-MORB source. We preformed two component mixing analyses on a Nb/U vs. $\varepsilon Nd(T)$ plot assuming starting compositions for E-MORB (Nb/U = 46.11, $\varepsilon Nd(T)$ = +7) and continental crust (Nb/U = 4.44, $\varepsilon Nd(T)$ = -7). With Nb/U ratios of our samples ranging from 15 – 25, our model indicates that mantle-derived magmas assimilated ~10% continental crust by weight.

Furthermore, our new Sm-Nd isotopic evidence support trace element analyses showing evidence of continental crustal assimilation (e.g. Jowitt et al. 2013) that, when coupled with evidence for magma fertility and variable chalcophile-element depletion, support models for Ni-Cu-PGE deposit potential. Isotopic data presented here demonstrate the importance of crustal assimilation in the evolution of HALIP magmas from source to emplacement.

Sedimentological and stratigraphic evidence for a multiple floods along the Beaufort Margin, Arctic Ocean

Klotsko, S.A.[1], Driscoll, N.W.[1] & Keigwin, L.[2]

[1]Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA, USA (E-mail: sklotsko@ucsd.edu); [2]Woods Hole Oceanographic Institution, Woods Hole, MA, USA

In 2013, a cruise on the USCGC Healy mapped the Beaufort margin from Barrow, AK into the Amundsen Gulf using a towed CHIRP subbottom profiler and a hull- mounted Knudsen CHIRP subbottom profiler. Sediment cores were also acquired. The seismic data image three margin-wide flood deposits, which have a diagnostic acoustic pattern. The first flood, characterized by a high amplitude reflector, correlates with increased ice-rafted debris (IRD). Above the basal reflector, an acoustically transparent interval is observed with thicknesses on the order of 7 m near the depocenter (stations 5 and 9); this second flood interval has diminished IRD and radiocarbon dates yield accumulation rates higher than 12 m/ky. Above the transparent interval is a series of high amplitude reflectors that record the third flood. Sediment core Healy1302-JPC15, from station 5 on the Mackenzie slope, was analyzed for grain size using a Laser Diffraction Particle Size Analyzer. These data were compared to the magnetic susceptibility data from the core. Peaks in the susceptibility correlate with increases in grain size, as well as high amplitude reflectors observed in the seismic data. The first and third floods, have grains sizes reaching ~20 µm, while the dominant grain size for the second flood is ~5 µm. We postulate that the deglaciation of Amundsen Gulf generated the first flood ~14 kya, with icebergs transporting the large amount of detrital carbonate IRD. The second flood was likely seasonal flooding of Lake Mackenzie and Lake McConnell draining down the Mackenzie River. The third flood, associated with the draining of glacial Lake Agassiz, entered the Arctic Ocean via the Mackenzie River ~13 kya. Planktonic oxygen isotope data for the first two floods reflects the light δO18 signature consistent with a large glacial meltwater input. The planktonic and benthic oxygen isotope data for the third flood co-vary, reflecting the prefreshening of the region. The timing and magnitude of this event suggests it may have caused the Younger Dryas cold period.

This work was supported by a grant from the U.S. National Science Foundation.

Onshore-offshore tectonic relationships in Troms and Finnmark, North Norway

Koehl, J.B.[1,2], Bergh, S.G.[1,2], Indrevær, K.[2,3] & Henningsen, T.[4]

[1]Department of Geology, University of Tromsø, NO-9037 Tromsø, Norway; [2]Research Center for Arctic Petroleum Exploration, Petroleum Systems and Play Concepts (ARCEx), University of Tromsø, N-9037 Tromsø, Norway; [3]Department of Geosciences, University of Oslo, P.O. Box 1047 Blindern, NO-0316 Oslo, Norway; [4]Statoil Nord-Norge, Postboks 40, NO-9481 Harstad, Norway

Previous studies on the Lofoten-Vesterålen and Western Troms Margins have been extended further north in order to better map and correlate rift-related, onshore and offshore brittle faults and sedimentary basins on the SW Barents Sea Margin. The results of these studies show that the Western Troms Margin is dominated by oblique-normal, NNE-SSW and ENE-WSW trending, post-Caledonian brittle faults that likely formed under WNW-ESE extension, at ca. 10 km depth, under greenschist facies conditions. These structures are believed to have acted as fluid conduit during faulting and to have, then, been quickly sealed due to decreasing P/T conditions. Moreover, major, NW-SE trending transfer zones, such as the Senja Shear Belt and the Fugløya transfer zone, developed in the Paleogene due to transform movements along the De Geer Zone and probably accommodated movements along the NNE-SSW and ENE-WSW trending fault sets. K/Ar and Apatite Fission Track dating on fault rocks onshore Western Troms have constrained faulting to the Carboniferous-Permian in this area, and to the Triassic - Cretaceous on the adjacent Lofoten-Vesterålen Margin. This suggests that rifting migrated to the west during or prior to the main, Late Jurassic – Early/Mid Cretaceous stage of extension. The margin, then, underwent major, rapid Cenozoic uplift and exhumation that are responsible for the current short-tapered, hyper-extended margin architecture. Furthermore, new high-resolution bathymetry data showed that ductile Proterozoic and Caledonian fabrics, as well as Paleozoic-Mesozoic brittle fractures can be mapped with accuracy on the strandflat off the coast of Troms and Finnmark. These data also evidenced brittle structures that display trends similar to the NW-SE trending Trollfjorden-Komagelva fault zone and will be investigated further through this project. Two additional goals for the project are the characterization of potential Carboniferous basins bounded by major brittle faults on the Finnmark Platform and of potential Devonian half-grabens bounded by the probable offshore continuation of the Trollfjord-Komagelv fault zone off the coast of Finnmark.

On the quantification of Late Cenozoic glacial erosion of the northern Norwegian – south-western Barents Sea continental margin (69 – 74^{o}N)

Laberg, J.S. & Rydningen, T.A.[1]

University of Tromsø – The Arctic University of Norway, Dept. of Geology, N-9037 Tromsø, Norway (E-mail: jan.laberg@uit.no); [1]Now at: GeoPlayGround Consult AS, Stadionvegen 3, N-9007 Tromsø, Norway

A dramatic episode of landscape evolvement affecting both the Norwegian mainland and its corresponding continental margin involved the transformation of a pre-glacial terrain into a glacial topography, and – at the same time – the alteration of a partly subaerial Barents Sea area into an epicontinental sea with a characteristic glacial morphology including troughs and banks. These major changes took place over the last ~2.7 Ma, a very short period of time which must have involved high rates of erosion and sedimentation. In this study, our estimates of erosion and sedimentation are based on the sediment volume – mass balance approach, i.e. based on isopachs of the erosional products along the margin the sediment volumes and their most likely source area were mapped, and from this the corresponding average erosion and sedimentation rates were calculated. The largest uncertainties relates to the chronology, the source area of the older part of the deposits, and the sediment volumes of the most distal accumulation areas which was not considered due to lack of data. Thus our results should be considered minimum average estimates. Reporting our results we have divided the study area into a southern and a northern part; the southern part is that of a coastal, alpine source area of crystalline bedrock; the source area of the northern part was the SW Barents Sea where the bedrock is dominated by Mesozoic sedimentary rocks.

The total average erosion of the northern part, the SW Barents Sea area has been relatively high in the troughs throughout the last ~2.7 m.y., about 1000–1100 m. For the banks, erosion is inferred to have peaked between 1.5 and 0.7 Ma, resulting in a total of 500-650 m of erosion. The minimum average erosion rate in the Barents Sea is found to be 0.4 mm/yr. Corresponding average values for the southern area are an order of magnitude lower; bedrock lowering of 140 m and bedrock erosion rate in the catchment area of 0.05 mm/yr have been estimated. The rates reported are averaged over a number of glacial – interglacial periods, and are thus lower compared to rates of peak glacials when erosion was extensive, as has been estimated for fjords and vallies slightly south of the study area where average erosion rates of 1.7 mm/yr is estimated for the last glacial.

From this we conclude that parts of the areas affected by glacial erosion have experienced high average glacial erosion rates, up to 0.4 mm/yr, while the rates were up to an order of magnitude lower in nearby areas, ~0.05 mm/yr. We relate this to differences in bedrock composition and properties of the sediment source area, i.e. softer, more easily erodible sedimentary rocks versus harder crystalline rocks more selectively eroded, but also to the timing (including onset), properties and drainage pattern of the ice sheets.

Age and origin of multiple ice-rafted debris horizons in the Canadian Beaufort Sea: implications for Arctic Ocean stratigraphy and paleoclimate

Lakeman, T.R.[1], Pieńkowski, A.J.[2], Nixon, F.C.[3], Furze, M.F.A.[2], Blasco, S.[4] & Andrews, J.T.[5]

[1]Geological Survey of Norway, Trondheim, Norway; [2]Department of Physical Sciences, MacEwan University, Edmonton, Alberta, Canada; [3]Nova Scotia Department of Natural Resources, Halifax, Nova Scotia, Canada; [4]Geological Survey of Canada, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada; [5]Institute of Arctic and Alpine Research, University of Colorado, Boulder, Colorado, USA

Uncertainties regarding the age and origin of shelf and slope sediments in the Beaufort Sea constitute a major barrier to understanding the geological evolution of the western Canadian Arctic. Multiple sediment cores collected from the upper slope of the Beaufort Sea and from adjacent Amundsen Gulf provide evidence for rapid, intermittent deposition of discrete ice-rafted debris (IRD) horizons during the last deglaciation (i.e. 16–11 cal ka BP). The mineralogy of the IRD is defined by new quantitative x-ray diffraction (qXRD) analyses, which confirm a source area in the Canadian Arctic Archipelago. In addition, multiple radiocarbon ages of planktonic and benthic foraminifera constrain the ages of the IRD horizons. Three IRD events are identified in the shelf and slope sediments based on their age, stratigraphic position, and composition. Two, paired, closely spaced IRD horizons (each 10 to 20 cm thick) occur in the upper 230 cm of the sediment cores from Amundsen Gulf and the upper slope. Multiple radiocarbon ages imply that these two, upper IRD horizons were deposited during the Younger Dryas chronozone. A third IRD horizon (up to 30 cm thick) occurs at greater depth in two of the sediment cores from the upper slope. A radiocarbon age indicates that this lower IRD horizon was deposited during the late Bølling-Allerød chronozone. The occurrence and age of these new IRD horizons bears on the timing and nature of ice sheet retreat from the Canadian Arctic Archipelago during the last deglaciation. Specifically, the IRD is inferred to represent sporadic deposition by icebergs produced during phases of rapid or catastrophic withdrawal of a former ice stream in Amundsen Gulf. Importantly, the age of the two, upper IRD horizons accords with previous inferences of rapid ice stream withdrawal in Amundsen Gulf during regional deglaciation, based on detailed mapping and dating of the glacial geomorphology of Banks and Victoria islands. These new constraints on past ice stream dynamics provide insight into the variables that occasioned deglaciation of the marine channels of the archipelago, and constitute an important analogue for extant ice sheets. Further, recognition of discrete periods of high iceberg fluxes to the Arctic Ocean (during intervals of ice stream retreat) aids in understanding deglacial paleoclimatic archives. Finally, knowledge of the sources and timing of IRD entering the Arctic Ocean (i.e. glacier vs. sea ice) has implications for understanding the stratigraphy of sediment cores recovered from the deep basin and elsewhere.

Asynchronous Last Glacial Maximum of the Fennoscandian ice sheet

Larsen, E.[1], Fjeldskaar, W.[2], Fredin, O.[1], Lyså, A.[1] & Ottesen, D.[1]

[1]Geological Survey of Norway, P.O. Box 6315 Sluppen, N-7491 Trondheim, Norway (E-mail: eiliv.larsen@ngu.no); [2]Tectonor, c/o IPark, P.O. Box 8034, N-4068 Stavanger, Norway

Reconstructions of the Last Glacial Maximum (LGM) show a huge confluent Eurasian ice sheet (Svendsen et al. 2004) with the Fennoscandian ice sheet in-between the Barents Sea and British ice sheets. Already at the time of this publication, we knew that the maximum position was time-transgressive, but only recently have we been able to explore this in more detail. This presentation will focus on west to east (i.e. maritime to continental) differences in the growth and decay of the Fennoscandian ice sheet, and discuss the causes of these differences.

The available dates reveal an old (29-25 ka) maximum position in the western, maritime areas, and a young (20-16 ka) maximum position in the eastern, continental areas (Vorren & Plassen 2002; Demidov et al. 2006; Larsen et al. 2006; Sejrup et al. 2009; Clark et al. 2009; Kalm 2012; Marks 2012). A time-distance diagram across the ice sheet shows a rapidly advancing and retreating western ice front, as opposed to a steadily growing and decaying eastern ice margin. Thus, the ice sheet was never configured as we normally portray it (Svendsen et al. 2004), and time-slice reconstructions, although crude, show considerable detail in the pattern of growth and decay. Even if the maximum frontal positions were highly asynchronous and seemingly out of phase with global ice volumes, volumetric reconstructions of the Eurasian ice sheet place its maximum at about 21 ka BP, i.e. in phase with the global maximum.

Factors influencing the observed variability were: Asymmetry in terms of ice-growth nuclei areas, the continental edge being a topographic barrier to further growth, maritime versus continental climate, and east-west differences in topography and ice-bed conditions.

Colville Basin response to Arctic tectonics and climate: 3rd and higher order Aptian-Albian depositional sequences

Lease, R.O.[1], Houseknecht, D.W.[2] & Kylander-Clark, A.R.C.[3]

[1]U.S. Geological Survey, Anchorage, Alaska, USA (E-mail: rlease@usgs.gov); [2]U.S. Geological Survey, Reston, Virginia, USA; [3]University of California, Santa Barbara, California, USA

The architecture of Brookian 2nd order depositional sequences ("Lower Cretaceous"; "Upper Cretaceous"; "Cenozoic") reflects tectonic forcing at timescales of 40-60 m.y. The relationship between higher order sequences and specific tectonic and/or climatic forcing at 10 m.y. to sub-m.y. timescales, however, has been obscured by imprecise chronostratigraphy, qualitative metrics, and the local extent of studies.

The 3rd order Torok-Nanushuk sequence represents the world's most voluminous (1.2 million km^3), highest relief (>1 km thick), and longest (600 km from west to east) foreland clinoform depositional sequence. This sequence filled relict Colville basin accommodation that had developed as a flexural response to earlier Brooks Range tectonic loading. We established chronostratigraphy for the sequence with detrital zircon U/Pb geochronology from 16 sites. Maximum depositional ages defined by young detrital zircon U/Pb age populations, likely derived from coeval volcanism in Russian Chukotka, become progressively younger in the direction of eastward progradation. These data reveal a progradational surge between 115 and 106 Ma when the shelf margin prograded more than 450 km. Rapid progradation (~50 km/m.y.) and sediment flux (~111,000 km^3/m.y.) were sustained for 9 m.y. and suggest a supply-dominated system. Clinoform dip directions and detrital zircon provenance indicate that the sediment was derived primarily from Russian Chukotka during longitudinal, eastward sediment dispersal. Progradation slowed after 106 Ma when seismic stratigraphy shows a shift from progradational to aggradational shelf-margin trajectories. Rates of progradation and sediment flux diminished five-fold after this time. The shelf margin prograded only another 125 km eastward before the ultimate shelf margin occurred at 98 Ma.

Based on integrating our new geochronology with mapping of sequence boundaries, we estimate ~400 kyr cyclicity for the Brookian 4th order clinoform sequences. This estimate is equivalent to the Aptian-Albian periodicity of sea-level fluctuations observed on the relatively stable Arabian Plate as well as of deep water sedimentation and carbon cyclicity in European successions. These observations have been attributed to the 405 kyr long eccentricity orbital signal that modulated insolation throughout the Mesozoic. We suggest that deposition of the 4th order Brookian clinoform sequences was paced orbitally via insolation-driven fluctuations in sea-level and perhaps hydrology. This concept may provide a predictive tool to tune sequence stratigraphy for Mesozoic Arctic basins.

A crustal thickness model of the Arctic Region from 3D gravity inversion

Lebedeva-Ivanova, N.[1], Gaina, C.[1], Minakov, A.[1] & Kashubin, S.[2]

[1]University of Oslo, Department of Geosciences, CEED, Oslo, Norway (E-mail: ninanle@geo.uio.no); [2]A.P. Karpinsky Russian Geological Research Institute (VSEGEI), Saint Petersburg, 199106, Russia

The recent remarkable increase in the amount of new data collection and compilations for the Arctic region calls for a re-evaluation of our knowledge about the crustal structure and the tectonic evolution of the Arctic basins. We derive the crustal thickness of the High Arctic region by taking into account an updated bathymetric grid (Jakobsson et al. 2012), newly published gravity anomaly grids (Gaina et al. 2011) and dynamic topography for the area (Spasojevic & Gurnis 2012). TeMAr sedimentary thickness grid (Petrov et al. 2013) was modified according to the most recent published seismic data, and was re-gridded and incorporated into our algorithm. The inversion includes a lithosphere thermal gravity anomaly correction (Alvey et al. 2008; Minakov et al. 2012) and a vertical density variation for the sedimentary layer. Variable crustal densities for the studied region based on calculated Bouguer gravity anomaly were also incorporated. This approach allows taking into account diversity of the crustal nature, like continental blocks of the Arctic shelves, the Lomonosov Ridge and the Chukchi Borderland as well as oceanic crust under the Eurasian and Canada basins and the North Atlantic Ocean. Other input parameters of the inversion were calibrated by published crustal scale profiles.

The new crustal thickness and Moho depth grids which cover the area north of 69° N fit within a few kilometres with seismic crustal models for the most parts of the High Arctic region. The best fit for the whole region is obtained if the gravity inversion is done assuming a mantle density of 3.25 kg/cm^3, which is slightly lower than the standard mantle density of 3.30 kg/cm^3. We interpret this is result as an indication of pervasive subcontinental lithospheric mantle (Goldstein et al. 2008) under the whole Arctic region.

Our crustal thickness grid indicates a possible crustal connection between the Alpha and the Lomonosov ridges near the Canadian margin. The deepest Moho of c.34 km for Alpha-Mendeleev Ridge System is observed under the southern Mendeleev Ridge; it is consistent with recently published seismic crustal profiles across the System. The crustal thickness from gravity inversion of 12-15 km under the north Canada Basin (it is part of the Alpha-Mendeleev Large Igneous Province) differs from a thickness of c. 8 km based on seismic results (Chain & Lebedeva-Ivanova, 2015); what requires farther research. A suspicious thickened crust under the eastern part of the Eurasian Basin suggests that the sediment thickness available for this region is underestimated. Our results suggest sharper increase of dynamic topography in the North Atlantic towards to Iceland, than shown in Spasojevic & Gurnis (2012).

The derived Moho depth represents a substantial improvement from the publicly available grids (CRUST1 (Laske et al., 2013) and GOCE/GEMMA (Reguzzoni et al. 2013) and we hope that our results will become the CRUST 1.0 Arctic patch.

References:

Alvey, A., Gaina, C., Kusznir, N.J. & Torsvik, T.H. 2008. Integrated crustal thickness mapping and plate recon-structions for the high Arctic. Earth Planet Sci. Lett. 274:310–321.

Chian D. & Lebedeva-Ivanova N. 2015. Atlas of sonobuoy Velocity Analyses in Canada Basin. Geological Survey of Canada Open file 7661, 55 p., 1 zip file, doi.10.4095/295857.

Gaina, C., Werner, S.C., Saltus. R. &, Maus, S. 2011. Circum-Arctic mapping project: new magnetic and gravity anomaly maps of the Arctic. Geol. Soc. Lond. Mem. 35, 39–48.

Goldstein S.L., Soffer, G., Langmuir, C.H., Lehnert, K.A., Graham, D.W. & Michael P.J. 2008. Origin of a 'Southern Hemisphere' geochemical signature in the Arctic upper mantle. Nature, 453, 89-93, doi:10.1038/nature06919.

Jakobsson, M., Mayer, L., Coakley, B., Dowdeswell, J.A., Forbes, S., Fridman, B., Hodnesdal, H., Noormets, R., Pedersen, R., Rebesco, M., Schenke, H.W., Zarayskaya, Y., Accettella, D., Armstrong, A., Anderson, R.M., Bienhoff, P., Camerlenghi, A., Church, I., Edwards, M., Gardner, J.V., Hall, J.K., Hell, B., Hestvik, O., Kristoffersen, Y., Marcussen, C., Mohammad, R., Mosher, D., Nghiem, S.V., Pedrosa, M.T., Travaglini, P.G., Weatherall, P. 2012. The international bathymetric chart of the Arctic Ocean (IBCAO) version 3.0. Geophys Res Lett 39, L12609.

Laske, G., Masters, G., Ma, Z., Pasyanos, M.E. 2013. Update on CRUST1.0—a 1-degree global model of Earth's crust. In: Union EG (ed) EGU general assembly 2013. Geophysical research Abstracts, Vienna, pp. EGU2013-2658.

Minakov, A., Faleide, J.I., Glebovsky, V.Y. & Mjelde, R. 2012. Structure and evolution of the northern Barents-Kara Sea continental margin from integrated analysis of potential fields, bathymetry and sparse seismic data. Geophys. J. Int. 188, 79–102.

Petrov O., Smelror M., Shokalsky S., Morozov A., Kashubin S., Grikurov G., Sobolev N. & Petrov E. 2013. A new international tectonic map of the Arctic (TeMAr) at 1:5 M scale and geodynamic evolution in the Arctic region. EGU2013-13481.

Reguzzoni, M., Sampietro, D. & Sansò, F. 2013. Global Moho from the combination of the CRUST2. 0 model and GOCE data. Geophys. J. Int., 195, 222-237. doi: 10.1093/gji/ggt247.

Spasojevic S. & Gurnis M. 2012. Sea level and vertical motion of continents from dynamic earth models since the late Cretaceous. Am. Ass. Petr. Geol. Bull., 96, pp. 2037–2064.

The Late Triassic volcanic and subvolcanic rocks of the Vel'may terrane (Chukchi Peninsula) and their geodynamic setting

Ledneva, G.V.[1], Pease, V.L.[2] & Bazylev, B.A.[3]

[1]Geological Institute RAS, 7 Pyzhevsky per., Moscow, 119017, Russia (E-mail: ledneva@ilran.ru); [2]Department of Geological Sciences, Stockholm University, Svante Arrhenius väg 8, SE-106 91 Stockholm, Sweden; [3]V.I. Vernadsky Institute RAS. 19 Kosygina St., Moscow 119991, Russia

The Vel'may terrane (Zonenshain et al. 1990; Nokleberg et al. 1998) is one of the segments of the extended regional suture, which separates the Chukotka microcontinent from the Mesozoic fold belts of the Russian Far East. The terrane comprises chert-volcanic-sedimentary deposits of the Late Triassic (Tynankergav & Bychkov 1987; Tynankergav et al. 2011) along with plutonic and volcanic ultrabasic and basic rocks to be proved and inferred ophiolites of no younger than the Early Cretaceous (Kosygin et al. 1974).

Here we first represent the results of U-Pb zircon dating and geochemical investigations of volcanic and subvolcanic rocks in chert-volcanic-terrigenous sequences of the Late Triassic (the Kymyneiveem Formation) belonging to this terrane in the Chukchi Peninsula. The sequences include three members previously referred to as the lower, middle and upper ones. The lower and middle members are at gradual contacts whereas the upper member has no any contacts with them.

The lower-to-middle member is made of dolerite dikes, thin flows and lava breccias of basalts and basaltic andesites interbedded with mudstones, siltstones, sandstones, tuffs, siliceous varieties of these rocks and tuffites. Dolerites, basalts and basaltic andesites are co-genetic rocks showing geochemical features typical of subduction-related magmas. Their primary melts seem to be generated via melting of a subductionally reworked MORB-type mantle source and modified by the low pressure differentiation. Tuffs have basaltic andesite and dacite compositions. They also exhibit geochemistry of subduction-derived magmas, but they don't genetically related to basaltic lavas. Tuffs demonstrate features of differentiated magmas produced from enriched mantle melts. The deposition of the lower-to-middle member is suggested in a marginal basin placed in a close proximity to a volcanic arc with areal magmatism centers producing tuffs.

The upper member is composed of dolerite sills and pillow flows of basalts interpillowed and interbedded with siliceous slates, schists, rare siltstones, sandstones and limestones. Dolerites and basalts are co-genetic rocks demonstrating geochemical features of variably differentiated intra-plate alkali magmas. The upper member probably is a remnant of a large igneous province originated on an uncertain type of the lithosphere. The upper member formation was hardly related to the Chukotka microcontinent whose terrigenous sediments of shelf and continental slope are free of any Upper Triassic igneous rocks.

Despite the different compositions indicative of the different geodynamic settings, the studied igneous rocks of the lower-to-middle and upper members are almost coeval ones. The U-Pb igneous zircons from tuffs of the lower-to-middle member yielded the age of 206±5 Ma which is consistent with findings of the Norian marine fauna in tuffs (Tynankergav

& Bychkov 1987). This age probably corresponds to the timing of the lower-to-middle member deposition. The U-Pb igneous zircons of dolerites of the upper member yielded the age of 212±4 Ma which is considered as the timing of the upper member formation.

This work was supported by the Russian Foundation for Basic Research (grant 14-05-00031), by the program of the Leading Scientific Schools (grant 14.740.11.0190) u Swedish Research Council grant.

Triassic-Pliocene sedimentation history in the CircumArctic belt: A quantitative approach and possible influence for the Arctic Ocean sedimentation

Levitan, M.A.[1], Antonova, T.A.[1], Gelvi, T.N.[1] & Jokat, W.[2]

[1]V.I. Vernadsky Institute of Geochemistry and Analytical Chemistry RAS, Moscow 119991, Russia; [2]Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany

For better understanding of geological evolution in the Central Arctic we decided to study sedimentation history in the CircumArctic belt – the area limited by 60ºN from the south and the modern Arctic Ocean shelf break from the north. Our main goals look as follows: 1) to reveal the most general regularities of Triassic-Pliocene sedimentation history on the quantitative base and 2) to evaluate the role of global signal in this history. To reach these goals we've compiled a new set of lithological-facies maps (26 maps for 13 time slices, separately for East and West Hemispheres, azimuthal equal-area projection, scale 1: 25000000).

As the base, lithological-paleogeographic maps from the atlas published by V.E. Khain and co-authors (1983) have been used. It's important to note that for correct comparison of our regional data with global data by A.B. Ronov (1980) we were forced to use the same methods of mapping: with fixed position of continents and with mapping for stages of Mesozoic-Cenozoic. To receive comparable results with Ronov's data, we've used his volumetric method (Ronov, 1949). The geological scale by F.M. Gradstein et al. (2004) served as a stratigraphic base for our work, and all Ronov's data about sediment masses and intensities of their accumulation have been recalculated using the scale.

The most significant result is that terrigenous sediments were an absolutely dominant lithological group during Mz-Cz. No less important is that the relative role of seas was much bigger than in global scale for all stages (with exception for Paleocene). One can explain both results by the peripheric-continental position of the CircumArctic belt in the high latitude area for the last 250 Ma.

Distribution of sea areas (in %) demonstrates 2 major stages: Mesozoic (tallasocratic) and Cenozoic (geocratic). We manage to reveal 5 stages in the values of intensities of sediment accumulation (in trillion ton/my): Early Triassic (high), Middle Triassic-Middle Jurassic (low), Late Jurassic-Late Cretaceous (enhanced), Paleogene (low), Neogene (very high). Listed results (and some others) allow us to reveal the main stages in the history of sedimentation within CircumArctic belt: Early Triassic, Middle Triassic-Late Cretaceous, Paleogene, Neogene.

Pointed results can help to make an additional interpretation for some published seismostratigraphic data from the West Arctic Ocean (Jokat et al. 2013; Hegeweld & Jokat 2013; Weigelt & Jokat 2014). We mean terrigenous fluxes from the continents into the Arctic Ocean. For example, there is a close connection between changes in total intensity of sediment accumulation in the CircumArctic belt (in trillion t/my) on the Late Cretaceous/Paleocene boundary (0.9/0.2) and upper boundary of MB 1 seismic unit in the Makarov Basin; for boundary between MB 3 and MB 4 which probably corresponds to

Oligocene/Miocene, this change is 0.6/2.4; at last for boundary between MB 5 and MB 6 units (Miocene/Pliocene) such change is 2.4/3.5. Boundary between MB 2 and MB 3 (Paleocene/Eocene), probably, is connected with sharp change from Paleocene background terrigenous sediments to sediments of PETM and Early Eocene which are strongly enriched in biogenic matter.

Neoproterozoic and Late Paleozoic granitoids of Wrangel Island and North Chukotka

Luchitskaya, M.V.[1], Sokolov, S.D.[1], Sergeev, S.A.[2,3], Kotov, A.B.[4], Natapov, L.M.[5], Belousova, E.A.[5] & Katkov, S.M.[1]

[1]Geological Institute Russian Academy of Sciences, Pyzhevsky per. 7, Moscow, Russia, 119017 (E-mail: luchitskaya@ginras.ru); [2]Federal State Unitary Enterprise "A.P.Karpinsky Russian Geological Research Institute", Sredny prospect, 74, Saint Petersburg, 199106; [3]Institute of Earth Sciences, Saint-Petersburg State University, University quay , 7-9, Saint-Petersburg, Russia, 199034; [4]Institute of Geology and Geochronology of Russian Academy of Sciences,Makarova quay, 2, Saint-Petersburg, Russia, 199034; [5]ARC National Key Centre, Faculty of Science, Dept EPS, Macquarie University NSW 2109 Australia

Neoproterozoic (Cryogenian) granitoids are associated with metamorphic basement exposed on the Wrangel Island. Metamorphic basement is represented by stratified complex, composed of dislocated metavolcanic, metavolcaniclastic and metasedimentary rocks with single lenses and layers of carbonate rocks (Wrangel Island). In the lower part of metamorphic rocks of Wrangel complex (upper reaches of Khishchnikov River) there are conformable tabular bodies of foliated granitoids. They are metamorphosed and transformed in Bi-Mu-Fsp-Q-Ser and Mu-Fsp-Q-Ser gneisses and schists. In thin sections the relics of primary minerals (quartz, plagioclase, potassium feldspar, rarely biotite and muscovite) and equigranular granitic texture are seen. Dating of these granitoids was carried out on SHRIMP-II in the Center of Isotopic Studies of Federal State Unitary Enterprize "A.P.Karpinsky Russian Geological Research Institute".

Wheited mean ages of zircons from three probes of granitoidesare: 702±3 Ma (N=20), 707±4Ma (N=25), 682±2Ma (N=60). They indicate Neoproterozoic (Cryogenian) age of granitoids. Furthermore, some zircons contain inherited cores, for which following datings were obtained: 1.2, 1.01; 1.17; 1.44; >2.6 Ga. This data allow supposing the presence of ancient (Neoarchean–Mesoproterozoic) rocks in the basement of Wrangel Island and their participation in the melting process during granite magmas formation.

Paleozoic age of part of Chukotka granitoids was established for orthogneisses or granite-gneisses in the uplift structures (granite-metamorphic domes) of Anyui-Chukotka fold system. Zircon ages for orthogneisses from core part of Koolen' dome, East Chukotka, are 369 and 375 Ma [U-Pb TIMS, Natal'in et al. 1999]. Devonian age is established by V.V.Akinin with coauthors (Akinin 2011; Polzunenkov et al. 2011) (U-PbSHRIMP) for orthogneisses of Velitkenay massif- 363±44 Ma, Late Devonian, for granite-gneisses of Kuekvun' uplift - 380 Ma.

We carried out geochronological studies of granitoids of Kibera massif, Kuul Uplift and Kuekvun' massif of the same name uplift of Anyui-Chukotka fold system. Kuul Uplift is stretched in WNW direction along the East-Siberian Sea coast on 110 km with 15-30 km wide. In the central part of uplift terrigenous Devonian and terrigenous-carbonate Lower-Middle Carboniferous depoits are located. They are overlain with stratigraphical unconformity by terrigenous deposits of Late Permian-Triassic age.

Granitoids of Kibera massif intrude Devonian deposits. Granodiorites of endocontact zone of Kiber massif have Early Carboniferous age (U-Pb TIMS, 353±5 Ma (Katkov et al. 2013)). Similar datings are carried out by authors for granites of main part of Kibera massif (357±4Ma; U-Pb SIMS), granite-porphyre (352±4Ma; U-Pb SIMS) and biotite granites from conglomerate pebbles at the base of Carboniferous deposits (359±3 Ma; U-Pb SIMS). Similar ages just published for Kibera granitoids (351±6 Ma; U-Pb) and granitoids from pebble of Carboniferous conglomerates (355–361) by (Lane et al. 2015).

Kuekvun' Uplift is stretched in latitudinal direction on 90 km and is 25 km wide. In the centre of uplift metamorphosed Devonian-Middle Carboniferous deposits are located. They are framed with stratigraphical contact by terrigenous deposits of Late Permian-Lower Triassic age (Varlamova et al. 2004).

Metamorphic rocks include small (up to several tens of metres) bodies of light-colouredgranitoids, transformed in augen gneisses or granite-gneisses with “augens” of potassium feldspar, plagioclase and quartz. Quartz syenites of Kuekvun massif have concordant age is 352±6 Ma (U-Pb TIMS; Katkov et al. 2013).

Stated data confirm the existence of Late Paleozoic granitoid magmatism within Chukotka. Granitoid complexes of Devonian and Early Carboniferous age are continued on the territory of Arctic Alaska, including Seward Peninsula, Yukon and Arctic Canada (Ellesmere and Axel Heilberg islands) (Amato et al. 2009; Aleinikoff et al. 1993; Ruks et al. 2006; Trettin et al. 1991; Hadlaril et al. 2014). Devonian-Carboniferous boundary corresponds to the age of tectonic events of Ellesmerian orogeny in Arctic region. Structural studies on Wrangell Island allowed to establish Ellesmerian deformations (Verzhbitsky et al. 2014). All data indicate the community of geological history in the framework of single block Chukotka-Arctic Alaska, transported from the Arctic Canada region according to rotation hypothesis (Grantz et al. 2011).

The work was supported by RFBR projects 13-05-00249, 14-05-00031, Scientific school # NSh-2981.2014.5.

Opening of the Arctic oceanic basins – constraining the model, and some implications

Lundin, E.R.[1], Doré, A.G.[2], Gibbons, A.[3], Sømme, T.[3], Tørudbakken, B.O.[3] & Hendriks, B.W.[1]

[1]Statoil ASA, Rotvoll Trondheim, Norway; [2]Statoil UK Ltd. London, UK; [3]Statoil ASA, Oslo, Norway

The Arctic Ocean remains one of the more debated areas in terms of plate tectonic evolution, despite decades of academic, governmental, and industrial focus. Arguably, this is not so surprising considering the harsh environment and remoteness, imposing physical and economic constraints on fundamental data acquisition such as DSDP boreholes, but also on industrial activity and data collection. Despite its data challenges, the Arctic Ocean is a neatly confined oceanic area bordered by continents surrounding its perimeter. These continental margins provide geologic constraints that can be integrated with mainly geophysical data from the oceanic interior to constrain the plate tectonic evolution. The frontier nature of this region also requires integration of geological and geophysical methods to reduce uncertainty. Alike any plate model, our model hinges on constraining the continent-ocean-boundary (i.e. geometry), timing, and kinematics. Plate boundaries have largely been derived from potential field data, but also in part by seismic reflection and refraction data. Timing has been gained primarily from well data along the margins, geochronologically dated igneous rocks, magnetic isochrones where available, and coherence with a global plate model. Our Arctic plate model includes three main seafloor spreading episodes: 1) Canada Basin (ca 125-80 Ma), Makarov-Podvodnikov Basin (ca 80-60 Ma), and Eurasia Basin (ca 55-0 Ma). The model includes several major transform boundaries, such as the well-known “windshield wiper” transform at the distal end of the Canada Basin, a major shear along the Laptev Sea-East Siberian margin, as well as transforms linking Baffin Bay and the NE Atlantic to the Arctic. Several of our model “components” have been individually proposed by previous workers, but not with the suggested combination and timing. Significant exploration implications arise from the identification of hyperextended terranes and widespread transform margins around the Arctic.

Paleogeographic reconstructions in Western Barents Sea, Stø Formation (J1-J2)

Malysheva, E. O.[1], Volfovich E.M.[2], Vasilyeva N.A.[2] , Doronina M.S.[2], Leybenko A.I.[2] & Kukina N.A.[3]

[1]Department of geological modeling and database RN-Shelf-Arctic LLC, Moscow, Russia (E-mail: e_malysheva@rn_exp.rosneft.ru); [2]Department of geological modeling and database RN-Exploration LLC, Moscow, Russia; [3]RN Nordic Oil AS, Oslo, Norway

The Stø Formation of Early to Middle Jurassic age has proved to be major hydrocarbon bearing reservoir in the Western Barents Sea. It has been profoundly studied by previous works (Henriksen, E. et al. 2011) and used to be interpreted as distributary/estuarine channels, shoreface and foreshore sands, either as tidal sands or as high energetic shoreline deposits. However new areas constantly involved in exploration suggest actualization and further developing of the models. Current study was aimed on regional paleogeographic reconstructions of vast area of Norwegian and partly Russian sectors of Barents Sea incorporating 2D and 3D seismic data and well information including original core descriptions and photos (http://www.npd.no/). It was focused on identification of type sections by logs and core, analysis of macrostructures, additional analysis of attribute maps within 3D areas and thickness maps within study area.

The base of the Stø Formation is identified as a sequence boundary and is characterized by very sharp erosional contact demonstrating “transition” from relatively deep water dark shales with fauna to coarse grained sandstones. The lateral correlation reveals strong heterogeneity of the Stø Formation and allows to distinguish Lowstand (LST), Transgressive (TST) and Highstand (HST) systems tracts. As a whole gross thickness of Stø Formation varies from 6 to 162 m, net to gross ratio – from 0.16 to 0.98 with maximum values reported from the areas where LST development.

The major type LST section is represented by blocky sands unit. It starts with coarse-grained subunits with unidirectional crossbedding and could be interpreted as alluvial to alluvial fan deposits. The overlying part of the section is composed of massive, unidirectional crossbedded and wavy to discontinuous horizontal sandstone subunits occurring in different proportions. The specific features of many sections is the presence of the layers with double mud drapes and alternating layers of sand mud suggesting tidal influenced environments including channels, tidal flat, deltas and upper shoreface.

In all sections LST units are overlaid by TST composed of lower shoreface to offshore deposits providing a seal and hydrocarbon accumulations in the LST. The overlying HST consists of several units characterized by coarsening upwards units strongly bioturbated in the lower part (middle shoreface) and massive to crossbedding in the upper part (upper shoreface). As a whole HST is interpreted as shallow marine deposits embracing shelf shallows and ridges widely spread all over the area. The HST reservoir is overlaid by shaly deposits of Hekkingen Formation regional seal referred to the Transgressive system tract of the next sequence. As a result upper HST deposits were proved to be productive too.

To provide better understanding of reservoirs distribution and their combination with seals paleogeographic reconstruction were carried out separately for LST and HST intervals. LST is developed only in the western part (Hammerfest Basin, Ringvassoy-Loppa and Bjørnøyrenna fault complexes) and in sub-longitude cross-sections reminds incised valley. However this area was involved into the rifting controlled subsidence. The central and eastern parts of considered area are believed to be represented by emerged transitional shelf where LST was absent and only channels filled on transgressive stage could be present. The Stø Formation at these areas is composed of HST deposits with reduced thickness.

The North Greenland dyke swarm within the Greenland-Svalbard convergenze zone

Manby, G.M.[1] & Lyberis, N.[2]

[1]Earth Sciences, Natural History Museum, Cromwell Road London SW7 5BD, UK; [2]UPMC 4 place Jussieu Paris, 75005 France

Late Cretaceous isotopic ages, mainly in the 81 to 69 Ma range, have been obtained for the North Greenland Dyke Swarm which coincide with the Greenland-Svalbard convergence. Isotope, REE and trace element data support derivation of the dyke parent magmas from MORB to OIB sources which were subject to some limited lower crustal contamination. Ar/Ar isotopic ages obtained from the mylonites in the Eurekan fold belt of North Greenland suggest that the main thrust emplacement ended in Palaeocene time, prior to the onset of sea floor spreading in the Eurasian Basin. Aeromagnetic data show that the onshore North Greenland Dyke Swarm is continuous with N-S and NW-SE trending linear anomalies which extend, unbroken, 150 km across the Lincoln Sea indicating that there has been no significant strike-slip displacement between Ellesmere Island and North Greenland. The dyke and the offshore magnetic anomalies distribution appears to have been controlled by the boundary conditions as they are continuously orthogonal to the North Greenland margin. The intrusion of these dykes appears to have been guided by tension gash like fractures generated by the 200 km Greenland-Svalbard convergence produced by the anticlockwise rotation of the Greenland craton following the opening of the Labrador Sea-Baffin Bay basins. The further northward opening of these basins was prevented by the presence of the strong northern border of the thinned continental lithosphere of the Lincoln Sea and the oceanic lithosphere of the Alpha Ridge-Makarov Basin. As a consequence sea floor spreading jumped to the North Atlantic- Eurasian Basin. The continued northward motion of Greenland during this time coincided with a switch from orthogonal to oblique convergence to across the Greenland Svalbard Margin.

Re-interpretation of the structural geology of Wrangel Island based on the onshore geology of Chukotka and offshore deep crustal seismic data

Miller, E.L.[1], Dumitru, T.A.[1], Grove, M. J.[1], Gottlieb, E.[1], Meisling, K.[1] & Akinin, V.V.[2]

[1]Department of Geological Sciences, Stanford University, Stanford CA. 94305, USA; [2]NEISRI, Magadan, Russia

Wrangel Island is generally viewed as the northern continuation of the Jura-Cretaceous Brooks Range thrust belt onto the Siberian Shelf and this concept has been a strong influence in the interpretation of offshore seimic data.

Rock units on Wrangel Island are deformed by a high-strain, south dipping foliation formed during N-S stretching. Microstructural studies in combination with thermochronology of multiple mineral phases suggest that this deformation occurred during a short-lived thermal event at ~ 100 Ma with maximum T's ranging from 300 to < 450°C, cooling through 125-50°C by 95 Ma. This event is much younger than Jura-Cretaceous thrusting in the Brooks Range and development of the Chukotka fold belt (~155- 135 Ma). Along the coast of Chukotka, south of Wrangel Island, the crust was deformed and metamorphosed at high T's associated with syn-extensional magmatism (~108-100 Ma; U-Pb zircon) with crustal melting in the Velitkinay migmatitic gneiss complex peaking at ~103-100 Ma (U-Pb zircon) and cooling through biotite 40Ar/Ar39 Ar retention T's at ~ 96 Ma. Tectonic foliations in 105-103 Ma granitic rocks are concordant to country rock fabrics and cut by 100 Ma granitic-gabbroic intrusions, illustrating that magmatism and penetrative deformation were coeval. It is likely that the main and youngest deformation on Wrangel Island developed during this pulse of syn-extensional magmatism rather than during the earlier history of Brookian and Chukotka crustal shortening. Faulted, gently tilted volcanic rocks as old as 87 Ma (U-Pb zircon) cap the granites, gneisses and country rocks of Chukotka above a profound unconformity. Deformation similar in nature and age to that on Wrangel Island has been described in the Bering Strait region, Seward Peninsula and southern Brooks Range where synextensional magmatism is implicated as the heat source enabling large-scale extension of the crust.

Deep crustal seismic data in the Bering Strait region (Klemperer et al. 2002) resemble the 5-AP deep crustal seismic data collected across the Wrangel Arch west of Wrangel Island (Sakulina et al. 2011). The characteristic features of extended continental crust in the Bering Strait region include a sharp Moho at ~ 30 km depth and middle and lower crust that is strongly reflective. Xenolith studies provide evidence that the middle and lower crust beneath the Bering Strait was magmatically intruded and reconstituted by flow at granulite facies conditions in the Late Cretaceous (Akinin et al. 2009; 2013). The 5-AP crustal section illustrates that Wrangel Arch has a sharply defined Moho and also exhibits subhorizontal reflectivity in the middle and lower crust. In terms of Moho depth, the Wrangel Arch represents a crustal-scale "boudin" bound by the thinner crust of the Longa Basin (south) and the deep North Chukchi Basin (north). The 5-AP line and other published seismic sections south of Wrangel Island exhibit packages of dipping crustal reflectivity that likely define crustal-scale normal sense shear zones bounding Wrangel Arch on its southern side. These new data and interpretations have significant bearing on the interpretation of structures on other offshore seismic lines, which until now have been mostly interpreted in context of crustal shortening and thrust faulting.

Funded by CRDF RUG1-2994-MA-11 (Akinin and Miller); ACF-PRF45432-AC8 and NSF-0948673 (Miller).

Early Carboniferous (?) volcanic complex of the Wrangel Island

Moiseev, A.V.[1], Sokolov, S.D.[1], Tuchkova, M.I.[1] & Verzhbitsky, V.E.[2]

[1]Geological Institute RAS, Pyzhevsky per. 7, Moscow, Russia, 119017 (E-mail: moartem@yandex.ru); [2]P.P. Shirshov Institute of Oceanology RAS, Moscow, Russia, 117997

Structure of Wrangel Island belong to Wrangel–Herald Arch which is a linear rise the Eastern Arctic shelf sedimentary cover's basement. It composed of Neoproterozoic metamorphic basement (Berri Formation, Wrangel Complex) and carbonate and clastic Upper Silurian–Triassic sediments (Til'man et al. 1964; Kos'ko et al. 2003) which are complexly folded with north vergency. During 2006 an International expedition organized by Geological Institute RAS, carried out comprehensive studies that led to several important conclusions.

1. U-Pb SHRIMP zircon dating for conformable bodies of gneissosed and foliated granitoides been confirmed metamorphic rocks of Neoproterozoic age: 702.3 Ma (N=19), 701.7 Ma (N=3), 707.4 Ma (N=25). Furthermore, some zircons contain inherited cores: (1.1-2.6 Ga). These data suggest presence of ancient (Neoproterozoic-Mesoproterozoic) rocks in the basement of Wrangel Island (Luchitskaya et al. 2014).

2. Fundamentally new results of the mesostructural studies (Verzhbitskii et al. 2014) were establishment of different structural styles in the Carboniferous–Triassic (sublatitudinally striking compression structures) and the Silurian–Lower Devonian complexes (with submeridional strike). This fact, as well as the presence of conglomerates in the Upper Devonian–Lower Carboniferous (Til'man et al. 1964; Kos'ko et al. 2003) implies the presence of a structural unconformity between these complexes. Thus, this is the first evidence of the Ellesmerian orogeny in Wrangel Island. It is important to examine the geodynamic position of Early Carboniferous (?) magmatism which may be associated with the Post-Ellesmerian event.

The volcanic rock exposed in the central part of the island along Neizvestnaya River banks, were collected. It is overlain by Lower-Middle Carboniferous limestones. A discontinuous exposure of basal conglomerate separates the carbonate and volcanic rocks. Basal conglomerates contain fragments of metamorphic rocks and underlying volcanites. Both the volcanic rocks and carbonate are in fault contact with Devonian slate. There are different points of views on the age: (1) Proterozoic (Kameneva 1975) and Lower Cambrian; (2) Early Carboniferous (Ageev 1979, Cecil, kosko). The apparent thicknesses of volcanic rocks are about 150-200 m.

Six basalt samples were analyzed. The volcanic rocks are basaltic in composition and metamorphosed in greenschist facies. Geocemical composition (high LILE, HFSE, TiO_2, REE concentrations and they соотношения) suggest basalts were formed from enriched melt. On TiO_2/Yb vs Nb/Yb diagram (Pearce 2008) samples fall in OIB field, reflecting melt origin below continental lithosphere during early stage of its destruction. Strong negative Nb-Ta and Zr anomalies (Nb/Nb*=0.26-0.60; Ta/Ta*=0.34-0.63) indicate most likely the interaction between melt and continental crust during its ascent to the surface.

Conclusions: Early Carboniferous (?) volcanic rocks reflect rifting event, and may be associated with Post-Ellesmerian tectonic reorganization.

Supported by RFBR grant # 14-05-00031, Project of Presidium RAS, ONZ#9, Scientific School 5177.2012.5

Geoscience for extended continental shelf mapping in the Arctic Ocean

Mosher, D.C.[1], Hutchinson, D.[2], Mayer, L.A.[3], Marcussen, C.[4] & Verhoef, J.[1]

[1]Geological Survey of Canada, Dartmouth, NS, Canada (E-mail: dmosher@nrcan.gc.ca); [2]US Geological Survey, Woods Hole, MA, USA; [3]Center for Coastal and Ocean Mapping, University of New Hampshire, NH, USA; [4]Geological Survey of Denmark and Greenland (GEUS), Copenhagen, Denmark

Article 76 of the United Nations Convention on the Law of the Sea specifies two approaches that a coastal State may employ to determine the outer edge of its' continental shelf: a) 60 nautical miles (M) seaward of the foot of the continental slope (FoS), or, b) to a point seaward of the FoS where the sediment thickness is 1% of the distance from the FoS. These formulae require two fundamental pieces of data: 1) bathymetry for water depth and seabed morphology, and 2) seismic reflection for sediment thickness determination. There are at least two other fundamental pieces of data needed that are not explicitly stated in the article: 3) velocity information to convert seismic reflection data to the depth domain. In the Arctic, this is usually derived from refraction profiling (hydrophone arrays are too short to gather stacking velocities), and 4) geologic evidence, usually interpreted from subbottom profiles. This fourth type of data has been allowed by the Commission on the Limits of the Continental Shelf (CLCS), recognizing that geomorphologic complexity can complicate identification of the FoS and geologic evidence can distinguish different geologic domains to help in this regard.

For a small ocean basin, the Arctic has a plethora of different geologic domains, making extended continental shelf mapping in this region complex. The difficulties of acquiring data in perennially ice-covered seas add to the already immense challenges. Article 76 requires identification of the FoS and along margins with a significant change in gradient from the slope to the deep ocean floor, such as Northwind Ridge into Canada Basin, or Lomonosov Ridge into Amundsen Basin, the FoS is readily identified from bathymetric data alone. On gradual slopes, such as the Mackenzie River prodelta or along the Canadian Archepelago margin, subbottom and seismic reflection profiles help distinguish slope processes, such as submarine landslides, from deep ocean floor processes such as turbidites. In these cases, the FoS is identified with geomorphologic evidence supported by geologic arguments.

Sediment thicknesses are determined with seismic reflection and refraction data. Determination of sedimentary seismic facies versus bedrock can be subject to interpretation, but in general, basement is recognized as the point where all coherent acoustic energy is lost. Through an extensive array of sonobuoy deployments, a basin-wide velocity model provides the infrastructure to convert seismic reflection data to the depth domain for determination of sediment thicknesses. Additionally, these refraction data provide information on the structure and composition of bedrock and these data provide control on tectonic interpretations.

Underpinning most, if not all, geologic arguments, is the tectonic framework of the basin. In the Arctic, because of limited data prior to recent programs, little was known of its tectonic history. New data are only now beginning to reveal this story. As a result of its tectonic history, the Arctic Basin is host to a number of undersea features, such as Lomonosov Ridge, Gakkel Ridge, Alpha Ridge, Mendeleev Ridge, and Northwind Ridge and Chukchi Plateau. In some cases, the geologic nature of these features may be critical to its use in the context of extended continental shelf mapping. It can be geologically or morphologically continuous with the continental margin of the coastal State and this distinction determines its use in extended continental shelf delineation.

The Triassic Svalbard Hydrocarbon Play Model; A prospective model for the Barents Shelf

Mørk, A.[1,2] & Lundschien, B.A.[3]

[1]SINTEF Petroleum Research, Trondheim; [2]Department of Geology and Mineral Resources Engineering, Norwegian university of science and technology (NTNU); [3]Norwegian Petroleum Directorate (NPD)

With contributions from: Ingrid B. Hynne, Tore Høy, Tore Klausen, Gareth S. Lord, Mai Britt E. Mørk, Rita S. Rød, Kristoffer H. Solvi & Marina A. Tugarova

The near 700 m thick Lower and Middle Triassic Sassendalen Group is generally shale dominated although it also contains minor sandstones. The upper part, the Botneheia Formation, is very organic rich and contains mixed type II and III kerogen. The Upper Triassic to mid. Jurassic Kapp Toscana Group is rich in sandstones representing fluvial, deltaic and shallow marine deposits (up to 500 m thick in exposures but 700 m thick including the near subsurface on Svalbard). Sediments from both groups continue southwards in the Barents Shelf where they form a prospective hydrocarbon play model.

These groups outcrop on all major islands of the Svalbard Archipelago and we have visited numerous localities to study facies variations, as well as organic and reservoir properties. Between Svalbard and the southern part of the Barents shelf, where hydrocarbon exploration has taken place since 1980, NPD has carried our extensive seismic studies and drilled 12 shallow stratigraphic coreholes penetrating the Triassic succession, while IKU/SINTEF have drilled similar stratigraphic coreholes in the southern part of the Barents Sea. Together with exploration wells this gives a good data coverage to extrapolate interpretations for understanding the northern Barents Sea which is presently not open for exploration.

Major parts of the Barents shelf display Triassic and Jurassic sediments under a thin Quaternary cover, implying that these rocks form the upper part of the sedimentary succession. It also implies that hydrocarbon accumulations may be relatively shallow making restrictions for source rock maturation and possibility for tight seals; the post Triassic time may thus be critical for filling and unfortunately emptying of any possible reservoirs.

After the Permian formation of the Pangea Supercontinent, by fusing Laurentia with Siberia forming the Uralian Mountain chain, a large shallow shelf bay was formed on the northern coast of Pangea facing the Panthalassa sea. This bay, mainly around 400 m deep, was filled by sediment during the Triassic. We have mapped parallel clinoform-belts, representing sedimentation in front of prograding fluvial plain down to the shelf-floor starting in the Late Permian-Induan close to the Norwegian mainland ending in the Late Carnian north-east of Svalbard.

Organic rich mudstones, similar to the Botneheia Formation on Svalbard, occur all the way to the southern Barents shelf, however the organic rich facies started earlier (in the Olenekian) in the areas most restricted and distal to the Panthalassa sea. It is also possible that similar organic rich accumulations occurred in the deeper areas in front of the clinoform belts. The northwestward prograding clinoforms that during the Late Triassic fills the Barents shelf bay leaves behind an extensive delta system rich in sand filled channels which rests in fine-grained delta top sediment. Such channels are nicely displayed in the steep cliffs of Hopen, the southeasternmost island of Svalbard, and similar channels systems are mapped throughout the Barents shelf. Sandstone properties, a result of primary mineralogy and the transport processes control reservoir properties. When the Barents shelf was finally filled by sediment in the latest Triassic extensive reworking of these sediments during the Early to Middle Jurassic resulted in maturation of the sandstones improving reservoir properties.

Pleistocene ice-grounding events along the East Siberian margin and on the Lomonosov Ridge: Implications for circum-arctic ice shelves in the Arctic Ocean?

Niessen, F.[1], Stein, R.[1], Jensen, L.[1], Schreck, M.[2,1], Matthiessen, J.[1], Jokat, W.[1], Hong, J.K.[2] & Nam, S.-Il[2]

[1]Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany; [2]Korea Polar Research Institute, Incheon, Republic of Korea

Over many years there was a general acceptance that thick ice sheets of marine isotope stages 2, 4 and 6 were restricted largely to continental Eurasia, Greenland and North America including the adjacent shelves of the Arctic Ocean. With this "Beringia" was understood as an ice-free land bridge between the continents of Asia and America during glacial times with low sea levels and exposed shelves. However, since about 15 years a growing number of evidence is found in water depth up to more than 1000 m that grounding of ice has occurred in various places of the Arctic Ocean since MIS 6 and/or before including the "Beringian" continental margin. With the decline in Arctic Ocean summer sea ice during the last decade it has been possible to hydro-acoustically survey areas so far sparsely investigated because of operational constrains. Glacial landforms were discovered on many continental slopes as well as ridges and seamounts of the Arctic Ocean, which rise up to less than about 1000 m below present sea level. These landforms include moraines, drumlinized features, glacigenic debris flows, till wedges, mega-scale glacial lineations (MSGL), and iceberg plough marks. They suggest that thick ice has occurred not only on nearly all margins of the Arctic Ocean but also covered pelagic areas.

In our studies we present submarine glacial landforms from the western and central Arctic Ocean, which are interpreted as a result of a complex pattern of Pleistocene glaciations along the continental margin of the East Siberian Sea. This was discovered during the cruises of RV "Polarstern" in 2008 and RV "Araon" in 2012. Orientations of these landforms suggest thick ice has flown north onto the deep Arctic Ocean, thereby grounded on plateaus and seamounts of the Medeleev Ridge. In addition, during the recent RV "Polarstern" cruise in 2014, hydro-acoustic data is presented from the Lomonosov Ridge (Siberian side to close to the North Pole), which support the hypothesis of widespread grounding of ice in the Arctic Ocean from different Eurasian sources. The data suggest that thick ice-shelves have developed from continental ice sheets on a nearly circum-arctic scale. These ice shelves extended far north and covered large areas of the Arctic Ocean. It now depends on the stratigraphical analysis of existing and future sediment cores to find out whether or not these ice shelves have occurred contemporaneously and when the individual grounding events have occurred.

Sever Spur - Chukchi Plateau: Conjugate Margins?

Oakey, G.N.[1] & Saltus, R.W.[2]

[1]Geological Survey of Canada; [2]U.S. Geological Survey

Two distinctive magnetic lineations are observed in Canada Basin, equidistant from the central linear gravity low interpreted to be an extinct spreading axis. Crustal velocities defined by sonobuoy refraction data indicate that oceanic crust in present only in the central portion of Canada Basin and that most of the basin is underlain by thinned continental and transitional crust. The conjugate pair of magnetic lineations correspond with the landward limit of oceanic crust. Although magnetic anomalies are observed within this oceanic domain, there is no evidence of systematic lineation patterns consistent with sea-floor spreading magnetic reversals. The oceanic crust may have formed during the late Cretaceous "quiet zone". (i.e. M0 to C34 / 124 to 84 Ma). The calculated pole-of-rotation for the conjugate pair of magnetic lineations (64.6º N / 130.8º W, 13.2º rotation) is consistent with models for counter-clockwise rotation of the Alaska-Chukotka plate; however, the new pole is significantly further south than previously published poles which implies less curvature in the resulting flow-lines. The new rotation pole has been used to produce a partial paleo-reconstruction of the Amerasia Basin that positions Chukchi Plateau close to Sever Spur. Spreading based on the new pole predicts some transform process between the oceanic domain and the undisturbed Lomonosov Ridge. Whether this was accommodated by a discrete transform structure or a broad zone of deformation is unresolved.

2-D gravity and magnetic models have been developed for Sever Spur and Chukchi Plateau to compare the morphological and physical properties of these conjugate margin features. Seismic reflection profiles collected during collaborative Canadian U.S. icebreaker operations were depth-converted using sonobuoy velocity models and used as constraints for the models. Density values were assigned to different units based on a standard velocity-density relationship. The continental cratons for both models were assigned an upper crust density of 2800 kg/m^3 and a lower crustal density of 2900 $kg.m^3$ based on velocity results from a published GSC refraction line.

Moho depths for the "Sever" model are highly variable (32 to 38 km) suggesting that large blocks of the continental crust were pulled away from the cratonic core but did not fully separate as the margin thinned. Although the structural highs appear to be basement blocks separated by fault-bounded grabens, they could not be modeled as crustal density rocks since the shallow source depths produced very large high frequency anomalies. Low density (2500 kg/m^3) and non-magnetic source bodies were required, and suggest that the structural highs are cored by Paleozoic sedimentary units. At the outer edge of the spur and into deep water, an anomalously high magnetized mid-crustal unit (0.1 SI) was required to fit the high amplitude (>650 nT) magnetic anomaly. This unit is not likely to be a volcanic block since a corresponding gravity high would be expected. The adjacent deep-water crust in Canada Basin is thinned to ~12 km. with a Moho depth of ~18 km. There is no evidence for a 2900 kg/m^3 lower crustal layer.

Moho depths for the "Chukchi" model ranged from 28 to 32 km. In contrast with Sever Spur, the edge of the craton (at Northwind Ridge) is near-vertical with little or no evidence of extension. If Sever Spur and Chukchi Plateau are conjugate margins the style of rifting is highly asymmetric. The structural highs were again modelled with low density and non-magnetic source bodies. Finally, the crust adjacent to the craton is thinned (~ 8 km) with an underplated high-velocity layer (assigned a density of 3100 kg/m^3) and Moho at ~18 km. A similar magnetic high (> 400 nT) is observed near the cratonic edge which also requires a highly magnetized mid-crustal block in the modeling.

Models for the complex tectonic development of the Amerasia Basin are subjects of heated debate and our new paleo-reconstruction describes only the last episode for the formation of Canada Basin. However, new data are providing improved constraints on crustal structures and new ideas on the regional geological and structural framework are evolving. We show some compelling reasons to suggest that Sever Spur and Chukchi Plateau have similar crustal structures and are likely conjugate margins, but how do we test this? Obviously we need more data.

Results of the Arctic Shelf Exploration Works performed by Rosneft in 2012–2014

Obmetko, V.V., Malyshev, N.A., Streltsov, T.M., Verzhbitskiy, V.E., Borodulin, A.A., Reydik, Yu.V. & Ikhsanov, B.I.

Rosneft Oil Company, Dubininskaya St. 31A, Moscow, Russia, 115054 (E-mail: v_obmetko@rosneft.ru)

In recent years, 26 license blocks offshore the Russian Federation in the Arctic shelf were licensed to Rosneft Oil Company of total area about 1.2 million km^2, where the Company together with its partners actively pursues the exploration works. The license blocks are located in the sedimentary basins, characterized by different geological structure, complex petroleum systems and huge hydrocarbon potential. Considering the remote conditions and high exploration cost, the Rosneft's strategy on the Russian Arctic shelf is targeted to reconnaissance of large hydrocarbon accumulations.

In the Barents-Kara region, the exploration works covered the edge zones with the Paleozoic and Triassic prospective formations on the East Barents megatrough (Central Barents zone of uplifts and Admiralteisky Megaswell), where there is a unique combination of the largest hydrocarbon kitchen and large anticline traps. In this region, in 2013 and 2014 Rosneft in partnership with Eni acquired about 10 thousand line km of 2D and 3000 sq. km of 3D seismic data and prepared the large structure Svodovaya for exploratory drilling, in partnership Statoil acquired 6.5 thousand line km on the Perseevsky block and independently conducted 3D seismic survey in the amount of 2,800 sq. km over the large structure Pakhtusovsky.

Over the past three years, in the South Kara basin Rosneft together with Exxon Mobil conducted 2D seismic survey in the amount of more than 18 thousand line km and 3D seismic survey of more than 7000 sq. km, prepared several large structures for drilling, where in 2014 on one of them (University) drilled the first exploration well in harsh ice conditions and within the shortest possible time, which led to discovery of oil-gas-condensate Pobeda field.

On the offshore extension of the Timan-Pechora basin, the hydrocarbon-bearing target objects include complex traps at the Lower Devonian carbonate truncation on the Bolshezemelsky Arch and on the inversion swells in the Khoreiver Depression and Varandey-Adzva structural zone, which has rich source rocks in the Upper Devonian (Domanic) and Silurian. In this region Rosneft carried out the 2D and 3D detailed seismic acquisition of more than 5,000 line km and about 1,500 sq. km, respectively, and prepared for prospecting and exploration drilling the Madachagsky, Pakhanchesky, North Gulyaevsky, etc. prospects.

The poorly studied Eastern Arctic basins (North Kara, Laptev-Sea, the North and South Chukchi) have an enormous HC potential but require a thorough regional study prior to the best prospect selection and their preparation for drilling. In 2014, Rosneft in partnership with ExxonMobil in tough ice conditions (work season 1,5-2 months) acquired 12 thousand line km of regional seismic data and completed a large-scale coverage by aerogravity and magnetic data of 225 thousand line km as well as 4 geological field expeditions on the adjacent onshore and islands.

The lower crust and upper mantle beneath Svalbard and the Western Barents Sea: evidence from combined active-source and array seismology

Odden, G.[1], Minakov, A.[1] & Schweitzer, J.[2]

[1]Centre for Earth Evolution and Dynamics, University of Oslo, Oslo, Norway; [2]NORSAR, Kjeller, Norway

Svalbard is one of the unique places on Earth where an upwelling mantle flow associated with recently formed divergent plate boundary in the North Atlantic interacts with continental lithosphere. Seismic tomography studies, elevated heat flow and petrological data from upper mantle xenoliths indicate anomalously hot mantle and thin lithosphere (about 50 km). Before seafloor spreading the Arctic Amerasia Basin had opened. The Early Cretaceous opening of the Arctic Ocean and formation of the High Arctic Large Igneous Province resulted in abundant dolerite sills in the sedimentary cover and giant like dike swarms cross-cutting the crystalline basement in the Svalbard region. Despite decent data coverage, velocity models obtained from wide-angle seismic data in the Svalbard region are often characterized by poor resolution in the upper mantle due to limited source-receiver offset.

The datasets in this study originates from two wide-angle refraction surveys conducted in the vicinity of Kong Karl's Land in 2008 and Hopen Island in 2014. Both surveys were shot with airguns with the total volume of about 90l by the research vessel Håkon Mosby. The seismic line shot in 2008 was recorded with the seismological array on Spitsbergen (SPITS) and sampled crust and upper mantle in east-west direction, while the line shot in 2014 was recorded with SPITS, and the seismic stations at Hornsund (HSPB) and on Hopen Island (HOPEN) leading to sampling of crust and upper mantle in both north-south and east-west directions.

Band-pass filtering, cutting, NEZ-LQT rotation, beamforming both at the source and receiver sides, and tau-p transformations have been performed on the data to enhance the signal-to-noise ratio for certain seismic phases and have resulted in clear mantle refractions at offsets up to 420 km. The travel-time data are inverted for a 1D P-wave velocity model, following Diebold and Stoffa (1981). We also discuss other 1D velocity models previously published by different authors. The 3D model Barents50 has been evaluated by raytracing and travel-time modelling has revealed some difference in travel times when compared to our data.

Full waveform modelling by a frequency-wavenumber integration method (Bouchon 1981) has been performed in order to study offset depending amplitude variations and the generation of converted S-waves and their implications for the structure of the uppermost mantle.

With this contribution we discuss new methodological developments that will allow for better imaging of the uppermost mantle from long-offset refraction data.

References:

Diebold, J. B. & Stoffa P. L. 1981. The traveltime equation, tau-p mapping, and inversion of common midpoint data. *Geophysics* 46(3), 238-254.

Bouchon, M. 1981. A simple method for calculating Green's functions for elastic layered media. *Bull. Seismol. Soc. Am.* 71, 959-972.

The strandflat - a Mesozoic weathered paleosurface exhumed and eroded in the Pleistocene?

Olesen, O.,[1] Brönner, M.,[1,2] Dalsegg, E., [1] Fredin, O.,[1] Rønning, J.S.[1,2] & Solbakk, T.[2]

[1]Geological Survey of Norway, P.O. Box 6315 Sluppen, 7491 Trondheim, Norway; [2]Norwegian University of Science and Technology, S.P. Andersens veg 15a, 7034 Trondheim, Norway

Deeply weathered bedrock on the Norwegian strandflat is similar to weathering occurring under Mesozoic strata on offshore basement highs (e.g. the Utsira High in the North Sea) indicating this surface has an older origin. We observe two types of weathering on the strandflat: 1) Linear weathering along faults and fractures. 2) Areal weathering over larger areas of several square kilometres. Electrical resistivity profiling on the Norwegian strandflat reveals weathered bedrock extending to more than 100 m depth. Calculations of weathering indices and mass balance from XRF analysis show leaching of the major elements. We argue that the weathering is partly of Early Mesozoic age, since the Late Jurassic to Early Cretaceous faults are little affected by the alteration. The linear weathering occurs quite frequently while the areal weathering seems to be concentrated in the Vestfold and Lofoten-Vesterålen-Hamarøya region. The weathered sites can be found up to an altitude of 500 m asl. and were most likely exhumed during the Plio-Pleistocene. This observation is supported by previous marine-geological studies suggesting a Pleistocene erosion of ~500 m along the coast of Norway. The main difference between western and mid Norway and the Lofoten-Vesterålen-Vestfjorden region is the location relative to the rifting in the North Sea and the Norwegian Sea. The greater Vestfjorden region constitutes a part of the Mesozoic rift system with an abundance of uplifted and rotated fault blocks, whilst the western and mid Norway were located more remotely relative to the rift centres in the North Sea and the Møre-Haltenbanken area. Consequently, we find the remnants of deep weathering on rotated fault blocks in Lofoten–Vesterålen whereas similar regoliths occur in the more gentle landscape along the coast of western Norway and Trøndelag. We suggest that the deep weathering in the Hamarøya, Lofoten and Vesterålen in northern Norway is preserved because of the young uplift and erosion of this area (Late Pleistocene age). Most of the ice was transported in ice streams through Vestfjorden and Andfjorden leaving the interior of the mainland and the Lofoten–Vesterålen archipelago relatively unaffected. Some of the palaeosurfaces on the uplifted and rotated fault blocks were therefore relatively undisturbed. The little consolidated Mesozoic rocks were easily removed by ice sheet aerial scouring and glaciofluvial erosion during numerous glacial cycles. The present-day large scale topography along the coast of Nordland may consequently be an inheritance from the Mesozoic. The numerous, shallow, Mesozoic basins occurring on the strandflat support this conclusion. The deeply weathered and fractured basement rocks could have facilitated effective glacial erosion during the *c.* 40 glaciations in the Pleistocene. Freezing and thawing combined with abrasion by ocean waves during fluctuating sea levels in non-glaciated periods would have assisted in the formation of a relatively wide strandflat along the coast from Rogaland to western Finnmark. We consequently interpret the Norwegian strandflat as a deeply weathered and surface of Triassic to Early Jurassic age that has been exhumed and peneplanated during Pleistocene erosion similar to the subcropping sedimentary units further west. We also suggest that this model may be applicable for explaining the formation of other strandflats in the NE Atlantic and Arctic.

Structural framework at the NE Atlantic-Arctic margin junction: the Devonian Keiserhjelmen Detachment, Northern Svalbard

Osmundsen, P.T.[1,2], Braathen, A.[3] & Maher, H. Jr.[4]

[1]Geological Survey of Norway, P.O.box 6315 Sluppen, NO-7491 Trondheim, Norway; [2]Dept. of Arctic Geology, University Centre in Svalbard, 9171 Longyearbyen, Norway; [3]Dept. of Geosciences, University of Oslo, 0316 Oslo; [4]University of Nebraska at Omaha, USA

At the junction between the North Atlantic and Arctic margins, the large-magnitude extensional Keiserhjelmen Detachment juxtaposes Devonian sedimentary rocks with a corrugated metamorphic core complex consisting of mid-crustal migmatitic gneiss. The detachment zone comprises hundreds of meters of mylonites, phyllonites and cataclasites. Well-developed ductile and brittle kinematic indicators give consistent evidence for top-to-the-north tectonic transport. The magnitude of displacement is likely in the order of tens of kilometers, perhaps as much as 100 km. The core complex, the detachment zone and the overlying (Siluro?)-Devonian supradetachment basin are all affected by folds with axes parallel to the main tectonic transport and elongation trend. The basal coarse continental (Siluro?)-Devonian strata in the hanging wall rest on a strongly fractured and faulted metamorphic substrate, with basement topography controlling deposition at low stratigraphic levels. Normal faults are, however, also common higher up in the mantling Devonian stratigraphy. The overall strain pattern associated with the Keiserhjelmen detachment together with the tectonometamorphic and tectono-sedimentary relationships identified so far resemble detachment systems in the West Norwegian Caledonides and in East Greenland. They point towards basin formation in a constrictional strain field, albeit this remains yet to be demonstrated for Svalbard. Interpretation of seismic refraction and reflection data offshore NW Spitsbergen by other workers indicates a possibly Devonian sedimentary basin on a north-dipping detachment fault. We propose that this configuration contains a continuation of the extensional system associated with the Keiserhjelmen detachment. Carboniferous and younger reactivation of the N-S trending structural grains associated with the flanks of the corrugated detachment shows it is a fundamental architectural element in the tectonostratigraphy of northern Svalbard.

Fossil bioarchives to discover and track methane releases in the Arctic

Panieri, G.[1], Lepland, A.[1,2], Graves, C.[3], Schneider, A.[1], Consolaro, C.[1,4] , Hong, W. [1], James, R.[3] & Mienert, J.[1]

[1]Centre of Excellence CAGE - Centre for Arctic Gas hydrate, Environment and climate, Department of Geology, UiT The Arctic University of Norway, Dramsveien 201 N-9037 Tromsø, Norge (E-mail: giuliana.panieri@uit.no); [2]Geological Survey of Norway, 7491 Trondheim, Norway; [3]National Oceanography Centre, University of Southampton Waterfront Campus, EuropeanWay, Southampton SO143ZH, UK; [4]School of Geography, Earth & Environmental Sciences, Plymouth University, Plymouth PL48AA, UK

Biogenic carbonate archives as foraminifera record evidence for past environmental conditions in their shells; recently, the possibility of using foraminifera to establish the location and times of methane venting during the last Deglaciation in the Arctic area has been explored (Panieri et al. 2014; Consolaro et al. 2015).

Micropaleontological investigations, isotopic measurements (δ13C and δ18O), scanning electron microscopy (SEM) equipped with EDS, and ion microprobe for isotopic measurements (SIMS) provide the compulsory tools for obtaining all the paleo-data archived in one of the most abundant groups of organisms in the marine realm. In an effort to locate and track the periodicity of methane venting in the Arctic, to understand the triggering processes for those releases, and to define the biogeochemical processes involved in methane migrations, a vast investigation which comprises numerous sediment cores from different areas in the Arctic (Vestnesa ridge and Prins Karl Forland) is ongoing. Both areas are characterized by vast amounts of methane as free gas and gas hydrates; this gas is considered vulnerable to climate change.

Results obtained so far indicate that the geologic record in the deep Vestnesa Ridge and at the present-day GHSZ limit offshore Prins Karls Forland is punctuated by several methane venting events. The reconstruction of similar events is complicated by the migration of the SMTZ (sulphate-methane transition zone) where methane-derived authigenic carbonate also precipitates on foraminifera shells, and by the biogeochemical processes involved in methane migrations.

Combined analyses show the value and complexity of separating primary vs. secondary signals with relevance to understanding fluid-burial history in methane seep provinces. We demonstrate that foraminifera tests can record methane in the shell and also serve as a template for authigenic carbonate precipitation favoring the preservation of different phases of past methane emissions. These records can then be integrated with observations of modern methane emissions and will be used in a computer model to infer past as well as predict future climate changes.

This research is partially supported by the Research Council of Norway through its Centres of Excellence funding scheme, project number 223259.

References:

Consolaro, C., Rasmussen, T.L., Panieri, G., Mienert J., Bünz S. & Sztybor K. 2015. Carbon isotope ($\delta^{13}C$) excursions suggest times of major methane release during the last 14 ka in Fram Strait, the deep-water gateway to the Arctic, Climate of the Past, In press.

Panieri G., James R.H., Camerlenghi A., Westbrook G.K., Consolaro C., Cacho I., Cesari V. & Sanchez Cervera C. 2014. Record of methane emissions from the West Svalbard continental margin during the last 23.500 yrs revealed by $d^{13}C$ of benthic foraminifera. Global and Planetary Change, 122,151–160.

Potential field modelling of the Seiland Igneous Province in the geodynamic framework of the northern Baltican margin

Pastore, Z.[1], Fichler, C.[2] & McEnroe, S.[1]

[1]NTNU-Norwegian University of Science and Technology, Department of Geology and Mineral Resources Engineering, Trondheim, Norway; [2]Statoil ASA, NO-7005 Trondheim, Norway

More than 25000 km^3 of mafic and ultramafic magmatic melts formed the Seiland Igneous Province (SIP), intruded during a period of major continental disruptions at ca 560-570 Ma coinciding in time with the opening of Iapetus ocean. The SIP, now located on the Baltican margin is within the Kalak Nappe Complex (KNC), a part of the Middle Allochthon of the North Norwegian Caledonides. Based on geological and geochronological constraints, the debate on the origin of the KNC is still open, and hypotheses vary from western Siberia to the peri-Gondwanan realm.

The rocks of the SIP with their high densities form a geoid anomaly and a pronounced positive Bouguer gravity anomaly of up to 100 mGal above background. A clear, but less pronounced magnetic anomaly is found associated with the gravity anomaly. In this study we developed a 3D gravity and magnetic model of the intrusive body integrating petrophysical data (density, magnetic attributes) from field work and published gravity and aeromagnetic data (Geological Survey of Norway). Selected densities for the intrusives range from 2800 to 3400 kg m^{-3} with an average density contrast to the host complex of approximately 400 kg m^{-3}.

A multi-profile based 3D model (IGMAS+) is developed and the deep structure of the SIP will be discussed. This new model suggests an irregular shape with its lower boundary varying in depth from less than 3 km to 10 Km. Three different deep reaching roots have been identified located below Øksfjord peninsula, Seiland and the Sørøya islands.

The geometry of the intrusive body carries information about multiple factors (rheological, thermal and tectonic) responsible for the emplacement and geodynamic development. Our new model contributes to the understanding of tectonic, magmatic and the paleogeographic evolution of the SIP and adds new insights into the tectonic development of the rich hydrocarbon basins of the Southern Barents Sea.

Holocene primary productivity variability and sea ice coverage in the western Barents Sea

Pathirana, I. & Knies, J.

Geological Survey of Norway, Trondheim

We investigate late Holocene primary productivity (PP) variability in the western Barents Sea and its response to variable sea ice coverage. A multi-proxy geochemical and organic-sedimentological approach is coupled with organic facies modelling. OF-Mod 3-D, an organic facies modelling software tool, is used to reconstruct and quantify the marine and terrestrial organic carbon fractions and to make inferences about marine primary productivity changes across the marginal ice zone. By calibrating the model against an extensive set of sediment surface samples, we improve the Holocene organic carbon budget for ice-free and seasonally ice-covered areas in the western Barents Sea. We show that PP inferred from organic carbon burial in areas outside the marginal ice zone is significantly lower compared to PP within the MIZ. This is opposite to modern simulation of surface water productivity in the Barents Sea and discrepancies between data and models are discussed and alternative explanations are given.

Numerically modelling extensive glaciation of the Eurasian Arctic

Patton, H.[1], Andreassen, K.[1], Winsborrow, M.C.M.[1], Auriac, A.[2] & Hubbard, A.[1]

[1]CAGE - Centre for Arctic Gas Hydrate, Environment and Climate, Department of Geology, UiT The Arctic University of Norway, Tromsø, Norway; [2]Department of Geography, Durham University, Durham, United Kingdom

The stratigraphy of trough mouth fans that border the Barents Sea continental shelf reveal that the Eurasian Arctic has been host to numerous, shelf-wide glaciations throughout much of the Quaternary period, with ice having removed and transported vast volumes of sediment from the shelf to the deep ocean. Recent geophysical data collected from the Barents and Kara seafloors have helped significantly advance our understanding of a number of important process dynamics related to marine-based glaciation of this domain, particularly related to constraints on ice build-up, flow patterns, and the timing of retreat during the last glacial cycle.

We present results from a 3D thermomechanical ice-sheet model that examine the pattern and drivers of glaciation across northern Eurasia during the Mid to Late Weichselian, as well as the impacts ice-sheet cover had on the continental shelf. Crucial to the build-up and deglaciation of the Barents Sea Ice Sheet is its sensitivity to non-linear feedbacks associated with the spatially heterogeneous climatic and oceanographic forcings that affect the domain. However, during periods of widespread glaciation, phases of internal thermomechanical switching act to stabilise the ice sheet through repeated cycles of ice streaming, thereby reproducing key elements of the geological palimpsest. The model calculates subglacial thermal conditions, isostatic loading effects, and potential erosion – output used to investigate the long-term evolution of the continental shelf including shifting zones of subglacial erosion, delivery routes of sediments to trough-mouth fans, subglacial meltwater availability, and gas-hydrate stability.

Age and geochemistry of Cretaceous basalts from Axel Heiberg, Canada

Pease, V.[1] & Nobre Silva, I.[2]

[1]Department of Geological Sciences, Stockholm University, Stockholm, Sweden; [2]Departmenof Earth Sciences, Memorial University of Newfoundland, St. John's, Canada

Mafic volcanic and intrusive rocks associated with the Cretaceous High Arctic Large Igneous Province (HALIP) are recognized across the Canadian Arctic Islands, northern Greenland, Svalbard, Franz Josef Land, and Chukchi Borderland. The origin of this Cretaceous volcanism is most likely related to the opening of the Amerasia and Eurasian basins. The nature of the mantle source(s) and petrogenesis of HALIP rocks, however, remain subjects of debate. Two magmatic suites are generally recognized amongst HALIP rocks: an earlier, mantle plume-related tholeiitic suite (130 - 80 Ma) and a later, rift-related alkalic suite (85 - 60 Ma). We present new $^{40}Ar/^{39}Ar$ ages, elemental and isotopic compositions for basaltic dikes, sills, and lava flows from NW Axel Heiberg Island (AHI) in Arctic Canada.

The best constrained argon release spectra yield plateau ages of c. 123 Ma. All samples are tholeiitic, with high TiO2 (2 - 4 wt%) and restricted MgO (3.2 - 7 wt%) contents. They are LREE-enriched [La/Yb(N) = 2.6 – 5] and Nb-depleted relative to Th and La. Compared with other HALIP rocks, the samples have a limited range of eNd(t) (+2.5 to +5.5), except for one lava flow with eNd(t) = +8.5. In contrast, Pb and Sr isotopic compositions show considerable variation [206Pb/204Pb(t) = 17.792 – 18.729; 87Sr/86Sr(t) = 0.70362 – 0.70778], despite acid leaching treatment prior to isotopic analyses for removal of post-magmatic alteration. Variable assimilation of Svedrup Basin sediments by an enriched mantle source of estimated composition similar to that of an Iceland-like mantle plume at c. 125 Ma, could account for the trace element and Nd-Sr isotopic signatures of AHI basaltic rocks. However, it cannot explain their higher $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ values at a given $^{206}Pb/^{204}Pb$, thus requiring an additional source component.

AHI basaltic rocks are isotopically similar to metasomatized peridotite xenoliths, suggesting that variably enriched old subcontinetal lithospheric mantle was involved in the genesis of Cretaceous magmatism of AHI during the opening of the Canada Basin. This is consistent with seismic studies which suggest large amounts of exhumed subcontinental mantle in the Amerasia Basin. High T-geochronology is needed to better constrain HALIP ages. Further geochemical studies of HALIP related rocks are needed to constrain the composition and extent of involvement of this lithospheric source in Cretaceous Circum-Arctic volcanism.

Structural-tectonic zoning of the Arctic

Petrov, O.[1], Smelror, M.[2], Morozov, A.[3], Sobolev, N.[1], Grikurov, G.[4], Shokalsky, S.[1], Pospelov, I.[1], Kashubin, S.[1] & Petrov, E.[1]

[1]Russian Geological Research Institute (VSEGEI), Saint-Petersburg, Russia; [2]Geological Survey of Norway (NGU), Trondheim, Norway, [3]Rosnedra, Moscow, Russia, [4]VNIIOkeangeologia, Saint-Petersburg, Russia

Zoning of the Arctic over the age of consolidated basement, crustal type, and features of geological structure of the sedimentary cover has been carried out. The zoning is based on the results of compilation of the tectonic map under the international project "Atlas of Geological Maps of the Circumpolar Arctic at 1: 5 000 000 scale", as well as on new data on the geological structure of the eastern Arctic, obtained in recent years as a result of state geological mapping at 1: 1 000 000 scale.

Zoning of consolidated basement has been made over the age of final folding. The new data confirming close structure of the basement in the western and eastern continental margin of the Eurasian oceanic basin have been obtained. Here, areas of the Neoproterozoic (Baikalian) and Paleozoic (Ellesmerian) folding are successively distinguished from south to north. Neoproterozoic foldbelt is found on central Taimyr (Byrranga Mountains). Chukotka-Novosibirsk fold system is an extension of this belt in the eastern Arctic. Ellesmerian orogen includes the northernmost areas of Taimyr and Severnaya Zemlya Archipelago, wherefrom it is traced to the Geofizikov Spur of the Lomonosov Ridge and further through the De Long Archipelago and North Chukchi Basin to the north Alaska Peninsula and in the Beaufort Sea. From the north, Ellesmerides are bounded by the Precambrian continental blocks - North Kara and Mendeleev Ridge, the sedimentary cover within which is represented by the undisturbed Paleozoic and Mesozoic sediments.

Geophysical investigations enabled to find out that most of the Arctic region has a continental crust except for the Eurasian Basin and the central Canada Basin, which are characterized by oceanic crust type. Continental crust thickness from seismic data varies widely: from 30-32 km on the Mendeleev Ridge, to 18-20 km of the Lomonosov Ridge, reducing to 8-10 km in rift structures of the Podvodnikov-Makarov Basin at the expense of reduction of the upper granitic layer.

Mesozoic (pre-oceanic) stage associated with the completion of the continental crust formation within the entire Arctic region is an important milestone to understand the modern tectonic structure of the Arctic. The Ural paleoocean closed during the Late Permian - Early Triassic, and the South Anyui during the Late Jurassic - Early Cretaceous, forming, respectively, the Ural and Verkhoyansk-Chukotka foldbelts. Postcollision development stage of both Ural and South Anyui paleooceans took place on a single plan. It is characterized by intraplate rifting with extensive trap magmatism, contributing to the formation of the Triassic Siberian and Cretaceous High Arctic (HALIP) igneous provinces and postrift sedimentary basins (koilogens) - mature West Siberian and Amerasian, which was in the initial stage of development.

Modern tectonic structure of the western Arctic is influenced by divergent processes caused by opening of the Atlantic with the formation of passive continental margins - the Barents-Kara and Amerasian. In the eastern Arctic, divergent processes characteristic of the Atlantic are superimposed on the convergent processes in the Pacific Belt, which are accompanied by the formation of island arcs and marginal back-arc basins.

The Eurekan deformation in the Arctic – architecture and kinematics of a strange foldbelt

Piepjohn, K.[1], von Gosen, W.[2], Tessensohn[3], F. & Reinhardt, L.[1]

[1]Bundesanstalt für Geowissenschaften und Rohstoffe, Geologie der Energierohstoffe, Polargeologie, Stilleweg 2, D-30655 Hannover, Germany (E-mail: Karsten.Piepjohn@bgr.de); [2]GeoZentrum Nordbayern, Friedrich-Alexander-Universität Erlangen-Nürnberg, Schlossgarten 5, D-91054 Erlangen, Germany; [3]Lindenring 6, D-29352 Adelheidsdorf, Germany

The polyphase Eurekan deformational history in the Arctic was not the result of a single tectonic episode. It rather represents a complex sequence of successive tectonic stages, which produced a number of intra-continental deformation zones with changing, sometimes opposing, lateral, oblique, and convergent kinematics along the involved plate boundaries in the Canadian Arctic Archipelago, North and Northeast Greenland, and Svalbard.

The Eurekan Deformation is characterized by a different structural style with the development of fold-and-thrust belts in Spitsbergen and in the Canadian Arctic, distinct compressional thrust zones in North Greenland and Ellesmere Island, large systems of strike-slip fault zones in Spitsbergen, Northeast Greenland and Ellesmere Island, and the combination of both compressional and lateral fault zones in northern Ellesmere Island.

Eurekan zones of deformation in the Canadian Arctic display several curvatures of the trend of the thrusts and folds. The front of the deformation belt towards the Greenland shield, for example, changes from a NE-SW trend parallel to Nares Strait into an E-W trend west of Kane Basin and again to a N-S-trend west of the Inglefield Uplift. This contrasts to North Greenland and Spitsbergen, where Eurekan structures show straight trends over long distances. The phases of the Eurekan deformational history span the Late Cretaceous-Oligocene interval and were caused by different stages of the plate-tectonic evolution in the developing ocean basins surrounding Greenland.

The evolution of the different Eurekan deformation zones is related to the development of the circum-Greenland plate boundaries from Late Cretaceous to Oligocene times. Tectonism was caused by the initiation of the opening and continuous evolution of the Eurasian Basin in connection with the development of the Labrador Sea/Baffin Bay and the North Atlantic Ocean spreading ridges. The interaction between the different continental plates, especially in combination with the development of transform faults, resulted in the formation of several complex zones and areas of (onshore) Eurekan Deformation. Four major stages can be distinguished for the Eurekan Deformation:

Stage 1: sea-floor spreading in Labrador Sea and rifting in Baffin Bay, Norwegian/Greenland seas and the Eurasian Basin between 100 and 55 million years ago.

Stage 2: The Early Eurekan phase with sea-floor spreading and transform faults around Greenland resulted in a NE-directed movement with (a) sinistral transpression along Nares Strait and probably sinistral motion along the fault zones parallel to the north margin of

Ellesmere Island, and (b) compression at the West Spitsbergen Fold-and-Thrust Belt 55 to 49 million years before present.

Stage 3: The Late Eurekan phase resulted in a NW-wards directed movement of Greenland with (a) compression along Nares Strait and parts of Ellesmere Island combined with dextral motions parallel to the continental margin of the Canadian Arctic Archipelago (b) and dextral transpression and transtension along Fram Strait 49 to 36 million years ago.

Stage 4: final Eurekan movements, termination of sea-floor spreading in Labrador Sea/Baffin Bay and separation of Greenland and Svalbard.

Some remaining main problems concerning the Eurekan deformational history in the Arctic are related to (1) the unprecise dating of main tectonic onshore events, (2) the still unsolved problem of the Wegener Fault (important transform fault or not?), and (3) the western continuation and effects of Eurekan Deformation in western Canada and Alaska.

Seismic characterization of a > 100 km long hydrate province close to an oceanic ridge-transform fault complex in Fram Strait, Arctic Ocean

Plaza-Faverola, A.[1], Vadakkepuliyambatta, S.[1], Waghorn, K.[1], Johnson, J.[1,2], Mienert, J.[1] & Bünz, S.[1]

[1]CAGE-Centre for Arctic Gas Hydrate, Environment, and Climate; Department of Geology, UiT The Arctic University of Norway, N-9037 Tromsø, Norway; [2]Permanent Address: Department of Earth Sciences, University of New Hampshire, Durham, NH, 03824 U.S.A.

On the west-Svalbard margin a sediment drift known as Vestnesa Ridge has been accumulating sediments on top of < 19 Ma old oceanic crust at water depths > 1000 m. Despite its location on a passive margin, Vestnesa Ridge is in close proximity to active ocean spreading ridges and transform faults of Fram Strait. It is surrounded by the Molloy Ridge (MR) to the west, the Knipovich Ridge (KR) to the south-east and the Spitsbergen Transform Fault (STF) and Molloy Transform Fault (MTF) to the north and south respectively. Sediments along the ridge are thus subjected to much higher geothermal gradients if compared with slope regions of the passive west-Svalbard continental margin. Vestnesa Ridge hosts the largest known Arctic deep-water gas hydrate province. Seafloor pockmarks along the ridge were first discovered in the late 80s and the ridge is now one of the main CAGE targets for multi-disciplinary investigation of Arctic gas hydrate systems. Here we estimate the lateral extent and thickness of the gas hydrate stability zone and associated shallow free gas reservoir beneath it along the entire extend of Vestnesa Ridge (i.e., from the eastern flank of the MR to the recently discovered extension of the ridge, on the western flank of the KR, south of the MTF), based on an integration of seismic indicators such as bottom simulating reflectors and gas hydrate stability zone modelling. We use 2D seismic lines acquired in the framework of numerous CAGE cruises and compile information from other studies in the region of Fram Strait. This is the first step for a quantitative estimation of the amount of gas hydrate and free gas trapped underneath gas hydrate bearing sediments in Fram Strait of the Arctic Ocean.

A complex pattern of marine glaciations on the Amerasian Arctic margins

Polyak, L.[1], Dove, D.[2], Kim, S.[3], Nam, S.-Il[4], Niessen, F.[5] & Coakley, B.[6]

[1]Byrd Polar and Climate Research Center, Ohio State University, Columbus, OH, USA; [2]Centre for Gas Hydrate, Environment and Climate, University of Tromsø, Norway; [3]British Geological Survey, Edinburgh, UK; [4]Korea Polar Research Institute, Incheon, Republic of Korea; [5]Alfred Wegener Institute, Helmholtz Center for Polar and Marine Research, Bremerhaven, Germany; [6]University of Alaska Fairbanks, AK, USA

Multiple glacigenic bedforms are being revealed by seafloor swath (multibeam bathymetry) and subbottom mapping on the Chukchi, Beaufort, and East Siberian margins (e.g., Polyak et al. 2007; Jakobsson et al. 2008, 2014; Niessen et al. 2013; Dove et al. 2014). These bedforms indicate various aspects of repeated glacial impact on sea floor produced by ice streams/shelves originating from the Laurentide, Chukchi, and East Siberian glaciation centers. The Chukchi Rise (northern extension of the Chukchi Shelf) appears to be the area of confluence and complex interaction of these ice streams, but their pathways are not well understood. In particular, coast-parallel megascale lineations found on the Alaska Beaufort margin could be the "missing link" between the northwestern (Keewatin) sector of the Laurentide ice sheet and the SE-NW trending lineations on the Chukchi Rise and Plateau. However, a survey of the Amundsen Gulf mouth, one of the major outlets for Arctic Laurentide ice streams, did not find a connection between bedforms indicative of streaming from the Keewatin center and lineations on the Beaufort margin further west (McLean et al. 2015). This apparent disconnection gave a reason to suggest that the latter lineations were formed by a mélange of sea ice and icebergs driven by the surface water circulation during deglaciation. It remains to be investigated, whether such mélange could form glacigenic erosional and depositional features on the Alaskan and Chukchi margins reaching 900 m water depth.

Another important but poorly understood aspect of the glacial history of the Amerasian margins is the timing of glacial events. While a reliable stratigraphic framework is not yet developed, correlation of subbottom profiles with available sediment cores allows for a conclusion that marine glaciation during the Last Glacial Maximum was diminutive, extending to water depths not exceeding ~450 m, while the last widespread glacial impact on the Chukchi margin can be tentatively attributed to Marine Isotope Stage 3. This stratigraphy suggests a discrepancy between the development of land-based ice sheets and their marine extensions into the Arctic Ocean. This discrepancy highlights the complexity of glacial processes in the Amerasian Arctic and the importance of paleoglaciological modelling coupled with marine geological evidence. Insights into mechanisms of formation, propagation, and collapse of former Arctic marine ice sheets/shelves will help understand the dynamic behaviour of their modern counterparts in the West Antarctic and Greenland.

Arctic methane storage and release across a formerly glaciated polar margin

Portnov, A., Vadakkepulyambatta, S., Mienert, J. & Hubbard, A.

CAGE - Centre for Arctic Gas Hydrate, Environment and Climate, UiT The Arctic University of Norway, Tromsø, Norway

We examine the complex interplay between paleo-ice sheet retreat, sub-glacial thermal adjustment, glacio-isostatic loading, sea level rise, oceanic variability and the stability of gas hydrate reservoirs across the NW-Svalbard Arctic margin. Methane-flares imaged by acoustic echo-sounding in this region have been attributed to the active dissociation of submarine gas hydrates under oceanic warming over the last 30 years. However, dating of seabed methane expulsion sites (pockmarks) suggests that gas release has also been an on-going process active for millennia.

We combine data on ~1800 fluid escape features (pockmarks and active gas flares) with numerical modeling to investigate the timing and spatial domain of different fluid release processes during deglaciation. A perfect-plastic approximation is used to reconstruct the Last Glacial Maximum ice sheet profile which is then implemented within a steady-state model to determine the Gas Hydrate Stability Zone (GHSZ) under both cold and warm-based subglacial thermo-mechanical scenarios. Results reveal a massive subglacial GHSZ in excess of 600 m under the paleo-ice sheet which abruptly tapers out to the west across the shelf beyond the ice sheet margin. Here, the model predicts a pinch out of the subsea GHSZ on the seafloor in ~400 m water depth (~520 meters below the present sea level). In contrast to the subglacial environment, the subsea GHSZ was considerably thinner attaining a maximum thickness of just ~200 m. These results suggest that across the NW-Svalbard continental shelf, active methane release was concurrent with deglaciation from a sub-glacial interface that existed in water depths of 150 to 520 m.

Seismic stratigraphy of sedimentary cover in Central Arctic Uplifts Complex, Amerasia Basin

Poselov, V.A., Butsenko, V.V., Zholondz, S.M. & Kireev, A.A.

I.S. Gramberg All-Russia Research Institute for Geology and Mineral Resources of the World Ocean (VNIIOkeangeologia), Anglyisky prospect 1, St. Petersburg 190121, Russia

Seismostratigraphic models of sedimentary cover in the Central Arctic uplifts (Lomonosov Ridge, Alpha-Mendeleev ridge system, Chuckchi Borderland, Podvodnikov Basin, Makarov Basin) were successively determined for the Cenozoic and pre-Cenozoic parts of the sedimentary section and were based on correlation of the Russian MSC data with seismic data documented by wells (ACEX-2004 on the Lomonosov Ridge – Cenozoic section; CRACKERJACK, KLONDIKE, POPCORN on the Chukchi shelf – pre-Cenozoic section).

Cenozoic sedimentary section:

1. All Russian MSC data obtained in the Central Arctic uplifts are correlated with AWI91090 section calibrated by ACEX-2004 drilling on the Lomonosov Ridge (the line passes through the well).
2. Two major unconformities are traced across the study area. The upper regional unconformity (RU) is associated with a major pre-Miocene hiatus at the base of hemipelagic deposits. Another major hiatus is recorded in the well section between the Campanian and the Upper Paleocene units. In the seismic sections, it is recognized as the post-Campanian unconformity (pCU).
3. Formation of RU and pCU is associated with a fundamental change in depositional environment: the first one, at the Paleogene/Neogene boundary, was initiated by opening of the Fram Strait gateway; the second one, between the Cretaceous and Paleogene, is correlated with the initial stage of the Eurasian Basin opening.
4. Cenozoic sedimentary units are continuously traced from the Eurasian shelf across the transit zone to the Lomonosov Ridge. Their seismostratigraphic and seismofacies characteristics do not change fundamentally, which would be inevitable in case of a major shear (strike-slip) displacement of the Ridge with respect to the Laptev Sea shelf. No major fault displacements are recorded in the transit zone as evidenced by the absence of such displacements in the acoustic basement topography in the Vilkitsky Trough.
5. Paleogene unit (between pCU and RU) is characterized by an extremely small thickness on the Lomonosov Ridge (less than 200 m), on the Mendeleev Ridge and in the Podvodnikov Basin (not more than 300-400 m). According to well data, it formed under the neritic depositional environment. Hence, most of the Podvodnikov Basin with a thin Paleogene unit can be regarded as a submerged flank of the Lomonosov Ridge.
6. Judging by sonobuoy data, interval velocities in the Paleogene unit vary within 2.8-3.2 km/s; in the Neogene (hemipelagic) unit, within 1.8-2.7 km/s.

Pre-Cenozoic sedimentary section:

1. Above the acoustic basement the pre-Cenozoic section is mainly represented by terrigenous units. Their stratification is based on tracing of four major unconformities, Permian (PU – Top of Lower Ellesmerian unit), Jurassic (JU – top of the Upper Ellesmerian unit), Lower Cretaceous (LCU) and Brookian (BU – base of the Lower Brookian unit), from

Chukchi shelf wells to the North-Chuckchi Trough and further to the Mendeleev Ridge as well as to the Vilkitsky Trough and the adjacent Podvodnikov Basin (Fig. 1).

2. Two major unconformities of the pre-Cenozoic section (pCU and BU) are distinguished virtually on all MSC lines intersecting the Mendeleev Ridge along its entire extent. They are also traced from the Mendeleev Ridge to the admittedly continental structure of the Chuckchi Borderland.

3. Over the entire area of the Podvodnikov Basin, the sequence between the post-Campanian unconformity (pCU) at the base of the Cenozoic section and the Brookian unconformity (BU) underlying deposits of the Lower Brookian unit, is recorded as a synrift unit.

4. Judging by sonobuoy data, interval velocities of the Upper Cretaceous units (limited by pCU and BU) in the Vilkitsky Trough – Podvodnikov Basin range within 3.2-3.9 km/s. Pre-Upper Cretaceous units (between BU and the acoustic basement) are characterized by values of interval velocity ranging within 4.1-4.8 km/s.

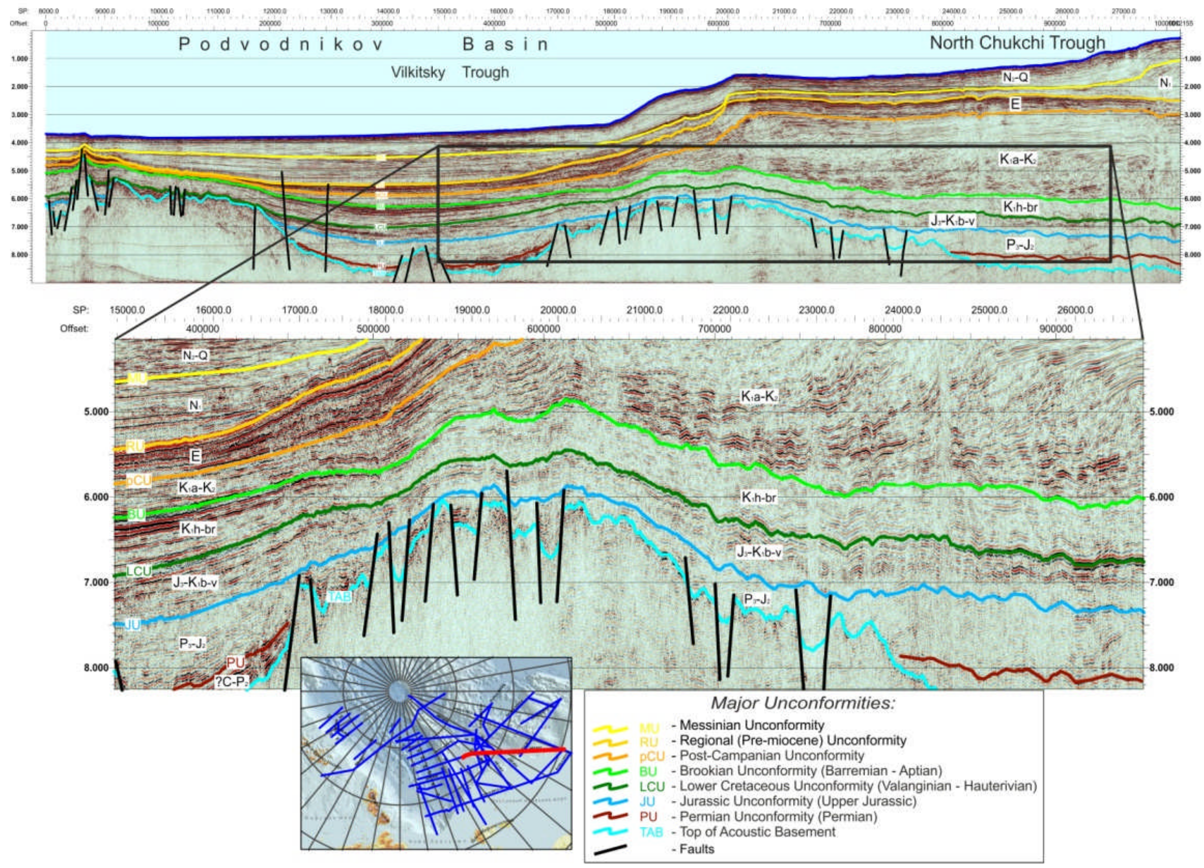


Fig. 1. MCS section along Russian ARC1401 line.

Mesozoic-Cenozoic Tectonic History of New Siberian Islands

Prokopiev, A.V.[1], Ershova, V.B.[2], Anfinson, O.A.[3], Khudoley, A.K.[2], Vasiliev, D.A.[1] & Stockli, D.F.[3]

[1]Diamond and Precious Metal Geology Institute Siberian Branch Russian Academy of Sciences, 39, Lenin Avenue, Yakutsk, 677980, Russia (E-mail: prokopiev@diamond.ysn.ru); [2]St. Petersburg State University, University nab. 7/9, St. Petersburg, 199034, Russia; [3]Jackson School of Geoscience, University of Texas at Austin, USA

The New Siberian Islands are located in the eastern Russian Arctic at the border between the Laptev and East Siberian seas. Here we present an integrated tectonic analysis of the New Siberian Islands based on detailed structural studies and apatite and zircon (U-Th)/He ages.

Jeannette Is.: Uppermost Cambrian–lowermost Ordovician volcanogenic-sedimentary rocks generally dip to E-NE. Common are similar folds of NW strike accompanied by cleavage and W-vergent thrusts. Apatite (U-Th)/He ages from a sample of andesitic tuff have a mean age of 52.8±7.4 Ma (9 grains, 2σ) suggesting the island was uplifted during an Early Paleogene tectonic event.

Henrietta Is.: Uppermost Cambrian–lowermost Ordovician volcanogenic-sedimentary rocks are intensely deformed in the southwest portion of the island. There are numerous thrusts and folds of W-SW vergence. Apatite (U-Th)/He ages from a sample of sandstone have a mean age of 163±41 Ma (4 grains, 2σ) and from a sample of trachybasalt have a mean age of 139±39 Ma (5 grains, 2σ) suggesting the island experienced exhumation during a Late Jurassic (?) – Early Cretaceous tectonic event. The trachybasalt yielded an age of 135.9 ±2.8 Ma (U-Pb, SHRIMP-II, zircon) very close to apatite (U-Th)/He age.

Kotel'nyi Is.: Devonian to Triassic rocks are deformed into folds striking to the NW. There are SW-verging thrusts, N-S, E-NE and NE-trending strike-slip faults. Zircon (U-Th)/He ages from uppermost Devonian–lowest Carboniferous sandstone have a mean ages of 125±22 Ma (8 grains, 2σ) and 106±28 Ma (8 grains, 2σ) pointing to a tectonic event with Early Cretaceous uplift.

Bel'kovsky Is.: Devonian-Permian rocks are deformed into folds of NW strike. Reverse faults have E-SE vergence. N- and W-trending dextral and sinistral strike-slip faults are present. Deformed Paleozoic rocks are overlain with angular unconformity by Paleogene-Neogene deposits. Apatite and Zircon (U-Th)/He ages from Permian sandstone are similar and yielded a mean age of 85±12 Ma (7 grains, 2σ) and of 90±11 Ma (12 grains, 2σ), respectively. Apatite (U-Th)/He ages from Oligocene sand have a mean age of 105±20 Ma (8 grains, 2σ), which is older than the depositional age.

Thus, on the New Siberian Islands, the oldest Mesozoic-Cenozoic tectonic events are dated as Late Jurassic (?) - Early Cretaceous. The apatite extracted from the trachybasalt of Henrietta Is. show ages close to age of hosted magmatics, pointing to synchronous Early Cretaceous mafic magmatism and uplift. Apatite (U-Th)/He ages from Oligocene sands of Bel'kovsky Is. suggests erosion of an Early Cretaceous orogenic belt. The Early

Cretaceous ages could indicate evidence of an intensive orogenic event coinciding with the final stages of South Anyui ocean closure and the formation of the South Anyui suture. Similar Apatites and Zircon (U-Th)/He ages from Permian rocks on Bel'kovsky Is. could be interpreted as either a rapid exhumation of these rocks in the Late Cretaceous, or the thermal effect by synchronous numerous mafic dikes and sills, whose age is not yet firmly established. The youngest tectonic events are dated as Early Paleogene, recorded in the eastern part of the Archipelago.

This research was supported by RFBR grants 13-05-00700, 13-05-00943, DPMGI SB RAS VIII.66.1.4, Project N 53 (program of Russian Academy of Sciences N 44P).

Wiping the Arctic Windshield: On plate kinematics, hyperextension, and Alpha-Mendeleev magmatism

Redfield, T.F.[1] & Lundin, E.R.[2]

[1]Geological Survey of Norway, PO Box 6315 Sluppen, Trondheim, 7491, Norway; [2]Statoil ASA, Trondheim, 7005, Norway

A simple geometrical explanation has been presented (Lundin et al. 2014) for the distribution of the now-well-described architectural zonation across fully developed magma-poor margins (e.g., limited crustal stretching, extreme crustal thinning, exhumed mantle, ultraslow or normal "Penrose" oceanic crust). This zonation is observed along the lengths of many rifted margins on the super-regional scale. Diachronous development of the oceanic crust, younging towards the rift tip, indicates that at the plate tectonic scale break-up occurred on these margins by rift propagation. At the local to regional scale propagation occurs by progressive opening of segments. Because the relative motion of crust adjacent to a rift segment can be described by an Euler pole, the local linear plate separation rate can be interpreted as a function of distance to that pole. In turn, plate separation rates influence the architectural zonation and ultimately the degree of melt generation. Within each rift segment, the rift tip propagates by "unzipping" the hyperextended continental crust. A stepwise migration of Euler poles must occur in order for a large continent to break up, leading in turn to faster linear rates and attendant melt generation/oceanization at margin segments that have become more distal. Although this conceptual rifting model primarily explains magma-poor rift architecture, it may also apply to magma-rich margins. The latter may form when continents break apart at a high extension rate following rapid propagation (e.g., a long-distance pole jump). Both rifted margin types can be viewed as end members of the same process, firmly rooted in geometric requirements of plate tectonics.

Here we apply our 2014 hypothesis to describe the evolution of the Amerasia Basin under the presumption that a ca 70° CCW net rotational 'windshield wiper' kinematic model best fits the generalized plate tectonic constraints. Break-up involved a continental fragment of limited dimensions on one side (Alaska-Chukotka) as opposed to a singular colossal continental entity, and probably for this reason required only limited pole propagation. Nevertheless we suggest the ca 2000 km distance between the rotation pole in the MacKenzie Delta and the distal part of the basin would have governed a significant range in extension rates, from ultraslow near the pole to fast along the windshield wiper transform. We propose that the variation in linear rate will be reflected in the architectural zonation, and potentially also in the degree of post-breakup fault reactivation, along the strike of the High Arctic margin. The high rate most distally away from the pole may have been responsible for generating intense pressure melt magmatism along the Alpha-Mendeleev Ridge.

References:

Lundin, E.R., Redfield, T.F., & Peron-Pindivic, G., 2014, Rifted continental margins: geometric influence on crustal architecture and melting, In Pindell, J., Horn, B., Rosen, N., Weimer, P., Dinkleman, M., Lowrie, A., Fillon, R., Granath, J., & Kennian L. (Eds.), *Sedimentary basins: Origin, depositional histories, and petroleum systems,* 33rd Annual GCSSEPM Foundation Bob F. Perkins Conference, 18-53.

Early Cenozoic Eurekan deformation: Attempts to refine the dating of deformation phases

Reinhardt, L.[1], Piepjohn, K.[1], von Gosen, W.[2] & Estrada, S.[1]

[1]Federal Institute for Geosciences and Natural Resources (BGR), Stilleweg 2, 30655 Hannover, Germany (E-mail: lutz.reinhardt@bgr.de); [2]GeoZentrum Nordbayern, Friedrich-Alexander University Erlangen-Nuremberg, Schlossgarten 5, 91054 Erlangen, Germany

Deformed rocks related to the Eurekan deformation in Early Cenozoic times occur inter alia on Spitsbergen (e.g., CASE Team 2001; Dallmann 2015), northern Greenland (e.g., Soper & Higgins 1991), and along the Canadian Arctic Archipelago, and there notably on Ellesmere Island (e. g., Okulitch & Trettin 1991; Piepjohn et al. 2013). Recently, von Gosen et al. (2015) related two phases of deformation in Paleocene clastic deposits of the Yukon North Slope to the Eurekan deformation as well.

The general timeframe of the tectonic movements is known to be the Early Cenozoic, when Greenland was surrounded by plate boundaries during the final break-up of Laurasia and the opening of Baffin Bay/Labrador Sea, the North Atlantic and the Eurasian Basin (Tessensohn & Piepjohn 2000). On the other hand, much less detail exists on the timing of individual tectonic phases in the different areas that were affected by the deformation.

Several CASE expeditions* therefore focused on examination of structural geology in combination with the search for new stratigraphic tie points in predominantly clastic Tertiary sediments, which often lack any stratigraphically relevant fossils at all.

This contribution sheds light on some first results from Stenkul Fiord and Split Lake on southern Ellesmere Island, where zircons from several altered volcanic ashes in deformed Late Paleocene / Early Eocene sediments could be absolutely dated by the U/Pb method (Reinhardt et al. 2013; von Gosen et al. 2012). Re-examination of the Stenkul Fiord outcrop in summer 2014 improved the understanding of the complex syn-sedimentary movements that took place in the early Eocene. This in combination with new sample material bears the chance to finally identify the position of the PETM with more certainty in the complex outcrop of Margaret Formation sediments, which are also famous for their Eocene fauna and flora.

Additional outcrops with bentonite layers have been identified on Ellesmere Island and in the northern Yukon/Mackenzie Delta area. Samples are currently processed in the laboratory. The search for bentonite layers, which also provide geochemical fingerprints of their respective volcanic sources, is complemented by palynological studies of organic carbon rich beds or coal seams that occur widespread in Late Paleocene /Early Eocene sediments affected by the Eurekan deformation.

Geological expeditions of the **CASE research program (**CASE** = **Ci**rcum-**A**rctic **S**tructural **E**vents) of the German Federal Institute for Geosciences and Natural Resources (**BGR**) in recent years took place on Ellesmere Island (CASE 8, 11, 12 and 16), Spitsbergen (CASE 14), and the Yukon North Slope (CASE 15).*

Hydrocarbon potential of the Russian Western Arctic: New data and the results of exploration in the Pechora and Barents seas

Reydik, Yu.V., Malyshev, N.A. & Obmetko, V.V.

Rosneft Oil Company, Dubininskaya St. 31A, Moscow, Russia, 115054 (yu_reydik@rosneft.ru)

The most western part of the Russian Arctic is explored best of all, comparing with the Eastern Arctic offshore regions. In recent years here the exploration works are heavily intensified near the onshore part of the Timan-Pechora basin as well as in different parts of the Barents and Kara Seas. These works substantiate the focus areas selected for exploration and identify the new ones.

Thus, the results of geological and geophysical works on the Pechora Sea shelf confirmed a significant amplitude reduction over the large positive tectonic elements tracked from seismic data onshore (Shapkin-Yuryaha Swell, Kolva Megaswell) and, consequently, a decrease in amplitude and size of highs, complicating those elements that causes the prospectivity reduction for the western part of the Pechora Sea shelf and the redirection of prospecting works to its eastern part. The major prospects here are related to the objects, identified and being identified within the Alekseevsky-Gulyaevsky Swell, Bolshezemelsky Arch and Vashutkin-Talotinsky fold-thrust zone.

As a result of Rosneft works in 2012-2014 in the eastern Pechora Sea, in the Vashutkin-Talotinsky fold-thrust zone the areas of interest were identified for prospecting medium to large reservoirs with plays from the Ordovician to Triassic on the depths accessible for drilling.

The new focus area for HC exploration in the Barents Sea region is the Timan-Pechora basin and the South Barents trough junction in the northeast part of the Pechora Sea shelf near the Novaya Zemlya Archipelago. A series of linear swells were identified here, being complicated by large structural and structural-tectonic traps of a strike-slip genesis. Given the proximity of these features to major HC kitchen, we can expect medium and large hydrocarbon reservoirs to be discovered there.

Over the past five years in the Barents Sea the extensive exploration works were carried out both by license-holders and state-contracted geophysical companies. Thus, in the period 2012 to 2014, only Rosneft Oil Company completed 16.5 thousand line km of 2D seismic acquisition, 5,800 sq. km of 3D seismic acquisition, gravimagnetic survey and extensive geological expeditions to the outcrops on the Franz Josef Land Archipelago, Spitsbergen and Novaya Zemlya islands.

The results of new seismic studies in the Central Barents zone of uplifts and Prinovozemelsky part of the Barents water area allowed a substantial clarification of the geological structure (morphology of different-scale structures, sedimentological features of the rock complexes, etc.) of the smaller scale highs, including local objects, within those large elements.

The Triassic clinoform complex is of a particular interest in the North Barents depression, as well as the Jurassic plays. New seismic data allow us to assess the potential of the Triassic formations for discovering commercial HC accumulations, associated with structural, structural-tectonic and lithologic traps. In the coming years, Rosneft plans a detailed study of this sedimentary complex on the basis of recent seismic data.

Blind mafic dykes of Ediacaran, Devonian and Carboniferous age revealed by high-resolution aeromagnetic data, Finnmark Caledonides, North Norway

Roberts, D., Nasuti, A. & Gernigon, L.

Geological Survey of Norway, PO Box 6315 Sluppen, 7491 Trondheim, Norway
(E-mail: david.roberts@ngu.no)

New high-resolution aeromagnetic data from the Caledonides of northern Finnmark provide spectacular evidence for the presence of extensive subsurface continuations of both metadolerite and unmetamorphosed dolerite dykes, mostly along faults transecting thrust sheets and the subjacent parautochthon from Magerøya in the west to Varanger Peninsula in the east. From isotopic dating studies in the region, in conjunction with dyke trends, three ages of mafic dykes have been recorded – Ediacaran (c.570 Ma), Late Devonian (c.370 Ma) and Early Carboniferous (c.337 Ma). In the case of the two younger dyke sets, actual dyke outcrop is very limited, tending to be restricted largely to coastal exposures.

In northwestern Varanger Peninsula, north of the Trollfjorden-Komagelva Fault Zone, high-amplitude magnetic responses in two thrust sheets beneath the Tanahorn Nappe are clearly shown to relate to swarms of NE-SW to ENE-WSW-trending, Ediacaran, metadolerite dykes. Individual dykes that have been mapped discontinuously on the surface can be followed inland over distances of 25 km as linear positive magnetic anomalies; and they also appear to extend offshore over indeterminate distances. In eastern Varanger Peninsula, 8-9, NE-SW to NNE-SSW-trending dolerite dykes of Late Devonian age occur in limited outcrops, mostly at or near sea level. The new aeromagnetic data show that up to 20 such unmetamorphosed dolerite dykes can be identified as blind intrusions in the region between Vardø and Syltefjorden, based on their linear positive magnetic anomaly fingerprints. South of the Trollfjorden-Komagelva Fault Zone, two Late Devonian dolerite dykes, well known to geologists from small but prominent coastal outcrops, are clearly identifiable as linear positive magnetic anomalies both on land and beneath the sea-floor of Varangerfjorden. The most spectacular manifestations of what we interpret to represent blind dolerite dykes are seen as linear positive magnetic anomalies coinciding with Early Carboniferous (Visean) dolerite dykes exposed on Magerøya and western Digermul Peninsula. These prominent linear anomalies can be traced along many of the mapped NW-SE- to WNW-ESE-trending faults that have disrupted the Caledonian nappes in this part of Finnmark; and some are continuous or semi-continuous over distances of more than 100 km from Magerøya to Varanger Peninsula. These particular dykes and faults are considered to relate to a major period of extension and rifting that occurred in the SW Barents Sea and onshore areas of Finnmark in Carboniferous time.

Contrasting spreading processes at Gakkel Ridge across the 3°E boundary shaped the Arctic Ocean lithosphere

Schlindwein, V. & Schmid, F.

Alfred-Wegener-Institut, Helmholtz Centre for Polar and Marine Research, Am Alten Hafen 26, D 27568 Bremerhaven, Germany (E-mail: vera.schlindwein@awi.de)

The Arctic mid-ocean ridge system is one of the two main representatives of the particular class of ultraslow spreading ridges with spreading rates of less than 20mm/y full rate. The formation of new ocean lithosphere at these ridges strongly deviates from any other ocean basin. Typical properties of ultraslow spreading ridges are alternating rift sections with magmatic and amagmatic spreading. At 3°E on Gakkel Ridge, a prominent boundary exists. Here magmatic spreading in the Western Volcanic Zone with basaltic seafloor and numerous axial volcanic ridges is sharply cut off from the amagmatically generated lithosphere of the Sparsely Magmatic Zone, characterized by a deeper rift valley and seafloor made up of mantle rocks.

We analysed the teleseismic earthquake record of ultraslow spreading ridges and collected local earthquake data at various ridge locations both at Gakkel Ridge and the Southwest Indian Ridge (SWIR). We found a marked contrast in seismicity across the 3°E boundary. Magmatic spreading in the west is connected with increased seismicity and frequent strong earthquakes often organized in earthquake sequences. Amagmatic spreading, in contrast, produces less and weaker earthquakes. By analogy with an amagmatic spreading segment at the SWIR where we analysed 10 months of local earthquake data, we can show that amagmatic spreading produces a thick lithosphere whose mechanical thickness may reach 30 km. Serpentinisation down to depths of 15 km below seafloor effectively reduces the strength of the lithosphere and results in a lack of seismicity. Magmatic sections show a brittle lithosphere throughout that is dramatically thinned beneath sites of volcanic activity.

We postulate that across the 3°E boundary at Gakkel Ridge a major change in lithospheric thickness and composition occurs. This boundary has potentially been very long-lived as it can be traced off-axis in the Eurasian Basin by marine magnetic anomalies. Differences in isotopic compositions of the mantle to either side of the boundary further support this theory. We further present our plans to test this hypothesis with a dedicated field experiment.

Tectonics and magmatism of the western Gakkel Ridge

Schmidt-Aursch, M.C. & Jokat, W.

Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung, Am alten Hafen 26, 27568 Bremerhaven, Germany (E-mail: Mechita.Schmidt-Aursch@awi.de)

Mid-ocean ridges are categorised primarily by their spreading rate. Each class is characterised by typical morphology, tectonics and volcanism. With decreasing spreading rate, not only the amount of produced melt decreases, but also the spatial and temporal continuity of magmatism. For very small effective rates of less than 12 mm/yr total spreading, melt supply is highly focused. Thus, the formation of basaltic crust occurs only at discrete volcanic centres; in between dominate amagmatic segments, where mantle material is emplaced directly at the sea floor. The approx. 1800 km long Gakkel Ridge in the central Arctic Ocean shows not only very low full spreading rates of 6-13.3 mm/yr, but also a remarkable absence of major transform faults and oblique spreading segments. The Gakkel Ridge is therefore an ideal example to study the typical characteristics of these so-called ultra-slow spreading ridges.

In this contribution, we present the results of geophysical and petrological studies on the western Gakkel Ridge. Wide-angle seismic measurements in the central valley and a three-dimensional gravity modelling of the central valley, the rift flanks and parts of the adjacent basins provide information about the structure of the oceanic crust and the upper mantle. Regional and local magnetic data provide insights into the long-term development of the dominant magmatic processes. In the so-called "Western Volcanic Zone (WVZ)" of the ridge, the formation of sea floor began about 33 Ma ago, the robust volcanism found there is more typical for faster spreading ridges. Crustal thickness of up to 6 km and a continuous positive magnetic anomaly over the central valley support models of stable melt supply. In the older part of the ridge east of 3.5° W, where spreading persists for 56 Ma, an alternation of magmatic and amagmatic segments typical for ultra-slow spreading ridges was found. The crust is mostly 1-4 km thin and the magnetic anomalies are generally weak, a positive anomaly over the central valley was found only at the volcanic centers. The border between the two different spreading regimes is very pronounced in the geophysical data sets, the analysis of rock samples indicates a similarly sharp boundary in the upper mantle.

Reconstructing extinct and current Arctic oceans from surface and mantle constraints

Shephard, G. & Gaina, C.

Centre for Earth Evolution and Dynamics (CEED), Department of Geosciences, University of Oslo, Blindern, Norway

Deep Earth and surface processes are intimately linked across broad spatio-temporal scales. The emergence of time-dependent, coupled plate tectonic-mantle convection, or "geodynamic", models that quantify this interaction have been facilitated by recent advances in computational resources, numerical solutions of mantle flow as well as geological and geophysical datasets of ever-increasing temporal and spatial resolution. The construction of plate tectonic reconstructions heavily relies on reconciling the seafloor spreading history of ocean basins. However, oceanic lithosphere is progressively recycled into the mantle and thus kinematic data is lost with time. The tectonic evolution of the circum-Arctic is no exception; since the breakup of Pangea, the region has seen the opening and closing of ocean basins including the extinct Oimyakon, Angayucham and South Anuyi oceans, and the present Amerasia and Eurasia basins. Notably, workflows require the integration of a wide range of complementary and independent datasets from both the surface record and underlying mantle, which we showcase here.

The timing, location, geometry and destruction of ancient ocean basins since at least the Late Jurassic have implications for mantle structure and long-wavelength surface topography, which can be used as an additional constraint for building plate boundary models. Based on a recently refined plate model for the circum-Arctic and northern Panthalassa, we model the fate of subducted oceanic slabs with forward mantle convection models. Through a comparison to seismic tomography and a discussion of mantle sinking rates, we build a complementary seismic catalogue of Arctic slabs. As a case study, we explore the origins for a distinct mid-mantle seismic tomography anomaly under present-day Greenland by integrating recent satellite gravity data and knowledge of the plate history. We suggest that a discrete high-Arctic subduction event related to the opening of the Amerasia Basin in the Jurassic, may account for this mantle feature and include potential geochemical links to regional Cretacous volcanism. Our methodology and results shows that a time-dependent consideration of surface kinematics and mantle dynamics can reveal new and powerful insights into the geodynamic evolution of the Arctic and its margins.

Spatial trends of seismic velocity within the sedimentary succession of the Canada Basin and southern Alpha-Mendeleev Ridge: Evidence for accelerated porosity reduction?

Shimeld, J.[1], Li, Q.[1], Chian, D.[2], Lebedeva-Ivanova, N.[3], Jackson, R.[1], Mosher, D.[1] & Hutchinson, D.[4]

[1]Geological Survey of Canada, Bedford Institute of Oceanography, 1 Challenger Dr., Dartmouth, Nova Scotia, Canada, B2Y 4A2 (E-mail: John.Shimeld@nrcan.gc.ca); [2]Chian Consulting Incorporated, Dartmouth, Nova Scotia, Canada, B2V 1C5; [3]Woods Hole Oceanographic Institution, MS 22, Woods Hole, MA 02543, U.S.A.; current address: Centre for Earth Evolution and Dynamics, University of Oslo, P.O. Box 1048, Blindern, 0316, Oslo, Norway; [4]United States Geological Survey, Woods Hole Science Center, 384 Woods Hole Rd., Woods Hole, MA 02543, U.S.A.

The Canada Basin and southern Alpha-Mendeleev Ridge underlie a significant proportion of the Arctic Ocean, but the geology of this remote, undrilled, and mostly ice-covered frontier is poorly known. Valuable new information is encoded in seismic wide-angle reflections and refractions on expendable sonobuoy records acquired between 2007 and 2011. Velocity-depth measurements of the sedimentary succession are extracted from published analyses of the records for 142 sonobuoy stations distributed irregularly across an area of 1.9E+06 km^2. The measurements are modelled at regional, subregional, and station-specific scales using an exponential function of inverse velocity with geologically meaningful parameters that are determined through conventional numerical regression techniques. With this approach, smooth, non-oscillatory velocity-depth estimates can be generated for any desired location in the study area, even where the measurement density is low. The results comprise a useful comparative reference for global studies of seismic velocity, burial history, sedimentary compaction, seismic inversion, and overpressure prediction, particularly in mudrock-dominated successions. Sedimentary thickness in the Canada Basin and southern Alpha Ridge is obtained from seismic reflection horizons interpreted in the time domain and converted to depth using the velocity-depth estimate for each seismic trace. Mapping of the observed-to-predicted velocities at regional, subregional, and station-specific scales reveals systematic trends associated with: the Mackenzie fan; the continental slopes beyond the Mackenzie fan; the abyssal plain; the southwestern Canada Basin; and, the Alpha-Mendeleev magnetic domain. These trends are largely attributable to changes in lithology with distance from the ancestral Mackenzie River, which is confirmed to be the predominant sedimentary source. However, lithological factors do not account fully for the elevated trends of seismic velocity found in the southwestern Canada Basin and the Alpha-Mendeleev magnetic domain. A plausible additional factor in these subregions is accelerated porosity reduction, perhaps due to volcanism-related hydrothermal alteration.

On the strike slip zone between Chukotka and Arctic Alaska and the possible mechanism of the disclosure of the Canadian Basin

Shipilov E.V.

Polar Geophysical Institute Kola SC RAS, Murmansk, Russia, (E-mail: shipilov@pgi.ru)

The Chukchi segment of the Eurasian Arctic passive continental margin that commenced forming in response to initiation and opening of the Canada oceanic basin in the Jurassic–Cretaceous is of importance for reconstructing the initial stage in the geodynamic evolution of the formation of the ocean in the Arctic region.

In this communication, we discuss different geological–geophysical data indicating the existence of one such submeridional transverse strike slip zone in the region under consideration. It extends from the Canada Basin along the eastern escarp of the Northwind Rise and across the shelf continental margin in the Chukchi Sea toward the Bering Strait. The role of this zone in the geodynamic evolution of the Canada oceanic basin and the adjacent continental margin of the Chukchi Sea is a subject of this research.

In the structure of the anomalous magnetic and gravitational fields, the zone under consideration is distinctly characterized by a combination of lineaments and linear anomalies. Some of them are recognizable farther southward despite the masking effect of the system of thrusts and the superposed structure of the South Chukotka Basin; they become again readily distinguishable in the Bering Strait.

The performed analysis of all the available geological–geophysical data reveals that the zone in question, which is called here the Chukotka–Canada zone, represented a high-amplitude strike-slip fault. Judging from its tectonic position, it played a decisive role in the opening of the Canada spreading basin. At the same time, contrary to the widely accepted concepts of the integrity of the Chukotka–North Alaska microplate, we assume that it served as a boundary with combined kinematics (in fact, continuation of the transform fault zone) between the New Siberian–Chukotka and North Alaska microplates. The segment of the Chukotka–Canada transform zone located north of the Northwind Ridge and the assumed northern continuation of the spreading center in the Canada Basin was presumably overlain by basaltoid rocks during the formation of the Alpha–Mendeleev magmatic province. The amplitude of the offset along this transform zone could reach 400-450km.

Thus, the analysis reveals that the defined Chukotka–Canada transform zone represents the main geodynamic element in the formation model of several geological structures of the Arctic region and allows a new interpretation of the mechanism responsible for the Canada Basin opening. The advanced motion of northern Alaska relative to the New Siberian microplate and its Chukotka block along the defined transform zone was responsible for the opening of the main, southern part of the Canada Basin with the formation of the spreading center and accompanying linear magnetic anomalies. It is clear that the opening of this basin was determined by convection in the upper mantle and subduction in the northern Paleo-Pacific.

This work has been prepared in the frame of the project "Arctic" (№ 44p) according to the Program of the Presidium of the RAS.

Crustal structure of the South Barents Sea Shelf

Shulgin, A.[1] & Mjelde, R.[2]

[1]GEOMAR, Kiel, Germany (ashulgin@geomar.de), [2]University of Bergen, Norway

The former disputed area of the Barents Sea is a hot area for geophysical investigations, since little is known so far about its deep crustal structure, while the area is of a particular interest for hydrocarbon prospecting. Once the territorial disputes have been finally settled recently, a regional ocean bottom seismometer (OBS) survey was conducted in this area in summer 2012. The seismic line is a northeast-southwest trending profile located in the easternmost area of the Norwegian waters. The transect is approximately 600 km long and includes marine and onshore parts. The major part of the profile was recorded on the 38 OBS with an average spacing of 13 km. In addition, 80 land stations (with 1 km spacing) were deployed during the field campaign: 50 of them on the southern continuation of the marine profile, and 30 were deployed semi-parallel to the marine profile along the eastern coast of the Varanger Peninsula.

We present the crustal model of the craton-shelf transition obtained from the seismic tomography and gravity modeling. The model shows the presence of six principally different crustal domains, which correlate with the near- surface observations. The interpretation of these changes along the profile links to the different tectonic settings along the profile. Presence of the large volumes of the underplated material is attributed to the rifting events on the shelf. The lateral variations in the seismic velocities in the onshore part of the transect is interpreted as a change from the typical cratonic crust to the continental type crust of the Varanger terrane. We also show the results of the ongoing work on the S-waves tomography modeling for the same profile. The combined interpretation of P and S data will provide additional details on the compositional differences between crustal domains and will give extra information on the origin of the underplating.

New data on structural and tectonic zoning and evolution history of the Northeast Arctic

Sobolev, N.N., Daragan-Suscheva, L.A. & Petrov, E.O.

All Russian Geological Institute. Saint-Petersburg (VSEGEI)

Compilation of the Atlas of geological maps of the Circumpolar Arctic resulted in the refinement of structural and tectonic zoning of the basement under the Russian part of the Northeast Arctic and outlining boundaries of continental blocks of Central Arctic uplifts, which adjoin the North Chukchi depression to the south and south-west. The Wrangel and Kotelnichesky continental blocks are considered as part of the larger Chukchi-Kotelnichesky Superterrane. It has been identified that the boundary between the Neoproterozoic Kotelnichesky Block and Mesozoic Verkhoyansk structures is located between the Belkovsky and Stolbovoy islands on the one side and the Kotelny Island on the other. Studying sedimentary cover sections of the Belkovsky and Stolbovoy islands suggests that that Mesozoides of the North-East are distributed towards the Laptev Sea Shelf.

It is assumed that the West Chukchi Block together with adjacent shelf and Central Arctic elevations located to the north, have most likely the Neoproterozoic basement. Southern and south-western boundary of the block corresponds to the South Anyui suture, south of which there is a heterogeneous area, the basic structural plan and pattern of which formed as a result of the Late Mesozoic accretion. The late orogenic events also affected the southeastern part of the old platform, which in the modern structural plan corresponds to the Novosibirsk-Chukchi Fold System, whereas the De Long islands and the area of the Central Arctic uplifts evolved most probably during the Phanerozoic under subplatform regime and experienced, apparently, only the Late Mesozoic tectonomagmatic activation.

The Late Jurassic – Middle Cretaceous associated with the closure of paleooceanic basins in the Northeast and active intraplate rifting in the circumpolar areas of the present-day Arctic is of paramount importance for the formation of modern structures in the Northeast Arctic. The change of the passive-margin stage of evolution of the South Anyui paleoocean to the active-margin stage took place during the late Jurassic and is fixed by widespread island-arc complexes in Northeast Asia within and near the South Anyui suture zone and in structures of the Kolyma Loop. Early Cretaceous collision-orogenic processes also affected the Chukchi-Novosibirsk continental block. Fold deformations of this age have been identified in the New Siberian Islands and Wrangel Island, and according to seismic data, they are recorded in the shelf of the Laptev Sea, East Siberian Sea, and in the southwest Chukchi Sea. Postorogenic stage of evolution of the area resulted in the development of intraplate mafic magmatism, which peak took place in the Aptian - Albian, commonly including the studied area: the shelf of the Laptev Sea, East Siberian and Chukchi seas, in the New Siberian Islands, and in the structures of the deep part of the Arctic basin.

Formation of the northern branch of the Atlantic Ocean and the spreading Eurasian basin took place during the Paleogene-Neogene. Active tectonic movements in adjacent margins of the Eurasian Basin continue throughout the late orogen – Quaternary. This is evidenced by manifestation of volcanic activities on the De Long Islands, southern Chukchi Peninsula, western Chukotka, in central “circumpolar” areas of Northeast Asia represented by alkali-basaltic and even foidite volcanics dated from 9-8 to 0.4 Ma and less than 0.26 Ma.

Cretaceous magmatism of Svalbard and Franz Josef Land: Petrogenesis of the High Arctic Large Igneous Province

Tegner, C.[1]; Stolbov, N.H.[2]; Svensen, H.[3]; Brown, E.L.[1] & Planke, S.[3,4]

[1]Earth System Petrology, Department of Geoscience, Aarhus University, Denmark (E-mail: christian.tegner@geo.au.dk); [2]All-Russian Research Institute for Geology and Mineral Resources of the World Ocean, St Petersburg, Russia; [3]Centre for Earth Evolution Dynamics, Department of Geosciences, University of Oslo, Norway; [4]Volcanic Basin Petroleum Research, Oslo, Norway

Magmatism of the High Arctic spans at least the past 440 million years and provides insight into a rich history of tectonism that includes subduction zones, continental rifts and the formation of new ocean basins. The most widespread and voluminous magmatic event appears to be the flood basalts and associated sills and dyke swarms exposed on Svalbard, Franz Josef Land (FJL), Bennett Island, and the Canadian Islands. Although age constraints remain sparse it has been suggested that these basalts define a High Arctic Large Igneous Province emplaced at c. 124-120 Ma due to the presence of a mantle plume. Onland dyke exposures and offshore geophysical observations indicate a pattern of radiating dyke swarms focused on Alpha Ridge north of Ellesmere Island, where the centre of plume upwelling has been inferred.

Here we report the initial results of a new study on the petrology and geochemistry of doleritic sills, dykes and flood basalts of FJL (n=25) and Svalbard (n=42) aimed at evaluating the correlation of magmatism in these two locations and to constrain their petrogenesis. The main rock type on both islands is evolved tholeiitic ferrobasalt ranging from 5-7 wt% MgO in FJL and 3-6 wt% MgO in Svalbard. The TiO_2 contents are generally higher (2.3-5.9 wt%) in Svalbard compared to FJL (1.4-4.5 wt%); this difference can only partially be explained by fractional crystallization. The Svalbard ferrobasalts generally have higher Zr/Nb (17-23) compared to FJL (10-20). Moreover, our FJL dataset include alkaline basalt (n=3), basaltic andesite (n=3) and rhyolite (n=1); none of these rock types are recognized in the Svalbard dataset. Both FJL and Svalbard rocks display slightly negative Nb-Ta anomalies; this feature is most pronounced in basaltic andesites of FJL. Chondrite normalized Dy/Yb vs La/Sm shows that most Svalbard samples plot in a tight cluster at 1.3-1.7 and 1.2-1.7, respectively, whereas FJL ferrobasalts show more positive correlation between 1.1-1.5 and 1.2-2.1, respectively.

Our preliminary conclusions are: (1) the mantle sources beneath Svalbard and FJL were somewhat different, possibly as a consequence of variations in the mixing proportions of mantle components; (2) the dominant mantle component appears to be enriched mantle akin to that of plumes associated with ocean island basalt and other LIPs; (3) subduction modified mantle may be another key component, but we await isotopic data to better distinguish between the effects of crustal contamination and source composition; (4) the melting conditions slightly differed; perhaps with a relatively stable, thick lithospheric lid in the case of Svalbard and a more dynamic and thinning lid during FJL magmatism.

Composition and geochronology of the Cretaceous volcanic formations, Central Chukotka

Vatrushkina E.V.[1], Sergeev S.A.[2] & Sokolov, S.D.[1]

[1]Geological Institute RAS, Pyzhevsky per. 7, 119017, Moscow, Russia, (E-mail: evat_095@mail.ru); [2]Federal State Unitary Enterprise «A. P. Karpinsky Russian Geological Research Institute», Sredny prospect 74, 199106, St. Petersburg, Russia

Within Central Chukotka there are several volcanic complexes formed in the Aptian-Albian time. Tibilov distinguishes Tytylveem, Kremyankin and Etchikun formations located to the north of the Okhotsk-Chukotka volcanic belt (OCVB) (Tibilov & Cherepanova 2001). Tikhomirov considers Tytylveem and Kremyankin as local post-orogenic volcanic formations (Tikhomirov et al. 2012). Akinin refers Tytylveem and Etchikun formations to the Aptian pre-belt volcanics of andesite-latite compositions (Akinin & Miller 2011). Thus, after Early Cretaceous collision of the Siberian continent and the Arctic Alaska - Chukotka microcontinent but before the onset of the OCVB activity, some post-orogenic volcanism took place in local zones.

Tytylveem suite described within the Tytylveem depression consists mostly of andesites. However, several andesite formation outside the depression are also related to Tytylveem suite. For volcanic rocks from the lower and middle parts of the sequences within the Tytylveem depression zircon U-Pb ages 121,4 ± 2,8 and 118 ± 2 Ma were obtained. (Tikhomirov et al. 2009). We examine andesite formation to the north of the depression. In these parts, volcanic rocks with an angular unconformity overlie Triassic turbidites. Thickness of andesites is estimated at approximately 185 m.

The Kremyankin Formation comprises mostly of andesites and basaltic andesites with a thickness of approximately 300 m. In the bottom were described thin lenses of felsic tuffs and lavas. Kremynkin volcanic rocks unconformably overlie Valanginian clastic sequences with surface outcrop area over 520 km^2.

The Upper Cretaceous volcanic formation near Pevek is distinguished only on the 200,000 scale geological map. Its covers an area of about 10 km2 with a thickness of approximately 60-70 m. The Pevek Formation is composed of thin felsic lavas in the lower part and massive andesite in the upper part of sequences.

All studied andesites have similar geochemical affinity. They are high-K calc-alkaline andesite with negative Ta-Nb anomaly, Pb spike and high LILE/HFSE and LREE/HREE ratios. The Pevek formation differs by the presence of latites with K_2O>5%.The U–Pb SHRIMP dating of zircons from andesite revealed the following ages 94.70±0.96 Ma (Tytylveem suite), 97.3±1.0 Ma (Kremyankin formation) and 105.7±0.8 Ma (Pevek formation). These data suggest the association of studied formations with the first stage of OCVB activity. However, during the first stage (106-98 Ma), the “lower andesites” (over 2 km) were accumulated in the Anadyr segment. At the same time a dominantly felsic sequence (up to 1.5 km) was formed in the western Central Chukotka segment, superposed on the extinct Tytylveyem volcanic belt. Within the northern Central Chukotka segment, shoshonites and latites of the Etchikun suite (ca. 0.5 km) were erupted (Tikhomirov et al. 2012).

All these facts indicate that:

1. Andesite formation located to the north of the Tytylveem depression can't be referred to Tytylveem suite
2. The Kremyankin Formation and andesite mentioned in p.1 are very similar to the OCVB "lower andesites". These data suggest more wide spread occurrence of "lower andesites" in the western Central Chukotka segment
3. Composition and age of the Pevek Formation allows to refer them to the Etchikun Suite
4. The Aptian pre- OCVB volcanism took place within the Tytylveem depression

The work was supported by RFBR Project № 14-05-00031, by the program of Presidium RAS and NSh-2981.2014.5

Geology and hydrocarbon potential of the East Siberian - Chukchi Sea region

Verzhbitskiy, V.E., Malyshev, N.A., Obmetko V.V., Borodulin, A.A. & Ikhsanov, B.I.

Rosneft Oil Company, Dubininskaya St. 31A, Moscow, Russia, 115054 (E-mail: v_verzhbitskiy@rosneft.ru)

The shelf sedimentary basins of the East Siberian and Chukchi seas occupy the vast area of the East Russia Arctic. The area is characterized by complicated and questionable geological structure and huge oil and gas potential. Here we discuss a recently acquired marine seismic and onshore geological data, which we believe is very helpful (together with the previous results) for understanding of tectonics and petroleum geology of the offshore sedimentary basins. The southern domain of the East Siberian and Chukchi seas region is likely underlain by Late Mesozoic folded basement, which was formed as a result of the Chukotkian orogeny related to the "South-Anyui" collision in the Late Jurassic-Neocomian time. The available seismic data clearly demonstrates north-vergent fold and thrust structural pattern of the tectonic basement of the area. The seismic image of the tectonic basement is similar to the onshore structural style of the New Siberian Islands – Chukotka-Wrangel fold belt.

It is notable that the sharp angular unconformity that separates strongly deformed sequences of basement from the slightly folded overlying strata is identified on 2D seismic lines both in the East Siberian and the South Chukchi sedimentary basins. The unconformity is likely corresponds to well-known pre-Aptian one of the New Siberian Islands and Chukotka. Thus for the southern part of the East Siberian and the Chukchi Seas we propose the Aptian-Tertiary age of the sedimentary cover. The latter in its turn is divided by series of widely discussed regional unconformities to different seismic (lithostratigraphic) units. It is likely that the main post-orogenic extensional phase took place during Late Cretaceous-Early Tertiary. During the rifted stage normal faults often inherited pre-existing Early Cretaceous reverse and thrust the fault planes. The post-collisional rifting and subsequent episodes of and strike and compression led to the formation of variety of structural and stratigraphic traps. In the vicinity of the De Long Islands and to the north from the Wrangel Island the Mid-Paleozoic (Franklinian?) or even Precambrian age of the tectonic basement is presumed. It means that one can expect to find a significantly wider stratigraphic range of the sedimentary cover here and thus much more complicated story of the tectonic development and evolution of the hydrocarbon systems.

Gas chimneys in the uppermost part of the cover of the East Siberian and the South Chukchi basins are often associated with deeply penetrated (reactivated) extensional faults, representing an evidence of migration of the hydrocarbon gases from the proposed source rocks in the lower (Upper Cretaceous-Paleocene?) interval of the sedimentary succession. The existence of working hydrocarbon systems is in fact proved by anomalous concentrations of the migrated hydrocarbon gases within the bottom sediments, gas shows in shallow wells and bitumen occurrence on the New Siberian Islands. Taking into consideration all the information above we state that the hydrocarbon potential of the East Siberian Sea remains very high, similar with that of the Chukchi Sea region.

Seismostratigraphy of the Eastern Makarov Basin and Adjacent Lomonosov Ridge and Mendeleev Ridge

Weigelt, E. & Jokat, W.

Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany
(E-mail: estella.weigelt@awi.de)

The contribution presents a high-resolution seismic reflection section collected along a transect at 81°N from the Mendeleev Ridge, across the Makarov Basin onto the Lomonosov Ridge. The slopes of both ridges bordering the Makarov Basin are compared concerning their surface of acoustic basement and configuration of seismic units to research tectonic and depositional processes.

The surface of the acoustic basement shows horst and graben structures from the slope of the Lomonosov Ridge almost up to the centre of the Makarov Basin which suggests that the Makarov Basin is underlain by streched continental crust far more than previously known. In contrast the basement surface towards the Mendeleev Ridge is much smoother which supports the hypothesis of the volcanic origin of the ridge complex. Unfolded Cenozoic sediments in the Makaorv Basin indicate that the Makorov Basin including the adjacent Lomonosov and Mendeleev Ridges must have moved as a single plate during the opening and developement of the Eurasian Basin.

Age control for the sedimentary units was acquired via links to seismic lines and drill site data of the Canada Basin, the Lomonosov Ridge, and the adjacent Laptev Shelf. A tie point for dating is a pronounced sequence of high-amplitude reflectors, which is the most striking feature in the Siberian part of the Arctic Ocean. The top of the reflector band is suggested to mark the end of Oligocene, and its base likely corresponds to the base of Eocene (56 Ma).

Seismic units below the high-amplitude reflector sequence show a similar configuration on the slopes of the Lomonosov and Mendeleev Ridges. The layers onlap on the slopes of the ridges and fill the basement topography in the center of the Makarov Basin. That indicates a sedimentary transport from the ridges and also the Laptev Shelf into the Makarov Basin formed before Eocene times.

Seismic units above high-amplitude reflector sequence, and consequently younger than 23 Ma, show distinct differences in reflector configuration between the Lomonosov and Mendeleev ridges. The basement surface of the Mendeleev Ridge rises in several steps from the Makarov Basin with an angle of slope between 0.2 and 1.4 °. Here, sedimentary layers onlap or merge on the western slope of the ridge and show numerous traces of slumping. The crest of the Mendeleev Ridge, however, is covered by sedimentary layers of almost constant thickness indicating a pelagic deposition realm at least since the Top of Oligocene. Further, this constant cover of Neogene sediments indicates that all tectonic/volcanic processes which created the ridge must have ended since that time.

In contrast the slopes of the Lomonosov Ridge towards the Makarov Basin are less steep (< 0.5°) and the sedimentary layers drape with almost constant thickness the flanks and crest of the ridge indicating a pelagic deposition realm at least since the Middle Eocene.

Gas hydrate regulation of ice stream flow

Winsborrow, M.[1], Andreassen, K.[1,2], Hubbard, A.[1], Plaza Faverola, A.[1] & Gudlaugsson, E.[1, 2]

[1]CAGE- Centre for Arctic Gas Hydrate, Environment and Climate, Department of Geology, UiT The Arctic University of Norway, Tromsø, Norway; [2]Department of Geology, UiT The Arctic University of Norway, Tromsø, Norway

Ice sheet volume and dynamics are strongly influenced by ice streams, yet a full understanding of the processes which regulate their flow remains elusive. Traction at the ice-bed interface is thought a primary control, in particular the role played by localised zones of high basal traction, sticky spots, that maintain force-balance in an otherwise low traction/high slip sub-glacial environment. Here we consider the influence of sub-glacial gas hydrate formation on ice stream dynamics and its potential to trigger the formation (and persistence) of sticky spots.

We present marine geophysical data from a palaeo-ice stream which flowed across the Norwegian continental shelf. Here, the classic geomorphic imprint of fast ice streaming is interrupted by a glacitectonic landform assemblage indicative of a zone of high basal traction which we interpret as a large sticky spot. Immediately upstream of this location, the palaeo-ice stream crosses a fault system associated with abundant hydrocarbon reservoirs. Abundant features revealing shallow gas and fluid expulsion beneath and at the seafloor are observed, but confined to the footprint of the inferred sticky spot. Any gas, migrating from the deeper reservoir would have stabilised as gas hydrate under the ice stream due to the high pressure, low temperature conditions. Ice stream flow is crucially dependent on a well-lubricated ice-bed interface. Gas hydrate, however dehydrates and stiffens the sediments in which it forms, leading to an increase in sediment strength. We propose that strengthening of subglacial sediments due to gas hydrate formation locally increased basal traction, creating the sticky spot and retarding ice stream flow. Hydrocarbon reservoirs are widespread across the Barents, Norwegian and North seas. Gas migrating from these reservoirs would have been stable as gas hydrate under ice sheet conditions and likely exerted a major regulatory effect on palaeo-ice dynamics of the Barents-Fennoscandian and British ice sheets. Given the large potential for gas reservoirs beneath the Antarctic and Greenland ice sheets, we expect gas hydrate formation to represent a significant and previously unrecognised control on ice stream dynamics.

U-Pb detrital zircon provenance investigations of late Paleozoic to Mesozoic sandstones from Taimyr Peninsula, Russia, and their tectonic implications

Zhang, X.[1], Pease, V.[1], Skogseid, J.[2] & Wohlgemuth-Ueberwasser, C.[1]

[1]Department of Geological Sciences, Stockholm University, Stockholm, Sweden; [2]Statoil ASA, Norway

To understand Late Paleozoic to Mesozoic sediment provenance of Taimyr, detrital zircon U-Pb LA-ICPMS analyses were performed on sandstones from southern Taimyr. The results are compared to existing regional datasets to constrain the tectonic evolution of Taimyr within a regional framework.

Upper Carboniferous to Permian sandstones contain detrital zircon age populations of 688 - 420 Ma and 370 - 260 Ma, which are most consistent with derivation from Timanian and Caledonian sources for the former and from the Uralian orogen for the later. Overall, this suggests an ultimate Baltica source and is consistent with a pro-foreland basin setting relative to the bivergent Uralian orogen for southern Taimyr in the late Paleozoic.

Triassic sedimentary rocks contain detrital zircon age populations of 1000 - 700 Ma, 650 - 410 Ma, 355 - 260 Ma, and suggest a similar provenance as the Carboniferous to Permian strata. However, the addition of a significant 260 – 220 Ma component indicates derivation of detritus from Siberian Trap-related magmatism. Such magmatism occurrs in/near Taimyr and, in conjunction with the Late Carboniferous to Permian Baltica-inferred sources, is most likely to be derived from them.

By *Jurassic* time, the samples are dominated by the 255 Ma age peak with a concomitant reduction of Late Neoproterozoic to Early Devonian and Carboniferous-Permian input, suggesting that the increase in Siberian Trap-related input coincided with a decrease in erosional detritus from Uralian sources.

Regionally, detritus from the Uralian orogen was deposited across Taimyr, Novaya Zemlya and the New Siberian islands in the Permian, but not in the Lisburne Hills or Wrangel Island. In the Triassic, Taimyr, Chukotka, Wrangel Island, the Kular Dome in the northern Verkhoyansk of Siberia, Lisburne Hills and Svalbard shared sources from Taimyr, the Siberian Traps and the Polar Urals, indicating that there were no geographic barriers between these locations prior to opening of the Amerasia Basin. Uralian detritus from Taimyr was shed into the retro-foreland basin to the north-northwest and was further transported 20 – 30 Ma after Uralian orogenesis. The widespread distribution of material eroded from Taimyr and the Polar Urals during the Triassic is likely due to the arrival of the Siberian Traps plume head at c. 250 Ma. In the Jurassic, detrital zircon spectra from Taimyr, Chukotka, the Kular Dome and Svalbard show great differences, suggesting that these locations were becoming isolated physiographically from Taimyr and the Urals. The restricted distribution of detritus from Taimyr and the Urals indicates that erosion from the Uralian orogen was much reduced in the Jurassic when the depositional setting of southern Taimyr probably changed from a foreland to an intracratonic basin setting.

How to assess glacial sedimentary conditions in the light of missing local data?

Zieba, K. J. & Felix, M.

NTNU – Norwegian University of Science and Technology, NO-7491 Trondheim, Norway, (E-mails: krzysztof.j.zieba@ntnu.no; maarten.felix@ntnu.no)

Pleistocene glaciations are assumed to have played a major role in the development of the Barents Sea basin. Glacial loading-unloading series as well as glacial erosion and deposition resulted in multiple uplift and subsidence events as a result of isostasy. A history of the Pleistocene basin development can be reconstructed by using modelling software. However, no quantitative input data are available for the number of glaciations, or for erosion and deposition rates. Estimates for such values are only available for either the whole Barents Sea, of for very large timescales. This misses out a lot of detail both for temporal and spatial variations.

We approach this problem by using a new methodology based on Monte Carlo simulations where the Pliocene-Holocene sedimentary cover thickness is calculated as a function of glacial erosion and deposition as well as interglacial deposition. A glacial-interglacial timeframe used in the simulations is based on new results which were determined by using published historic ice-sheet volume estimations. We applied the methodology in the outer Bjørnøyrenna area (western Barents Sea) and compared the results with available data.

The results suggest that the study area was occupied by the ice sheets during four marine isotope stages: MIS 2, MIS 6, MIS 12 and MIS 16 for approximately 30 ka in total. By using the time-frame based on glacial volumes, the results show typical glacial erosion rates (between 25 and 38 mm/a) for short-timescale measurements. Glacial deposition rates were calculated to vary between 0 and 37 mm/a, fitting the rates estimated for the Last Glacial Maximum in the western Barents Sea. Although these results are still averages for longer time periods, the method does give more detail than regional estimates.

GEOLOGICAL
SURVEY OF
NORWAY
- NGU -

Geological Survey of Norway
PO Box 6315, Sluppen
N-7491 Trondheim, Norway

Visitor address
Leiv Eirikssons vei 39
7040 Trondheim

Tel (+ 47) 73 90 40 00
E-mail ngu@ngu.no
Web www.ngu.no/en-gb/