ICAM8 Abstracts

Circum-Arctic onshore/offshore geological sampling

Overview of Canada's 2016 Arctic Dredging operations

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In 2016, the Geological Survey of Canada conducted a multidisciplinary scientific expedition across the Arctic Ocean to acquire new data to support Canada's Extended Continental Shelf Program using the CCGS Louis S. St. Laurent and the Swedish Icebreaker Oden. As part of the expedition, two significant dredge recoveries were made: one from the edge of Lomonosov Ridge near the North Pole (89.271, -65.613), and the other at the crest of Alpha Ridge from the flank of Fedotov Seamount (86.825, -139.724). Dredging operations were conducted from the Oden using equipment from the Geological Survey of Denmark and Greenland (GEUS) with onboard technical support from Aarhus University. In addition, as part of a collaborative agreement between Canada and the United States, the USCGS Healy collected dredge samples from Nautilus Spur (82.073, -142.450), on the southern edge of Alpha Ridge.

Preliminary site locations were planned based on identification of high gradient bathymetric slopes (> 20º) from existing data; however, final targets were revised using new multibeam bathymetric mapping during the expedition and identification of the maximum slope gradient (typically > 30º). Two significant logistical constraints determined the final site location: there had to be ice to "dock" the ship (not open water); and, the ice had to be drifting toward the target slope. As such, dredging operations at two additional sites were aborted. This presentation gives an overview of the dredge sites, technical operations, and a summary of the ~1000 kg of recovered rock samples.

Bedrock sampling of Siberian and Central Segments of Lomonosov Ridge. Implications for the geological and tectonic framework

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The new petrographic, mineralogical and geochronological data from Russian "Arctika-2007-1" expedition on the Lomonosov Ridge presented. The high-grade metamorphic and clastic rock fragments that recovered from two faulted scarps on the Siberian and Central Segments of LR were attributed to the Lomonosov Ridge bedrocks. The U-Pb dating of hemipelagic detrital zircons shows a clear similarity of their assemblages all-over the Arctic Basin and undoubtedly shows the prevalence of Siberian rather than Canadian sources. The lack of the Mesoproterozoic detrital zircons in hemipelagites, indicates that the clastic rocks containing those zircons are beyond the Arctic depositional system, and cannot be correlated with IRD. The almost identical MP-NP zircon signatures were identified from clastic rocks all over Arctic suggest the vast continental source area should have existed in the Central Arctic. The basement of Arctida craton is considered to be a most likely source area. The Siberian Segment of LR is considered to be a northernmost extension of the Timanides of Kotel'ny Island that slightly deformed during Late Mesozoic orogeny. The Central Segment of LR is thought to be a frontal part of Caledonian convergent shear and fold zone. Our data suggests that Timanian crystalline basement of Central Segment was affected by Caledonian high-grade metamorphic event in Early Devonian.

Caledonian metamorphism of siliciclastic sediments from the Lomonosov Ridge and Franz Josef Land

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Rock samples collected from two dredge positions at water depths of 2 to 3.5 km on the Lomonosov Ridge are dominated by arkosic sediments deformed and metamorphosed at greenschist facies conditions at 470 Ma according to 40Ar/39Ar dating of metamorphic mica. This shows that the Lomonosov Ridge was involved in a Mid-Ordovician orogenic event correlating with early arc-terrane accretion observed in northern Ellesmere Island, Svalbard, and other parts of the Caledonian orogeny.

Mica in fine-grained arkoses from the Nagurskaya drill-core on Franz Josef Land, also deformed and metamorphosed under greenschist facies condition, show 40Ar/39Ar ages of ca. 400 Ma, probably related to a late Caledonian orogenic event. These rocks are very similar to the ones from the Lomonosov Ridge; the younger age may be due to metamorphic overprinting of the 470 Ma event. Detrital zircon age spectra of the metasediments on both the Lomonosov Ridge and Franz Josef Land span the Meso- to Paleoproterozoic with a main peak around 1.6 Ga, similar to Caledonian metasedimentary rocks in East Greenland and Scandinavia as well as from Cambrian sediments in Estonia and Paleozoic sediments on Novaya Zemlya.

The rocks from the Lomonosov Ridge are covered by an up to 8 Ma ferromanganese crust that proves that the samples represent in situ outcrops. The data from the Franz Josef Land and the Lomonosov Ridge indicate that mid Ordovician to early Devonian Caledonian orogeny extended from Scotland and Scandinavia into the Arctic, including Svalbard, the Pearya Terrane, Crockerland and the Chukchi Borderlands.

Composition of volcanic rocks dredged from the Alpha Ridge, Arctic Ocean

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In August 2016, a collaborative Canada-Sweden Polar Expedition under Canada's ECS-UNCLOS Program dredged approximately 100 kg of volcanic rocks from the Alpha Ridge. The samples consist of volcanic breccia, carbonate rocks, and a single fragment of fossilized plant material. Here, we report the results of laboratory studies on the sample of volcanic breccia.

The lapilli tuff consists of vitric lapilli clasts, angular lithic clasts of fine-grained, sparsely porphyritic basaltic lava, relict crystals of feldspar and olivine pseudomorphs. Vesicles are flattened and lined with zeolites. The vitric fragments consist of sideromelane glass overprinted by abundant plagioclase microlites. Texturally, these lapilli display a fresh glassy core surrounded by Fe- and Ti-rich zones and a palagonite rim. Major and trace element analyses of glassy cores indicate remarkably uniform, mildly alkaline basaltic compositions. Together with the dominance of glassy vitric clasts in the tuff, this feature suggests a primary eruption-fed origin during a single volcanic event. In contrast, angular clasts of basaltic lava show distinctive geochemical signatures indicating a cognate origin.

Detailed work on the volcanic glass confirms that it is suitable for isotopic studies, 40Ar/39Ar geochronology and an analysis of glass volatiles. To our knowledge, the size and pristine state of the dredged sample are unique, allowing our team to carry out the first comprehensive study of a single eruptive event preserved in the volcanic record of the Alpha Ridge.

Focused magmatism at extreme slow spreading rates in the Arctic Ocean close to the Laptev Sea

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The ultraslow spreading ridges represent a poorly understood type of plate boundary consisting of magmatic and amagmatic segments that expose mostly mantle peridotite and only traces of basalt and gabbro. The slowest part of the global spreading system is the eastern Gakkel Ridge in the Central Arctic Ocean where crustal accretion is characterized by extreme focusing of melt to discrete magmatic centers. Close to the eastern tip of the ridge is the Gakkel Rift Deep (GRD) with an unusual up to 5200 m deep rift valley in contrast to a broad sediment-filled rift valley towards the east and west. Here we report an isotopic age for a pillow basalt dredged from a seamount on the rim the GRD. Geochemical and Sr-Nd-Pb data are consistent with an alkaline MORB-type pillow lava with unusual trace element enrichment attributed to particularly low degrees of partial melting, at greater than normal depth, of a source region that has experienced prior geochemical enrichment (veining?).

New data from the expedition on Severnaya Zemlya (2016), Novaya Zemlya (2014, 2015) and Franz Josef Land (2015) Archipelagoes

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Investigations of Severnaya Zemlya and the SE part of the October Revolution islands are comprised of Lower Paleozoic deposits intruded by mafic and felsic intrusions, of supposed Pz & Mz age. Our results showed widespread Cambrian deposits across the region and Ordovician tuffs and lavas with ages of 461 - 472 ± 3 Ma. The granites have similar ages (previously considered to be late Devonian-Middle Carboniferous and Mesozoic in age). The age of basite dykes are early Devonian (407, 416 Ma).

In northern Novaya Zemlya, the existence of the Caledonian deformation was confirmed. A regional unconformity between late Silurian - Early Devonian strata and underlying Neoproterozoic-Early Paleozoic sediments was recognized on the west coast near the Inostrantceva Gulf in the north to the Bezymyannaya bay in the south. Detrital zircon investigations of the Upper Silurian-Lower Devonian basal conglomerates and sandstones showed dominant Neopterozoic (593-652 Ma) age peaks. Structural studies indicate that Early Cimmerian deformation overprints older deformation. Mafic dikes around of Cape Zhelaniya, previously considered to be Mesozoic in age, formed on the Devonian and Carboniferous boundary (346.32 ± 15.34 Ma, Ar40/Ar39).

On Franz Josef Land (Galya and Gray-Bell islands), the composition of clasts from Jurassic conglomerate include metamorphic rocks and late Devonian-Early Carboniferous granites (328 ± 1.1Ma; 345.3 ± 0.81; 363 ± 1,1 Ma).

Composition of Jurassic conglomerates of Franz Josef Land: implication for stratigraphy, composition and age of pre-Mesozoic rocks of northern part of Barents Sea.

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Franz Josef Land archipelago (FJL) is a crustal fragment exposing a Mesozoic sedimentary succession in the north-eastern part of the Barents Sea. Lack of deep well penetrations on surrounding shelf makes FJL a key for understanding the geology of the adjacent sedimentary basin. Moreover, only a single well (Nagurskaya) penetrated the basement on Alexandra Land Island (FJL). Thus, composition, age, and structural features of pre-Mesozoic succession of north-eastern part of Barents Sea are mainly based on seismic data. Here, we present detailed petrography, geochemistry, U-Pb and low-temperature thermochronology data of pebbles collected from Jurassic rocks of Halla and Graham-Bell Islands (FJL).

Studied pebbles are very diverse in composition, including metamorphic, magmatic, and sedimentary rocks. Zircon U-Pb dating of the 3 granitic pebbles yielded concordant Late Devonian (Famennian) - Early Carboniferous age. Detrital zircon U-Pb dating of 3 metasandstone pebbles showed Latest Neoproterozoic - Early Cambrian maximum depositional ages. Therefore, the pre-Mesozoic succession of FJL includes Late Neoproterozoic-Earliest Cambrian metasandstones intruded by Late Devonian-Early Carboniferous granites and overlain by a Carboniferous-Permian sedimentary succession. The detrital zircon (U-Th)/He data from metasandstone pebbles indicates that the youngest exhumation event in provenance source area took place in the Late Triassic.

This research was supported by RFBR grant 16-55-20012 and RCN project NOR-R-AM (no. 261729)

Sediment provenance at the edge of Baltica during the late Neoproterozoic and Cambrian: Insights from a multi-method approach on the Digermulen Peninsula (Finnmark, Arctic Norway)

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The Digermulen Peninsula contains an almost complete sedimentary record across the Ediacaran–Cambrian transition as well as microfossils, macrofossils and trace fossils for studying the Ediacaran biota and the Cambrian radiation. The site was located at the edge of Baltica during the Ediacaran–Cambrian transition, where potentially the dramatic climatic turnover from icehouse to greenhouse conditions can be deduced and tied to large-scale plate tectonics. The succession consists mainly of quartz-rich sandstones and mudrocks. Deposition took place in various environments including fluvial, shallow marine and deeper marine settings. As shown by previous studies using palaeocurrent data, sediment supply was from the Baltic Shield toward the passive margin of Baltica in pre-Ediacaran time. At one point within the Ediacaran succession, it shifted by 180 degrees due to the newly formed Timanian orogen. This orogen formed in north-eastern Baltica during the late Neoproterozoic. It caused a change in source area due to the formation of the Timanian foreland basin to the east of Digermulen Peninsula. Extensive field and laboratory work by the Digermulen Early Life Research Group allows for the first time a detailed analysis of sediment supply and to test current palaeotectonic models based on a multi-method provenance approach on Neoproterozoic and Cambrian sedimentary rocks of the Digermulen Peninsula. We present and discuss the first results to decipher the sediment sources and to track changes of sediment supply through this critical time interval of Earth history.

POSTER SESSION

A sedimentary provenance study of modern river sands from northern Fennoscandia and its insight into the source of Mesozoic successions deposited on the southwest Barents Shelf.

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A series of sedimentary provenance techniques were applied to 20 modern sand samples collected from twelve major river catchments in northern Fennoscandia. This was carried out in order to evaluate the extent that Mesozoic successions deposited on the southwest Barents Shelf were sourced from northern Fennoscandia.

One of the most distinctive provenance signatures in northern Fennoscandia comes from samples collected along the Tana River, which traverses the Lapland Granulite Belt (LGB). Downstream of exposures of the LGB, modern sands are dominated by rutile with c. 1.9 Ga U-Pb ages and a chemistry which indicate crystallization at c. 850 °C from a pelitic protolith. A rutile signature similar to the Tana River detritus is replicated in the Late Triassic – Early Jurassic Realgrunnen Subgroup deposited in the vicinity of the Nordkapp Basin, and indicates a common origin from the LGB. A strikingly different pattern comes from the Realgrunnen Subgroup deposited in the Hammerfest Basin where rutiles are mostly c. 430-515 Ma and crystallised at c. 650 °C from a pelitic protolith. The similarity of this pattern to rutile data collected from the Målselva River modern sands indicate a source from Caledonian allochthons affected by Palaeozoic amphibolite-facies metamorphism.

Models depicting rejuvenation of a Fennoscandian sedimentary source region and Late Triassic drainage reorganisation are supported by these data. The rutile technique provides one of the clearest mechanisms for tracing the dispersal of Fennoscandian-derived sediment across the Barents Shelf.

Age and provenance of the Mesoproterozoic-Lower Neoproterozoic strata of the Chetlass Stone (Timan Range): Constraints from U-Pb detrital zircon study

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Mesoproterozoic-Lower Neoproterozoic strata of the Chetlass Stone (Timan Range) are subdivided based on their lithology into siliciclastic and carbonate units. Three units were analyzed using LA-ICP MS. The detrital zircon age spectra of the Mesoproterozoic Novobobrovsk Formation and the Neoproterozoic (?) Paun Formation are similar, suggesting a common provenance. About 40% of all grains of the Paun and Nobobrovsk Formation have an age of 1.9 to 1.6 Ga, up to 30% of grains fall in the age interval 1.6-1.4 Ga. Most of dated zircon grains are much older than proposed age of host units and their most likely provenance is basement of the Baltica paleocontinent.

In the sample from the Upper Mesoproterozoic Svetlinskaya Formation detrital zircons of Late Mesoproterozoic age predominate with the main populations at ca. 1.0-1.5 Ga (40% of all grains) pointing on the erosion of Sveconorwegian Orogen. Lorenz et al. (2012) suggested that the orogen extended along the present northern margin of Baltica, and the abundance of Late Mesoproterozoic grains in the sample from Svetlinskay Fm. is consistent with this model.

This research was supported by RFBR grant 17-05-00858 & RCN project NOR-R-AM (no. 261729).

This will be a poster presentation in the "Circum-Arctic onshore/offshore geological sampling" session.

Bedrock sampling data for the continent-ocean constraints in the Circumpolar Arctic

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Geological sampling of seabed outcrops collected during recent Arctic cruises are used to test geological models of the last decade. Combined with seismic and bathymetric data, the data is used to start developing a new tectonic concept instead of popular tectonic hypotheses created in data deficit.

A main achievement in the Central Arctic was the videography of a large number of bedrock outcrops in the seafloor scarps of the Alpha-Mendeleev Rises made by Russian research submarine in 2012, 2014, 2016. These data show most samples obtained by dredge, grab or other traditional methods from such scarps reflect the local geology, but not IRD as previously thought.

Seabed rock samples show: (1) discontinuous volcanic cover of Cretaceous basalts (HALIP) in the Amerasia Basin was formed in shallow marine or subaerial setting and then submerged to 3.5 km; (2) Paleozoic and Lower Mesozoic carbonate and terrigenous rocks underlay the volcanic cover are shallow marine shelf facies typical for platform cover; (3) Carboniferous-Cretaceous uplift of the central Amerasia Basin providing detritus to peripheral sedimentary basins; (4) isotopic data reveal the Laurentian marks of the Central Amerasia Basin cratonic block; (5) the Precambrian block is surrounded by Timanide, and Caledonide-Ellesmerian orogenic belts, tectonically reworked in the Early Cretaceous.

The next step is deep-sea drilling of Lomonosov Ridge and Mendeleev Rise basement, which may be performed by ECORD and the Russian geological survey.

A circum-Arctic zircon uranium-lead age database

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Understanding how and when the Amerasia Basin opened has significant implications for the geological histories and petroleum systems of sedimentary basins within the circum-Arctic region. Uranium-lead detrital zircon geochronology, employed alone or in conjunction with Lu–Hf isotopes, is a widely employed tool for reconstructing sedimentary provenance. It can provide insights into the opening of the Amerasia Basin by constraining the pre-rift configuration of Arctic tectonic terranes and sediment transportation pathways.

Despite being comparatively remote, a large volume of published U–Pb age data exists from the onshore margins and offshore continental shelves of the Arctic Ocean. Rigorous comparison of these data is, however, seldom straightforward and often requires recalculation of data against a common set of parameters and criteria; for example, using the same U–Pb age system and employing thresholds on analytical precision and U–Pb age discordance.

To address some of these problems, a standardised dataset of published zircon U–Pb ages and Lu–Hf isotope data from the circum-Arctic region is being developed as a geographical information system (GIS) database using ArcGIS®. Custom database tools have been developed within ArcGIS® using Microsoft Visual Studio®. These facilitate the searching of the database and visualisation of U–Pb age and Lu–Hf isotope data within the GIS environment. Furthermore, similarity measures, using multidimensional scaling, are being developed to enable data to be compared with statistical rigour.

Zircon provenance in Mesoproterozoic-Cambrian sandstones of the northeastern Russia: Implications for the evolution of the Timanian orogeny

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Timan Orogen is considered to be the main source of clastics in Late Neoproterozoic - Cambrian across the Russian part of the Arctic (Severnaya Zemlya, Novaya Zemlya and New Siberian Islands Archipelagoes) and in the northern part of the Russian Platform (Lorenz et al, 2008, 2013; Ershova et al, 2015, 2016 Ivleva et al, 2016). U-Pb dating of detrital zircons from the Late Mesoproterozoic-Cambrian (Riphean-Cambrian) deposits of northwestern Russian platform (Baltic and Ladoga Monocline) and Mezen syncline allow us to restore prevailing provenance areas. The Paleo- and Early Mesoproterozoic ages of detrital zircons predominant in studied samples indicate that basement of the East European platform could be considered as one of the main provenance area during deposition of Meso-Early Neoproterozoic strata. Latest Neoproterozoic marked by significant shift in provenance area with prevailing zircons with ages close to age of sedimentation and Late-Middle Mesoproterozoic grains. This indicates that Timanian orogen became the main source of clastics across northern part of East European platform by the end of Neoproterozoic and possibly sourced the nowadays separated Arctic terranes.

This research was supported by RFBR grants 18-35-00407.

Dredged samples provide new insights on the geological evolution of the Alpha Ridge, Arctic Ocean

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In August 2016, a collaborative Canada-Sweden Polar Expedition under Canada's Extended Continental Shelf (ECS-UNCLOS) Program dredged approximately 100 kg of volcanic rocks from two localities on the Alpha Ridge. Samples dredged from the Fedotov Seamount (on the crest of the Alpha Ridge) include volcanic breccia, fossiliferous carbonate rocks and a single fragment of fossilized plant material. The samples recovered from Nautilus Spur consist mainly of volcaniclastic rocks.

Here, we present new laboratory results on the dredged samples in light of current knowledge of the Fedotov Seamount and surrounding area acquired from bathymetric and seismic surveys. On a local scale, multibeam bathymetric data enable the identification of volcanic features such as constructional edifices, summit calderas, terraces and individual lava flows. A rigorous classification of these morphological features may provide additional constraints on the eruptive style of lapilli tuffs recovered from the edge of Fedotov Seamount. On a regional scale, seismic reflection data constrain the lithological character and lateral continuity of igneous layers, providing new insights on the volcanic style and scale of magmatism in this part of the Alpha Ridge.

Analytical Results of Canada's 2016 Dredge Sampling of Lomonosov Ridge

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In 2016, the Geological Survey of Canada recovered over 700 kg of rock samples from a steep slope on the flank of Lomonosov Ridge near the North Pole in the Arctic Ocean. Dredging operations were conducted aboard the Swedish Icebreaker Oden. The recovered samples were predominantly sedimentary facies with mixed litholgies of sandstones, siltstones and mudstones. The samples have fresh angular surfaces and are remarkably well preserved. The siltstones typically have well defined thin laminations. The fine-grained sandstones commonly have significant cross-bedding structures indicating a high-energy fluvial depositional environment. Many of the samples exhibit minor compactional deformation, and in some cases, brecciation. Metamorphic biotite and brittle high-angle cleavage are observed in most samples. There is no evidence of micro-fossils.

We present an overview of the different sedimentary facies and analytical results conducted on a sub-set of the collected samples, including photography of polished slabs, thin section petrographic descriptions, XRD bulk mineralogy, SEM imaging, grain size analysis, bulk density, magnetic susceptibility, zircon dating, and apatite fission track thermochronology. A new multibeam bathymetric map and seismic reflection data provide an overview of the geological setting for this portion of Lomonosov Ridge. Additionally, we compare laboratory P-wave and S-wave velocity measurements with velocities modeled from sonobuoy data.