ICAM8 Abstracts

Volcanic provinces, tectonics & terrane correlation

Tectonics, volcanism and geodynamic events of the Central and Eastern Arctic

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Geology and tectonics of the Eurasian margin of the Arctic Ocean are of high scientific interest because this territory is one of the least studied areas on Earth and has great potential for oil and gas and mineral resources. Research on arctic objects is difficult first due to their limited accessibility, since the key targets for research are located on the islands of the arctic continental shelf or are located below sea level. Magmatism associated with plume activity, rifting, subduction, or collision is an essential agent in geodynamics and tectonic history of any area on the Earth, including the Arctic region. Basalts are especially widespread igneous rocks in oceans: basaltic crust underlies marine sediments, and fields or provinces of basalts occur in old and young orogens, young plates and Precambrian terranes. In our report, we will use the latest geological and geophysical data of the Eurasia arctic continental margin to study the links between magmatism and tectonics of the High Arctic. There will be a different age magmatism, which is well correlated with tectonic events. Some of them led to the disintegration and reorganization of Precambrian terranes, which currently represent Ridges, Rises and Uplifts in the Arctic Ocean, others are closely related to the Mesozoic–Cenozoic history of plume magmatism. Solving these issues will be a significant contribution to understanding the tectonic evolution of the key structures of the entire Arctic Ocean.

Late Paleozoic Granitoid Magmatism of Northern Taimyr

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The Taimyr–Severnaya Zemlya Fold and Thrust Belt is situated north of Siberian Platform and comprises the Taimyr Peninsula and Severnaya Zemlya Archipelago. It is subdivided into the Southern, Central, and Northern tectonic zones.

The studied granitoid intrusions are located within the Northern Taimyr Zone on the northern and northwestern coast of the Taimyr Peninsula. Various authors refer this region the southern part of the Kara Terrane. The studied intrusions are represented by muscovite–biotite granites, biotite granites and biotite–muscovite leucogranites. U-Pb zircon age of intrusions varies from 315 to 345 Ma. They are markedly older than previously published ages of granite intrusions and evidence that the onset of granitoid magmatism in the Northern Taimyr was related to Visean events. According to the geochemical data, the granitoids are magnesian, peraluminous, alkali–calcic and calc–alkalic rocks. The initial 87Sr/86Sr ratio of granitoids range from 0.70416 to 0.70527.

The petrographic, chemical and isotope composition of these intrusions is typical of I-type granites. An Andean-type continental margin is the most probable setting for them. The data indicate that the active margin at the southern edge of the Kara Terrane started to evolve in the Early Carboniferous.

The research was supported by the Russian Science Foundation (project no. 17-17-01171).

Vendian and Permian-Triassic plagiogranitic complexes of Ust'-Bel'sky and Algansky terranes, West-Koryak fold system, NE Russia: U-Pb zircon data, geochemistry and geodynamic setting

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The region of Ust-Belaya Mountains has fold-and-thrust structure where allochthon complexes comprise Ust'-Bel'sky (UB) terrane and paraautochtone complexes, Algansky (AL) terrane. The nappe system is unconformably overlain by Albian and Cenomanian-Turonian deposits.

Vendian and Permian-Triassic plagiogranitic complexes are present as blocks, veins in ultrabasic blocks and dikes in basaltic blocks in serpentinite melanges of UB and AL terranes. Lense-like bodies or veins of plagiogranites, leucodiorites cut UB ultrabasic-gabbroic massif of UB terrane.

Concordant zircon ages, calculated for 8 samples of Vendian plagiogranites (U-Pb SIMS) range from 548±3 to 559±4 Ma. Concordant age for one sample (LA-ICP-MS) is 538±7 Ma. For one sample of Triassic plagiogranite we obtained concordant zircon age 235±2 Ma (U-Pb SIMS).

Vendian and Permian-Triassic plagiogranites are mainly low-K and low-Al ones. Sr-Nd isotopic composition and style of REE patterns allow classifying them as formed during partial melting of primarily mantle substrate or fractional crystallization of basic magma.

Vendian plagiogranites may have formed in ensimatic island arc setting simultaneously with deposition of sedimentary-volcanic complex of one of tectonic slice of UB terrane. Permian-Triassic plagiogranites formation occurred within Koni-Taigonos arc on the margin of Asian continent as a result of partial melting of ophiolite material, presenting as a fragments of accretionary structure of this arc or due to fractional crystallization of basic magma, melted from such substrate.

EVOLUTION OF MAGMATISM WITHIN OMOLON-TAIGONOS BLOCK

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Evolution of magmatism within the ancient Omolon cratonal terrane records a long Proterozoic to Pliocene evolution. Knowledge of accurate ages and tectonic settings of magmatism in this"stable block" might help us synchronize and better constrain the evolution of Arctic margins due to its close proximity to the South-Anyui suture. A new generation of geological mapping (quad P-57) as well as new isotopic geochronological and geochemical data reveal the following major magmatic events in the Omolon-Taigonos block: 1) 1.9 Ga augen granite-gneisses with within-plate geochemical signatures suggest a possible plume-related event; 2) Neoproterozoic tholeiitic gabbro and diabase formed during rifting and destruction of Omolon; 3) Silurian (433-425 Ma) syenite and granitic intrusions with low initial Sr ratios reflecting slab-window asthenospheric upwelling; 4) voluminous Late Devonian (375-356 Ma) calc -alkaline subduction-related volcanic and plutonic complexes including the Kedon series; 5) the first documented extension-related monzonites and basaltic picrites of Permian age in the Taigonos block; 6) Berriasian-Valanginian transform continental margin magmatism; 7) 106-80 Ma subduction (early) to extension (late) related extrusive rocks of the Okhotsk-Chukotka volcanic belt; 8) 56-48 Ma extension-related basaltic magmatism (the Kytyimskaya unit) reflecting the onshore manifestation of the final stage of Okhotsk sea formation.

Provenances of the Middle Paleozoic –Mesozoic clastics in the southern part of the Prikolyma terrane (Verkhoyansk-Kolyma Orogen) based on U-Pb dating of detrital zircons

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Detrital zircons from the Upper-Middle Devonian sandstones group at the prominent peak at 390–406 Ma (Emsian-Eifelian). The source area for these youngest population possible is Uvyazka trachyte. Precambrian zircons group at two populations 1640–2080 and 2460–2800 Ma with possible source within metamorphic rocks of the Omolon terrane basement.

92% of zircon grains from the Carboniferous sandstones form peak at 346–348 Ma with subordinate populations of Proterozoic and Neoarchean in age. The potential sources for 346–348 Ma age zircons is Middle-Late Paleozoic volcanics of the Kedon Complex.

Two samples taken from rocks earlier considered as Late Carboniferous-Early Permian in age have more than 75% of detrital zircons are Late Jurassic (150–156 Ma) and Late Cretaceous (87–90 Ma) in age, with subordinate grains Silurian-Early Carboniferous (310–445 Ma) in age. Paleoproterozoic zircons (~1800–2200 Ma) are rare. This indicates that the studied rocks accumulated at the final stages of formation of the Okhotsk-Chukotka volcanic-plutonic belt. The likely source areas for the Late Jurassic zircons are volcanics of the Uyandina-Yasachnaya arc and granitoids of the Main batholith belt.

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New U-Pb ages and Hf zircon data from Brooks Range ophiolite (BRO) and Koyukuk arc, the upper plate of the Brookian Orogen, northern Alaska

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Siniktanneyak Mountain (SM) is an erosional BRO klippe in the central BR, the structurally highest sheet in the N-directed BR thrust belt. SM layering dips steeply to the NNW and suggests an apparent thickness of up to 12 km. From SE to NW, SM consists 2 km of ultramafic (UM) rocks, 6 km of cumulate gabbro (CG), and 4 km of isotropic gabbro (IG), diabase dikes (DD) and basaltic lavas (BL). Intermediate to felsic intrusions (FI) cross-cut the IG and DD, but also cut the basal UM. BL and DD have island arc tholeiite chemistry with low La/Yb (~2) and moderate Nb-Ta depletion. FI also have arc-type chemistry but distinctly higher La/Yb (~5), and are not co-genetic with the DD-BL. Scattered high-Mg boninite dikes also cut IG and CG, and are characteristic of early magmatism in modern island arcs. Three new SHRIMP-RG U-Pb zircon ages of FI at SM, as well as 2 from Misheguk and Asik Mountains, range from 161.1 to 163.7 Ma, all within error of each other. Zircon εHf(t) are juvenile and range from +16 (L. Jurassic depleted mantle) to +7; the most felsic dikes have the lowest εHf(t). By comparison L. Jurassic tonalite (SHRIMP-RG: 146.9 +/- 1.2 Ma) from the Koyukuk arc terrane S of the BR yielded similarly juvenile εHf(t) (+11 - +13) and a similar TE signature to the dated BRO samples. The arc tholeiite lavas and sheeted dikes, along with boninite dikes, suggest BRO was generated in an extensional setting during arc initiation (forearc of the Koyukuk arc system?). The dated BRO intrusive phases are younger than the main mass of the BRO, but how much younger is uncertain.

Evidence for differentiation of High Arctic Large Igneous Province basalt at depth

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Mesozoic HALIP sills on Ellesmere Is. are evolved (MgO<6%) tholeiitic to weakly alkaline basalt to andesite. An undifferentiated 17m sill at Hare Fiord has ~10% coarser grains. Olivine (Fo85.6) phenocrysts are in approximate equilibrium. Plagioclase phenocrysts (Type 1) have euhedral weakly-zoned cores (An 72-66) and strongly normally/oscillatory-zoned rims; also forming glomerocrysts with olivine and augite. Antecrysts record replenishment and mixing processes in the magma chambers where low-MgO HALIP magmas formed. Both primitive (An74-83) and evolved (An63-43) antecrysts have rounded edges indicating dissolution prior to mantling by Type 1 feldspar. Reverse growth zoning in antecrystic glomerocrysts implies admixture of primitive magmas upstream. Sieved plagioclase cores imply compositional breakdown/reequilibration through immersion in a primitive melt. Some antecrysts have proto-cumulate textures, with aligned, sutured grains, suggesting longer residence times in holding chambers. Globular pyrite clots formed as replacements of plagioclase, mimicking groundmass laths and coarser phenocrysts. Isotope data imply S is from metasediments but there are no veins or connecting structures. The globules may sample hydrothermal replacements of gabbro at depth, subsequently entrained.

Impact of basaltic sills on sedimentary host rocks in the High Arctic Large Igneous Province

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In the Canadian Arctic Islands, a complex network of dykes and sills are exposed that belong to the High Arctic Large Igneous Province (HALIP). The HALIP is a Mesozoic continental basalt suite, which intruded volatile-rich sedimentary rocks of the Sverdrup Basin (shale, limestone, sandstone, and evaporite) some 130 to 120 million years ago. In this study, we document how the thin (mostly <20m) sills of the HALIP have affected shaly host rocks (some organic-rich) on Axel Heiberg and Ellesmere Islands in the Canadian Arctic Archipelago. These magmatic intrusions can advect considerable amounts of heat into the crust, potentially generating large amounts of greenhouse gases from carbon and sulphur-rich host rocks. We focus on a specific narrow sill (17m) that experienced limited extents of internal differentiation after emplacement, as shown by the near-absence of internal bulk chemical evolution. A detailed traverse of this sill revealed variable magmatic d34S and d18O values, which is evidence for incorporation of crustal material. To gain insights into the actual processes involved in crustal digestion by sills, we carried out magma-shale interaction experiments at magmatic temperature of 1250°C for 600 s. The experiments document break-down of shale into magma and vigorous crustal degassing. Our initial results thus provide fresh insights into the actual processes and time-scales of magma-sediment interaction, which has been hypothesised to be a key factor in modulating the environmental impact of LIPs.

A tale of two volcanic provinces: geochemistry of bentonites in the Late Cretaceous Kanguk Formation, Sverdrup Basin

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The mudstone-dominated Late Cretaceous Kanguk Formation of the Sverdrup Basin, Canadian Arctic, contains numerous diagenetically altered volcanic ash layers (bentonites) that provide a record of Late Cretaceous volcanism within the High Arctic. Using whole-rock geochemical analyses, two distinct types of bentonite are identified from an outcrop section in the Sawtooth Range, Ellesmere Island. Decimetre-thick peralkaline rhyolitic to trachytic bentonites were erupted in an intra-plate tectonic setting. These occur throughout the late Turonian to early Campanian (c. 92–82 Ma) outcrop section and were likely associated with the alkaline phase of the High Arctic Large Igneous Province (HALIP). Two thinner, centimetre-thick, sub-alkaline dacitic to rhyolitic bentonites of late Turonian to early Coniacian age (c. 90–88 Ma) were also identified. The geochemistry of these bentonites is consistent with derivation from volcanoes within an active continental margin tectonic setting. The lack of nearby potential sources of sub-alkaline magmatism, together with the thinner bed thickness of the sub-alkaline bentonites and small size of euhedral zircons, are consistent with a more distal source area. The age and geochemistry of these two sub-alkaline bentonites correlate with an interval of intense volcanism in the Okhotsk-Chukotka Volcanic Belt (OCVB), Russia. Consequently, during the late Turonian to early Coniacian intense volcanism within the OCVB may have resulted in widespread volcanic ash dispersal across Arctic Alaska and Canada, reaching as far as the Sverdrup Basin.

POSTERS

Rifting and Volcanism around the Jan Mayen Fracture Zone, NE Greenland

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In 2017, we sailed with the German Research vessel Maria S. Merian offshore NE Greenland to study the architecture of the rifted continental margin around the Jan Mayen fracture zone. Newly acquired multichannel seismic data provide a structural image of the sediments and crustal architecture. Acquisition was done using BGR's reflection seismic instrumentation with a 4500-m-long digital streamer and a G-airgun array with a total volume of 3100 in^3.

Key questions are the distribution of volcanism as manifest in seaward dipping reflectors and the continent-ocean transition. From the pinch-out of seafloor spreading anomalies, a margin-parallel COT off East Greenland would indicate an N-S opening in the Norwegian/Greenland Sea, i.e. towards the postulated thermal anomaly. A second question is the timing, duration and distribution of magmatism that resulted in the formation of the North Atlantic large igneous province. Here, we study the dependence of magmatism with distance from the proposed thermal anomaly and the influence of major fracture zones on volcanism. The "volcanic province" offshore NE Greenland turns out to host several shelf basins, either rift basins or pull –apart grabens. The Jan Mayen Fracture Zone, which is clearly delineated in the oceanic domain, shows a structural continuation onto the continental shelf. This is, however, not a single straight line but consists of several shorter segments, which are offset in an N-S direction across the shelf.

Sulphur mobilisation from sedimentary host rocks in the High Arctic Large Igneous Province

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In the Canadian Arctic Islands, a complex network of dykes and sills are exposed that belong to the High Arctic Large Igneous Province (HALIP). The HALIP is a Mesozoic continental basalt suite, which intruded volatile-rich sedimentary rocks of the Sverdrup Basin (shale, limestone, sandstone, and evaporite) some 130 to 120 million years ago. These magmatic intrusions can advect considerable amounts of heat into the crust, potentially generating large amounts of greenhouse gases from carbon and sulphur-rich host rocks. Here we focus on a specific narrow sill (17m) on Ellesmere Island that was emplaced into Murray Harbour Formation balck shale. We performed in-situ Secondary Ionisation Mass Spectrometry (SIMS) □34S analysis of pyrite in rock slices from the sill margins and at ca. 60 cm distance from the margin. All samples analysed reveal strongly negative (sub-mantle) □34S values, commensurate with the strongly neagative □34S values of the surrounding shale and in contrast to the relatively mantle-like □34S values of the sill interior. Notably, the larger, cubic grains of pyrite analysed are homogeneous with respect to major elements and □34S values. Our data thus lead us to suggest that the sill margins record rapid flushing of sulphur from the surrounding sedimentary rocks, although the exact mode of sulphur transfer has yet to be determined. Despite this caveat, it seems plausible that sill emplacement during HALIP activity could have triggered widespread sulphur mobilisation.

Zircon grains from serpentinite of the Voykar Massif, Polar Urals: Trace elements, U-Pb and Lu-Hf isotopic data

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The Voykar Massif consists of an ultramafic complex in the NW, followed by a mafic complex and an evolved island arc to the SE. Previous radiometric dating has yielded a late Neoproterozoic age (585±6 Ma) for the ultramafic complex, a range of late Cambrian to Silurian ages (428±7 to 490±7 Ma) for the mafic complex, and Early Devonian ages (c. 390–400 Ma) for the evolved island arc. The mafic complex is dominated by gabbro, dolerite, and basalt with minor andesite and plagiogranite formed in a supra-subduction zone environment. By the river Lagortayu, the mafic complex also contains serpentinite fragments with zircon grains that are visible in thin section. LA-ICP-MS U-Pb dating of the zircon grains yield an upper intercept age of 548±5 Ma with an age range of 527–549 Ma. Additionally, few older grains up to 3277 Ma were found. Trace element patterns of the zircon grains show fractionation from high HREE to low LREE with pronounced positive Ce and negative Eu anomalies. Grains with younger ages (<548 Ma) are enriched in LREE without Ce anomaly. Hafnium isotopic data of the main age group show 176Hf/177Hf(t) from 0.28242 to 028249 and εHf(t) ranging from 1.9 to 1.0. Two grains show lower εHf(t) of 5.6 and 6.5. The previously obtained age for the ultramafic complex and our new age on mantle-derived serpentinite indicate zircon formation in the mantle during the Timanian Orogeny. Although a primitive island arc signature was found for the mafic complex, the evolved Hf isotope data point to an involvement of a crustal component in the underlying mantle.

Upper Cretaceous rhyolite ash beds from the New Siberian Islands

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Upper Cretaceous rift-related rocks are only found in the New Siberian Islands of the Anjou archipelago. Synchronous sedimentary rocks on Novaya Sibir Island are represented by a coal-bearing, mixed volcanogenic-terrigenous siliciclastics. The Turonian-Cogniacian Derevyannogorskaya Formation (with a thickness of 95 m) is mainly composed of unlithified rhyolitic tuffaceous rocks intercalated with brown coaly layers (up to 8 m) and multiple volcanic (rhyolitic) ash beds (up to 2.5 m).

The permanent presence of the fine-sized crystalloclastic and vitroclastic ash material indicates an intense explosive volcanic activity in this region during the Turonian-Cognacian time interval. Apparently, the Late Cretaceous volcanic centers were located close to Novaya Sibir Island and were inherited from the Early Albian volcanic activity in the region. Upper Cretaceous ash material from the Island Novaya Sibir is petrochemically similar to the Lower Albian volcanic rocks from other sites of the Anjou archipelago. This fact allow us to suggest the same chamber for the Early Albian and Late Cretaceous (Turonian-Cognacian) eruptions of acidic (rhyolitic) magma.

Late Ordovician granitoid magmatism of the Kara Terrane (Russian high Arctic)

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The Severnaya Zemlya Archipelago and the northern part the Taimyr Peninsula together constitute the southern part of the Kara Terrane. Two granitoid intrusions located within the southeast and east of October Revolution Island (Severnaya Zemlya Archipelago) were studied. Intrusions consist of granite-porphyries and biotite granites. According to their chemical composition, studied granites are magnesian, peraluminous, alkali-calcic and calcic. The granitoids have initial 87Sr/86Sr ratio of 0.70748. U-Pb dating of zircons show the Late Ordovician age of both intrusions crystallized at ca. 457 Ma.

The petrographic and chemical compositions of the Ordovician intrusions of the Severnaya Zemlya Archipelago indicate their formation in an island-arc environment. Granitoid intrusions similar in age and tectonic setting are widely distributed in the Caledonian Orogen of Greenland, Scotland and Norway. Probably, formation of the Ordovician granitoids of October Revolution Island was associated with subduction events along the active margins of the Iapetus Ocean as well.

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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.

New data on the tectonics and the age of granitoid and mafic magmatism of the northeastern part of October Revolution Island (Severnaya Zemlya Archipelago)

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In the northeastern part of October Revolution Island there is an exposed volcanogenic-sedimentary complex about 1000 m thick, including variegated tuff-siltstones, tuff-mudstones, tuff-sandstones, and rhyolite lavas aged at 483±3 Ma (Middle Ordovician, zircons, SHRIMP-II). They have associated subvolcanic granite porphyries dated at 461–472 Ma (12 samples, Middle Ordovician, zircons, SHRIMP-II) as well as basalts and basaltic lava breccias and dolerite sills with the ages of 467±16 and 435±15Ma (baddeleytte, SHRIMP-II). The rocks have sublatitudinal strike and are deformed by early WE-trending sinistral strike slips and thrusts and by late mainly submeridional strike-slip faults. This volcaniclastic complex is overlain by flat-lying thin Carboniferous-Permian continental terrigenous rocks.

To the east, these volcaniclastic rocks are separated by a submeridional dextral strike-slip fault from Cambrian (?) sedimentary rocks represented by deltaic sandstones, siltstones, mudstones, conglomerates and limestones rarely intruded by dolerite dikes of unknown age. The rocks underwent at least two periods of deformation. There are observed early east-verging tight to isoclinal folds of the first generation deformed by dextral strike-slip faults. Rare folds with subvertical axes are associated with the second strike-slip stage. Cleavage and bedding intersection lineation is steeply inclined to NE.

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