Study of the Arctic Seabed Rocks

O. V. Petrov, S. P. Shokalsky, T. Yu. Tolmacheva, O. L. Kossovaya, and S. A. Sergeev

Abstract The chapter presents results of studying the seabed rocks from scarps of steep mountainsides of the Mendeleev Rise collected during the Arctic-2012 expedition. The seabed collection consists of five thousand samples dominated by sedimentary rocks of shallow shelf facies. Carbonates are dominated by massive dolomites and limestones, which contain Devonian to Permian fauna. Terrigenous rocks are mainly represented by quartz sandstone and siltstone. Judging by the composition and age, the sedimentary rocks of the Mendeleev Rise belonged to the platform cover of the Early Precambrian cratonic block, which forms the crystalline basement of the uplifts in the Central Arctic. Basalt and gabbro-dolerite occupy no more than 10–20% of the raised seabed rocks. The basalt of the Mendeleev Rise belongs to the intraplate moderately alkaline Permian-Triassic basalt of the trap formation of Siberia and the Jurassic-Cretaceous basalt of the High Arctic Province (HALIP).

1 Study of the Arctic Basin Bottom-Rock Material

Geological sampling of the seafloor of underwater ridges and uplifts outcropped in the Central Arctic gives direct geological data on the structure and age of the rocks composing the seafloor morphostructures. Along with the geophysical data, it allows to reconstruct the formation history of these structures.

Over the past 10 years, a number of high-latitude expeditions took place, during which, sampling of modern loose hemipelagic sediments as well as geological sampling of seafloor hard rocks was carried out (Figs. 1 and 2) In the course of the latest field research works supplemented by photo and video recording, in many cases the stones a priori identified as “drop-stones” (the products of long-distance transfer by old ice or icebergs and exogenous scattering) in fact turned out to be of local origin and feature the underwater uplifts in which they were discovered. In numerous escarpments of the Lomonosov Ridge, Alpha-Mendeleev, and Chukchi

O. V. Petrov (✉) · S. P. Shokalsky · T. Yu. Tolmacheva · O. L. Kossovaya · S. A. Sergeev
Russian Geological Research Institute (VSEGEI), 74 Sredny Prospect, St. Petersburg 199106, Russia
e-mail: vsgdir@vsegei.ru

O. V. Petrov and M. Smelror (eds.), *Tectonics of the Arctic*, Springer Geology,
https://doi.org/10.1007/978-3-030-46862-0_5

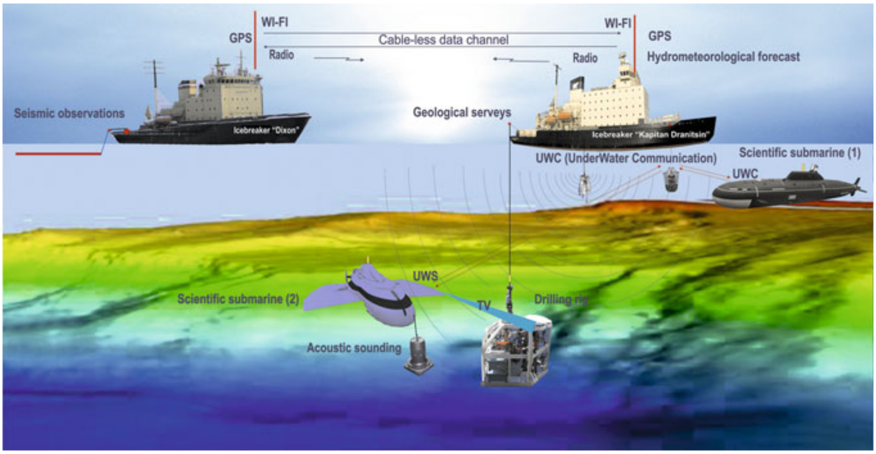

Fig. 1 The sketch-map of bottom sampling stations (dredging, deep-sea drilling and sampling from the research submarine—NIPL) in the Central Arctic underwater uplifts and the adjacent shallow shelf distributed by Russian and foreign high-latitude expeditions, mainly in accordance with the programmes: OLCS (Russia) and ECS (Denmark, Canada, USA) until 2016 and the concepts in the submissions of the Arctic states

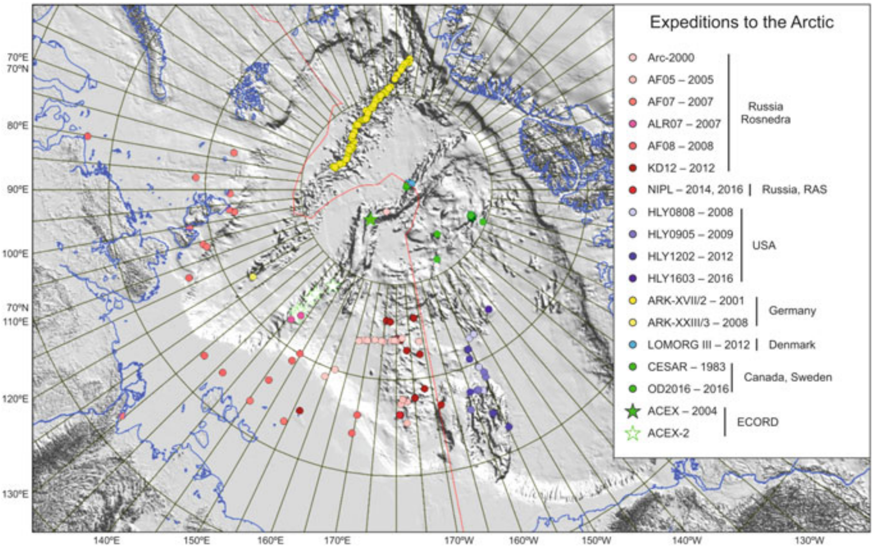

Fig. 2 Geological sampling of the seabed deposits in the Arctic Basin for different expeditions

Rises and their spurs at a depth of 1.5–3.5 km, there is a large number of exposures and outcrops of bedrock onto the surface of the seafloor, which are to be explored to benefit geological argumentation of the geological concepts in the submissions of the Arctic states.

The “Arctic 2012” expedition findings convincingly demonstrated outcrops of bedrock in the Mendeleev Rise (Fig. 3). The research submarine manipulator, a dredge and a grab lifted at least 100 rock fragments larger than 10 cm (Fig. 4). Complex studies of the bottom-rock samples as well as the rock samples from the Arctic islands and coastland were carried out (Fig. 5).

Steep slopes of 10 seafloor sites were sampled in the Mendeleev Rise in the course of the expeditions “Arctic 2000, -2005 and -2012” organized by Rosnedra and the Ministry of Natural Resources and Environment of the Russian Federation (Sevmorgeo and VNIIOkeangeologia, with the participation of VSEGEI).

Sites 5, 6 and 8 are located in the southwestern extremity of the Alpha Rise (in the Trukshin and Rogotsky underwater elevations).

Four sites (1, 2, 9, 10) are located in the northern Mendeleev Rise (in the Shamshura elevation and to the southeast of it). Three sites (0, 3 and TO) are located in the central Mendeleev Rise.

Three wells 2 m deep each were drilled in two sites. The first well was drilled in the SW Alpha Rise (site 6). The other two wells were drilled in the central Mendeleev Rise (site 0).

In accordance with the video recording made during the “Arctic-2012” seafloor sampling expedition, there are only sporadic, usually small (gravel and rarely pebble) hard rock fragments, apparently ice-breaking products, on the flat tops of table mountains. In such places, recent seafloor mud hardly contains accessory mature continental crust minerals—zircon, monazite, garnet.

The abundant accumulation of rock fragments, usually poorly rounded or angular, happened to be confined to steep slopes and footsteps of horst uplifts and escarpments, below bedrock exposures. In bottom sediments at the foot of underwater uplifts, for example, the Lomonosov Ridge and the Mendeleev Rise, detrital zircon accumulates, forming weight contents in mud.

Sedimentary rocks. Video recording made from the submarine and a core drill showed two types of bedrock in the sea floor escarpments. Some outcrops (of sinter type) resemble volcanic covers of basalt com position; the others are typical of practically unreformed platy-layered sedimentary rocks.

Bottom sampling in the Mendeleev Rise, the Chukchi Borderland and other structures showed that widespread Paleozoic sedimentary bedrocks in the acoustic basement outcrops on the surface of underwater elevations can actually account for the sedimentary rocks dominance in the composition of coarse detrital bottom-rock material.

Devonian Carboniferous-Lower Permian bioclastic (with fossils) limestone and secondary dolomite were identified among the sedimentary rock samples. Middle Late Paleozoic (and younger-Triassic-Jurassic) quartz sandstone was identified in the same bottom samples with U-Pb dating of detrital zircon (Fig. 6).

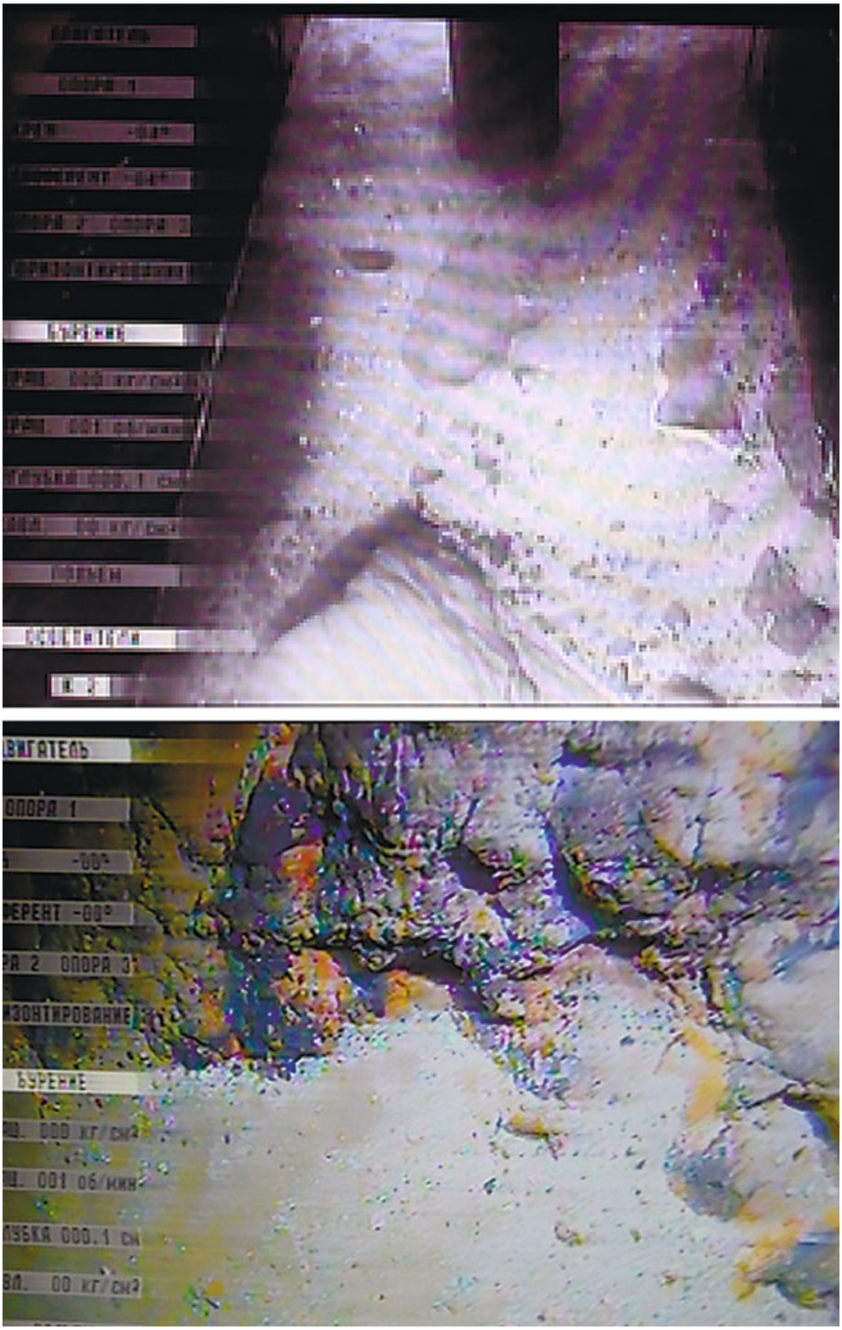

Fig. 3 View of the sea bottom of the Mendeleev Rise (photo of Arctica-2012)

Fig. 4 Rock samples from the Mendeleev Rise

Cenozoic hard carbonate crusts and flattened concretions were found in the samples (lifted from 2.3–3.5 km depth) from four escarpments of the Mendeleev Rise and no fewer than one site in the Chukchi Border land in addition to typically Paleozoic or older sedimentary rocks. They are composed of quartz-calcite or quartz-dolomite-calcite matrix, which contains abundant gruss and coarse dolomite sand, sandstone, dolerite and other rocks, usually coated in black ferromanganese, as well as small shell fragments. Numerous Cenozoic planktonic foraminifera were found in large quantities in carbonate crusts.

As a result of geochronological studies of subalkaline basalts and variegated volcanoclastic rocks of trachyandesite composition obtained from the wells in the central Mendeleev Rise, with U-Pb zircon dating in the CIR (Centre for Isotope

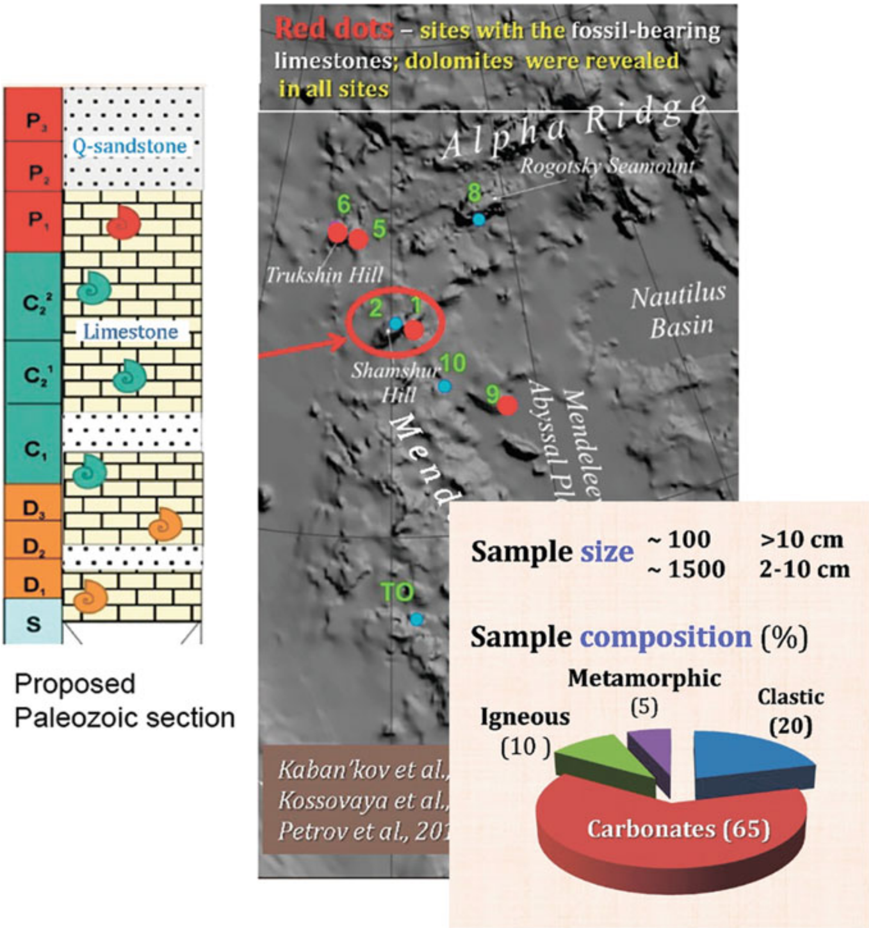

Fig. 5 Location of sampled fossiliferous carbonates on Alfa-Mendeleev Rise quantitative ratio of rock types collected during the expedition Arctica-2012 and proposed geological section of the Mendeleev Rise acoustic fundament

Research) VSEGEI and 40Ar/39Ar dating at the Laboratory of New Hampshire University (the USA) the basalts were identified as Cretaceous.

Based on obtained isotope-geochemical data, Russian and foreign experts discovered that the composition of these rocks is similar to the plateau basalt and volcanic formations of continental rifts. In accordance with the contour of the positive magnetic anomaly in the Central Arctic Elevations, Cretaceous basalt should be widespread over the roof of the acoustic basement not only in the Alpha-Mendeleev Rise, but also far beyond it—within the High Arctic large igneous province. Yet basalt and tuff is extremely rare in the seafloor rock fragments, which is a kind of geological enigma.

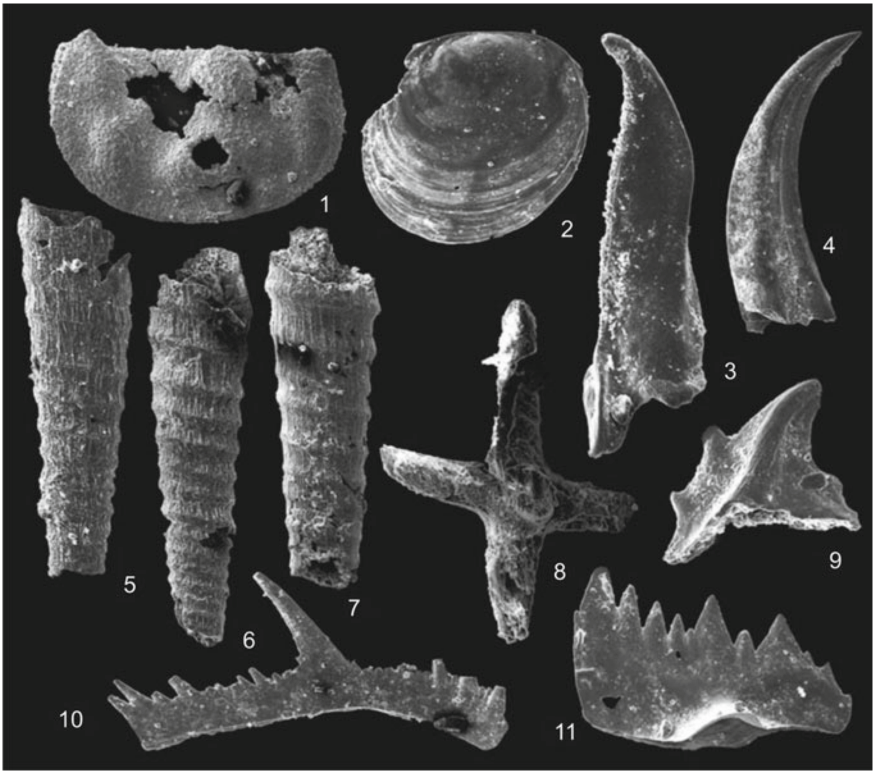

Fig. 6 Lower Devonian microfauna from sample KD-12-09-12d-85: *1* ostracod (Palaeocopamorpha); *2* Inarticulate brachiopod; *3* scolecodont; *4*, *9–11* conodonts [*4 Panderodus* sp., *9–11 Zieglerodina*? *remscheidensis* (Ziegler, 1960)]; *5–7* dacryoconarids (*Nowakia* cf. *zlichonensis* Bouček amd Prant); *8* sponge spicule

In the course of the "Arctic 2012" expedition, apart from Cretaceous volcanic rocks of the High Arctic large igneous province (HALIP), scarce but found in almost all the samplings and blocks, dredged up with the research submarine manipulator, gabbro-dolerite with intraplate petrogeochemical characteristics was dredged up as well. Its composition was studied and it was U-Pb zircon, Rb-Sr and Sm-Nd dated as Late Precambrian, Early and Middle Paleozoic. Such rocks usually occur at different levels of craton platform mantle in the form of silo-dike complexes.

The research works carried out by Rosnedra organizations in 2000–2012 resulted in the accumulation of over 500 rocks that were comprehensively studied; 400 of them come from deep-sea uplifts, including gabbro-dolerite (70), granitoid and metamorphic rocks (50), quartzite sandstone (80), sandstone and siltstone, dolomite and limestone (over 100), and in addition, 50 samples of bottom sediments from ground cores (Sergeev et al. 2014; Kabankov et al. 2004, 2008a, b, 2012; Grikurov et al. 2014; Morozov et al. 2013; Vernikovsky et al. 2013; Petrov et al. 2016, etc.)

VSEGEI built up a Depository to store and to carry out follow-up studies of the rock samples from the "Arctic 2012" expedition, as well as the samples from the Arctic islands that were accumulated in the course of the international Arctic expeditions to Novaya Zemlya, Anzhu and De Long Islands in 2011–2013. Following the same procedure, they were later analyzed together with the samples from the high-latitude expedition "Arctic 2012" in the VSEGEI CIR (Centre for Isotope Research) and CL (Central Laboratory). They were also compared and the findings were used to prove the relationship between the Central Arctic deep-sea Elevations and the shallow Eastern Russia Arctic shelf structures.

2 Geochemical and Isotope-Geochronological Knowledge of the Eastern Arctic

Up-to-date isotope-geochemical and isotope-geochronological analytical techniques were used to study the sedimentary and magmatic rocks from the Eastern Arctic (Fig. 7) The study was carried out in the Center for Isotope Researches of the FSBV "VSEGEI", and employed various techniques, including ID-TIMS (whole-rock and minerals), ICP-MS-(MC) coupled with laser ablation, noble gases isotope ratios measurements and SIMS local analyses.

Between 2012 and 2015, a total of 530 samples, collected from the islands of the Eastern Arctic, dredged from the Arctic Ocean and sampled in its continental surroundings were analyzed. The samples encompass a wide range of compositions including magmatic, metamorphic and sedimentary rocks, as well as deep-water silt:

4530 local SIMS (SHRIMP-II) U-Pb analyses of zircon and baddeleyite in 348 rock samples;
2319 local LA-ICP-MS U-Pb zircon analyses in 164 samples;
35 ID-TIMS Rb-Sr datings;
31 ID-TIMS Sm-Nd age determinations;
10 Ar-Ar age determinations;
6 isotope analyses of He-Ar systematic;
342 chemical analysis by XRD, ICP-MS and ICP-AES;
108 isotope analyses of O, C and Sr in carbonates;
61 isotope analysis of the Re-Os systematics;
231 isotopic analyses of Nd system of bulk rocks;
240 isotope whole-rocks analyses of Sr;
69 isotope whole-rocks analyses of Pb;
1193 local LA-ICP-MC-MS analyses of the Lu-Hf systematics in zircon from 61 samples.

The following results were obtained:

The Baikalian and Caledonian age of granitoid fragments, dredged from the Cenozoic sediments of the Geophysicists Spur was determined. The acid igneous rocks

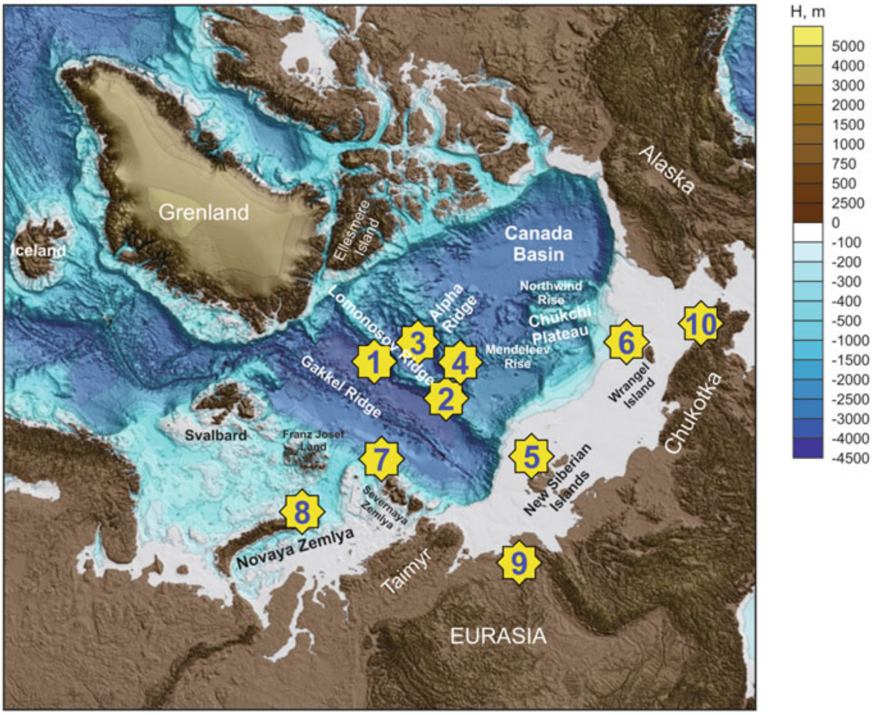

Fig. 7 Sampled localities: 1—Lomonosov Ridge (the Pole); 2—Lomonosov Ridge (Geophysicists Spur); 3—Alpha Ridge; 4—Mendeleev Rise; 5—Islands of De Long, Anjou and Lyakhovskie; 6—Wrangel Island; 7—Schmidt Island (Severnaya Zemlya); 8—Novaya Zemlya Islands; 9—Siberian Craton; Verkhoyansk-Kolyma and Anyi-Chjukchi fold-and thrust belts

dredged on the Mendeleev Rise proved to be gneiss granites of the Archaean and Palaeoproterozoic ages.

The distribution of the zircon ages in the Lomonosov Ridge and Mendeleev Rise bottom sediments is very close to that of the Asian continent, but differs sharply from the North American Continent and Europe (Grenvillian ages of c. 1100 Ma are absent). The pelagic silts contain a noticeable amounts of zircon, monazite, and garnet, which is not typical for the areas of the oceanic crust (Fig. 8). At least 25 provenance sources of detritus—Late and Early Cretaceous, Jurassic, Triassic, Permian and others, up to the Archaean were identified. The pelagic silts from the Lomonosov Ridge and Mendeleev Rise are of various origins, since differences of Re/Os ratios between these two sediment groups are quite large, hence they could not be derived from a single source.

The dating of the samples from the Mendeleev Rise implies existence of uneven-aged (Cretaceous, Ediacaran and Cryogenian) magmatic domains.

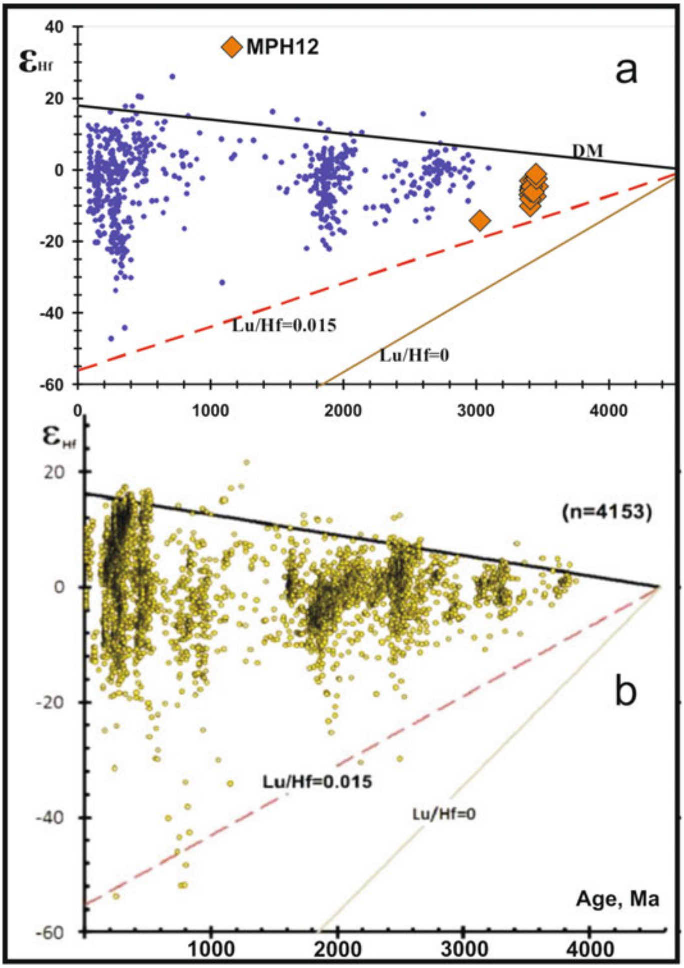

Fig. 8 Hf-isotope composition of detrital zircons from: A—hemipelagic deep-water deposits of Alpha-Mendeleev Rise. B—Asian sedimentary rocks. Plot U-Pb detrital zircon age vs ?Hf demonstrates that the main detritus portion of the deep-water muds and that of the present-day sediments with ages not exceeding 1.8 Ga is the result of river drift from the Asian continent of crustal matter of predominantly Caledonian age. The oldest 3450 Ma zircon from a meta-sandstone (MPN12) is shown as diamond

In the Mendeleev Rise, the age of dolerites was determined. The time of their intrusion from a moderately enriched or moderately depleted source (subcontinental lithospheric mantle) is estimated to 660 Ma.

Presence in basalts and dolerites of typical magmatic zircons with ages of 120, 180 and 260 Ma indicates existence of several magmatic complexes in the Eastern Arctic. The basic rocks themselves resemble those derived from plumes of the Jurassic-Cretaceous-Cenozoic (HALIP) and Early Triassic (Siberian trap formation) age. The studies showed that the basalts from the Mendeleev Rise are geochemically distinct from the rocks in the mid-oceanic ridges but similar to Arctic intraplate moderately alkaline Cretaceous basalts (HALIP) and Cretaceous continental traps of the Deccan Plateau.

Ages of detrital zircons from sandstones, dredged in the Mendeleev Rise were determined. The northwest of the Rise is dominated by the Devonian-Silurian and the Riphean-Paleoproterozoic ages with a subordinate amount of the Vendian and Neoarchaean detritus. The central part is dominated, by material of the Triassic age with minor Devonian-Silurian and other sources. In the south, bi-component sandstones were dredged: detrital zircons from those yielded Palaeoproterozoic and Archaean ages.

Geochemistry and geochronology of the Eastern Arctic Probability density plots U-Pb of detrital zircons ages from meta-sandstones (Fig. 9). Two chronologic levels may be distinguished: Proterozoic and Mesozoic-Cenozoic, corresponding to the structures of the Precambrian basement and continental cover, respectively. The figure shows a typical zircon composition of one of the meta-sandstone sample (MPN12) and the results of the local U-Pb SIMS analyses of its oldest component (see the Concordia plot).

Arctic intraplate moderately alkaline Cretaceous basalts (HALIP) and Cretaceous continental traps of the Deccan Plateau.

Ages of detrital zircons from sandstones, dredged at the Mendeleev Ridge have been determined. The northwest of the Ridge is dominated by the Devonian-Silurian and the Riphean-Paleoproterozoic ages with a subordinate amount of the Vendian and Neoarchaean detritus.

The central part is dominated, by material of the Triassic age with minor Devonian-Silurian and other sources. In the south, bi-component sandstones have been dredged: detrital zircons from those yielded Palaeoproterozoic and Archaean ages.

3 Geological Section of the Acoustic Basement of the Alpha-Mendeleev Rise

In 2014 and 2016, the Geological Institute of the Russian Academy of Sciences (GIN RAS) in cooperation with the Geological and Geophysical Survey of the Geological Institute (GEOSLUZHBA GIN) and the Main Directorate for Deepwater Research of the Ministry of Defense of the Russian Federation organized expeditions in area of the Alpha-Mendeleev Rise to collect data in order to study the geological section of the Rise. The work was carried out using research submarine technical equipment at three test sites confined to the bottom areas, where acoustic basement rocks protrude from the sedimentary cover in the southwestern and central parts of the Mendeleev Rise and in Trukshin seamount (Alpha Ridge). When choosing sampling sites, 2D CDP reflection data obtained during expeditions "Arctic 2011" and "Arctic 2012", were analyzed. Rocks were sampled by research submarine manipulators directly

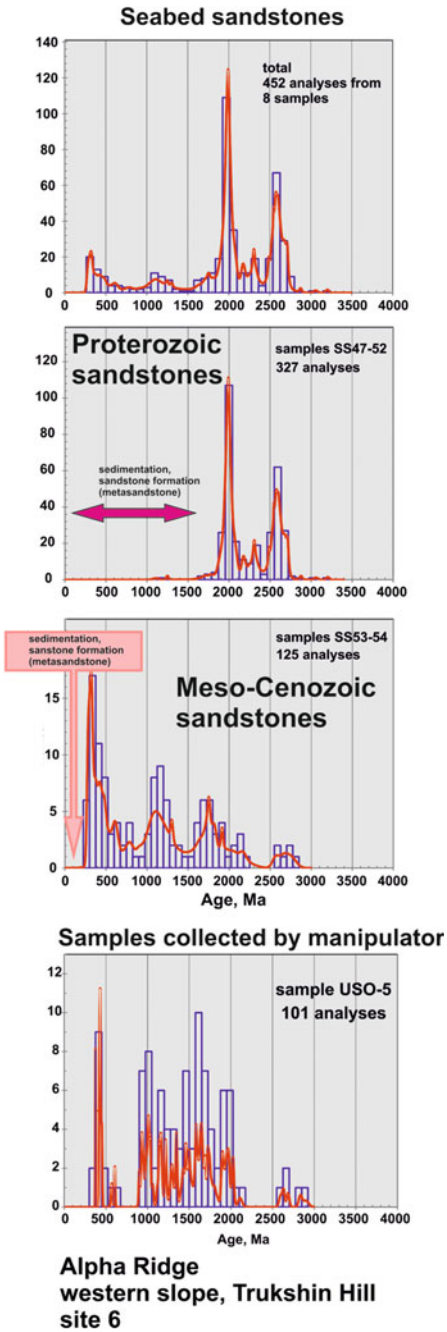

Fig. 9 Probability density plots U-Pb of detrital zircons ages from meta-sandstones. Two chronologic levels may be distinguished: Proterozoic and Mesozoic-Cenozoic, corresponding to the structures of the Precambrian basement and continental cover, respectively. The figure shows a typical zircon composition of one of the meta-sandstone sample (MPN12) and the results of the local U-Pb SIMS analyses of its oldest component (see the Concordia plot)

Fig. 10 Seabed exposures on the Mendeleev Rise sampled by research submarine manipulators (photo by GINRAS and GEOSLUZHBA GIN in Arctic-2014 expedition)

from cliffs, ledges, elevations, as well as from debris beneath them and loose rocks formed on their terraces and peaks resulted from bedrock destruction (Fig. 10). The rock collection is dominated by dolomite (37%), quartzite sandstone (20%), volcanic rocks (16%), limestone (10%), sandstone (6%), tuff (6%), microgabbro (3%) and dolerite (2%).

By now, the materials of the expedition 2014, obtained in the southwestern part of the Mendeleev Rise, have been analyzed. Twenty nine samples were studied, which are evenly distributed over the test site. Petrographic study of rocks was carried out, their chemical and mineral compositions were determined, and concentrations of impurity elements were measured. To determine the age of sedimentary rocks, their palyno-spectra were analyzed.

As a result of the studies, a visible geological section of the acoustic basement was reconstructed. In the lower part of the visible section, there is a lower rock sequence of apparent thickness of 230 m, composed of steeply bedded (30–40) dolomite and quartzite sandstone (Skolotnev et al. 2017a, b). Its outcrops are confined to the steepest lower part of the slope with a depth interval of 1500–1275 m. In the palynological collection of one of dolomite samples, there are abundant chorate forms—acritarchs such as *Baltisphaeridium* sp. ex gr. *B. varium* Volkova; Late Ordovician—Silurian acanthomorphic acritarchs such as *Micrhystridium* were also recorded (Fig. 11).

The *lower rock sequence* is overlapped with stratigraphic and angular unconformity by the *upper rock sequence* of about 40–50 m in thickness, composed of limestone and sandstone. Layers of the *upper rock sequence* of 5–10 cm in thickness show less steep bedding (15°–20°) than the *lower rock sequence*. The rock sequence forms the upper gently dipping part of the slope in the depth interval 1275 to 1230 m and, in accordance with seismic data, is directly overlain by the Mesozoic-Cenozoic sedimentary cover of oceanic origin. In the limestone, the palynospectrum is represented by a variety of myospores, the set of which makes it possible to refer it to the Contagisporites optivus—Spelaeotriletes krestovnikovii palynozone, characterizing Early Frasnian deposits of the Late Devonian. It should be noted that in the limestone,

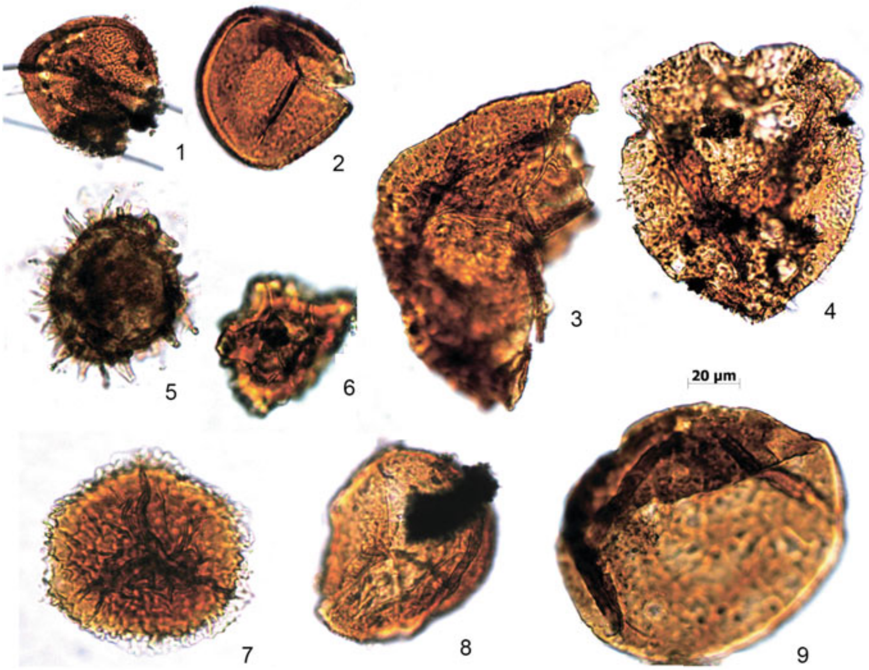

Fig. 11 Organic microfossils (spores and acritarchs) form the Lower Paleozoic carbonates sampled from seabed exposures (Skolotnev et al. 2019): 1—Geminospora micromanifesta (Naumova); 2—Geminospora lemurata Balme emend. Playford; 3—Contagisporites optivus (Tschibrikova) Owens; 4—Apiculatisporis adavalensis (de Jersey) Grey; 5—Baltisphaeridium sp. ex gr. B. varium Volkova; 6—Archaeozonotriletes timanicus Naumova; 7—cf. Acinosporites acanthomammillatus Richardson; 8—Cymbosporites sp.; 9—Inderites devonicus (Naumova) Telnova. ×500

the proportion of fragments of sandy and small-gravel size, composed of dolomite, quartzite sandstone and volcanic rock, is rather large (about 20%).

The *lower rock sequence* neighbours a tuff sequence of visible thickness of 50 m, consisting of layers of very loose clay rocks 10–20 cm thick, dipping at an angle of about 20°, which are easily broken off by the manipulator. Petrographic studies revealed relic structures of vitroclastic tuff in these rocks. The rock sequence makes up a terrace, formed at the foot of the slope. Judging by the nature of the sequence occurrence, it is a product of erosion and redeposition of tuff deposits accumulated in the upper part of the slope. According to seismic data (Jokat et al. 2003), tuff and lava horizons having a thickness of first hundreds of meters are located in lower parts of the Mesozoic-Cenozoic sedimentary cover overlapping the Alpha-Mendeleev Rise. The age of the tuffs has not yet been determined. Geochemically, they are close to volcanic rocks that form the Cretaceous magmatic HALIP province in the Arctic region (Estrada et al. 2016). Therefore, and also taking into account the above seismic data, it can be assumed that the *tuff sequence* has a Cretaceous age.

The *lower rock sequence* is cut by a *subvolcanic complex* of trachyandesite and trachybasalt, the formation time of which has not been identified. Probably, part of volcanic rocks of this complex is of Cretaceous age.

Intermediate results of the materials obtained in 2016 indicate that the geological structure of the Alpha-Mendeleev Rise in the area of two other above-mentioned test sites does not fundamentally differ from that in the southwestern part of the rise. This is indicated by close sets of selected rocks, and the discovery of late Devonian foraminifera in one of the limestones (Isakova et al. 2017).

As a result of the work performed, unambiguous evidence has been obtained that this rise has a continental-type crust, since the studied sedimentary rocks are widespread in the craton platform covers to form the lower Paleozoic parts of their sections.

In the Early Paleozoic (Late Ordovician-Silurian), thick carbonate and sandstone sequence formed under platform conditions in coastal, multifacies settings of the shallow sea (probably rift regime accompanied by volcanism) (Fig. 12). The warm climate contributed to the formation of deep weathering profiles on land and diagenetic dolomitization of silty mud under stagnant marine conditions. Caledonian orogenesis led to the rise of the area, which resulted in the dislocation of Early Paleozoic sediments; subsequently they were considerably eroded. The new land subsidence below sea level began in the Late Devonian. Sedimentation occurred during the subsidence under shallow-sea conditions complicated by islands, and probably continued until the late Paleozoic. During the Jurassic and Triassic, apparently most of the area was the land. During this period, the Late Paleozoic sediments were also dislocated and partially eroded. New submergence of the area, continuing to the present, started after the opening of the oceanic Canada basin in the Cretaceous. The beginning of the submergence coincided with the volcanic activity that led to the formation of the magmatic HALIP province, covering the Arctic region from Spitsbergen to the Chukchi Plateau, the origin of which is associated with the rise of the deep mantle plume (Estrada et al. 2016).

Supported by Program of the Presidium of the Russian Academy of Sciences No. P.49 Project “Geological Evolution of the Alfa-Mendeleev Rise in the Arctic Ocean and the role of chemical and biological factors in the formation of its sedimentary cover”.

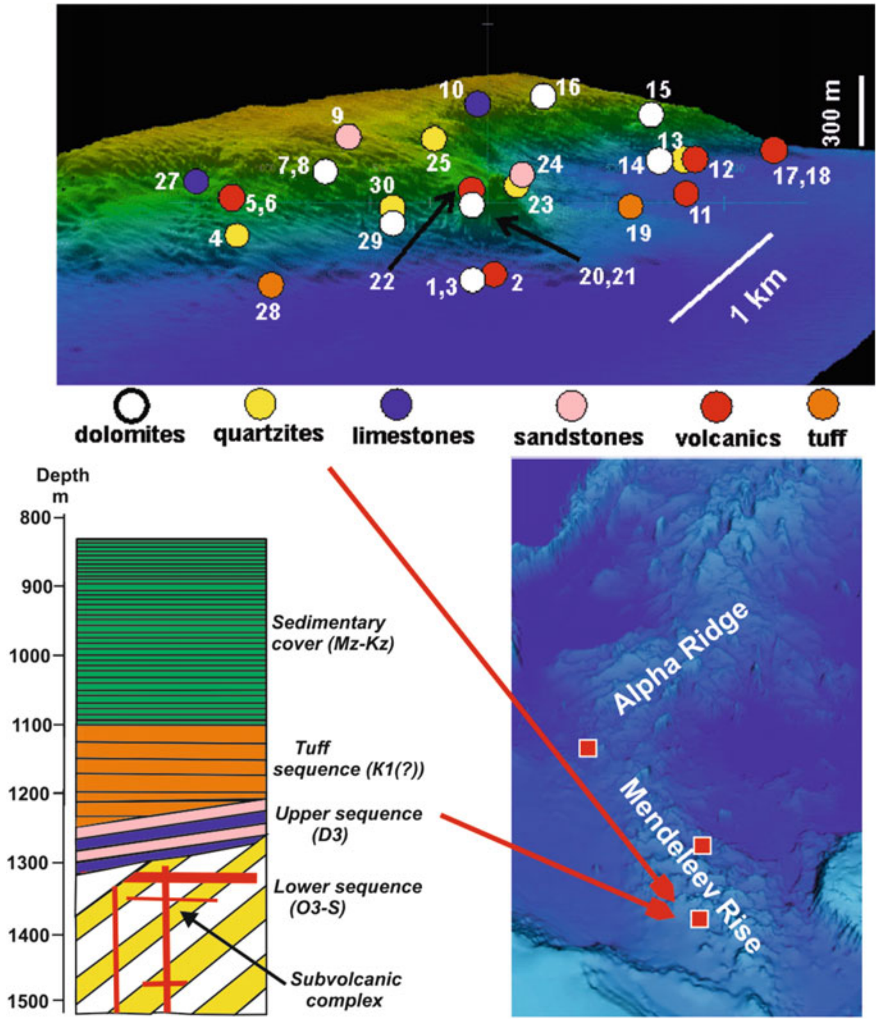

Fig. 12 Schematic geological section of the Mendeleev Rise revealed by Skolotnev et al. (2019) in a result of direct sampling of seabed exposures

References

Estrada S, Damaske D, Henjes-Kunst F, Schreckenberger B, Oakey GN, Piepjohn K, Eckelmann K, Linnemannn U (2016) Multistage cretaceous magmatism in the northern coastal region of Ellesmere Island and its relation to the formation of Alpha Ridge—evidence from aeromagnetic, geochemical and geochronological data. Norw J Geol 96(2). http://dx.doi.org/10.17850/njg96-2-03/

Grikurov G, Petrov O, Shokalsky S, Recant P, Krylov A, Laiba A, Belyatsky B, Rozinov M, Sergeev S (2014) Zircon geochronology of bottom rocks in the central Arctic Ocean: analitical results

and some geological implications. In: ICAM VI: Proceedings of the international conference on Arctic Margins VI, Fairbanks, Alaska, May 2011. SPb.: Press VSEGEI, pp 211–232
Isakova TN, Skolotnev SG, Kosovaya OL (2017) Paleozoic foraminifera of the Mendeleev Rise (Arctic Ocean, Eastern Arctic). Stratigraphic meeting, (in press) (in Russian)
Jokat W, Ritzmann O, Schmidt-Aursch MC, Drachev S, Gauger S, Snow J (2003) Geophysical evidence for reduced melt production on the Arctic ultraslow Gakkel mid-ocean ridge. Nature 423:962–965
Kabankov VY, Andreeva IA, Ivanov VI, Petrova VI (2004) About geotectonic nature of the system of Central Arctic morphostructures and geological significance of bottom sediments in its definition. Geotectonics 6:33–48 (in Russian)
Kabankov VY, Andreeva IA, Kaminskii DV, Razuvaeva EI, Krupskaya VV (2008a) New data on the composition and origin of bottom sediments in the southern Mendeleev Ridge Arctic Ocean. Dokl Earth Sci 419(2):403–405
Kabankov VY, Sobolevskaya RF, Lazarenko NP et al (2008b) On the problem of stratification of the Late Precambrian Early Paleozoic sediments of Central Taimyr. Novosibirsk: SNIIGGiMS, 169 p (in Russian)
Kabankov VYa, Andreeva IA, Lopatin BG (2012) Geology of the Amerasian subbassine. In: Geological and geophysical characteristics of the lithosphere of the Arctic region. Works VNIIOkeangeologiya, pp 30–40 (in Russian)
Morozov AF, Petrov OV, Shokalsky SP, Kashubin SN, Kremenetsky AA, Shkatov MYu, Kaminsky VD, Gusev EA, Grikurov GE, Recant PV, Shevchenko SS, Sergeev SA, Shatov VV (2013) New geological data substantiating the continental nature of the Central Arctic Uplifts area. Reg Geol Metallogeny 53:34–55 (in Russian)
Petrov OV, Morozov A, Shokalsky S, Kashubin S et al (2016) Crustal structure and tectonic model of the Arctic region. Earth-Sci Rev 154:29–71
Sergeev S, Petrov O, Belyatsky B, Sobolev N, Shokalsky S, Shevchenko S, Krymsky R, Petrov E (2014) Age (U-Pb zircon) and isotope-geochemical characteristics of bedrocks from New Siberian islands and its tectonic implications. Geophys Res Abs 16:EGU2014-10984
Skolotnev SG, Fedonkin MA, Korniychuk AV (2017a) New data concerning the geological structure of the South-West part Mendeleev Rise (Arctic Ocean). Doklady RAS 476(2):190–196 (in Russian)
Skolotnev SG, Fedonkin MA, Aleksandrova GN (2017b) Geological section of the acoustic foundation of the southwestern part of the Mendeleev Rise (Arctic Ocean). XLIX Tectonic collection of materials: "Tectonics of modern and ancient oceans and their suburbs"/M.: GEOS, pp 196–200 (in Russian)
Skolotnev S, Aleksandrova G, Isakova T, Tolmacheva T, Kurilenko A, Raevskaya E, Rozhnov S, Petrov E, Korniychuk A (2019) Fossils from seabed bedrocks: Implications for the nature of the acoustic basement of the Mendeleev Rise (Arctic Ocean) Marine Geology 407: 148–163
Vernikovsky VA, Metelkin DV, Tolmacheva TYu, Malyshev NA, Petrov OV, Sobolev NN, Matushkin NYu (2013) On the problem of paleotectonic reconstructions in the Arctic and the tectonic unity of the New Siberian Islands terrane: new paleomagnetic and paleontological data. Proc Russ Acad Sci 451(4):423–429 (in Russian)