The structural integrity of the Lomonosov Ridge with the North American and Siberian continental margins

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ABSTRACT

The Lomonosov Ridge crosses the Arctic Ocean connecting the North American and Siberian margins. The Ridge consists of a number of linear, parallel topographic highs that deepen toward the adjacent basins where they are buried by sediments. Bathymetric, seismic reflection, refraction, and potential field data show that the structure of the Ridge is continuous with the adjacent continental margins. The sedimentary section on the Lomonosov Ridge can be traced from the North American margin across the Pole to the Siberian margin. A reflection profile shot in the transition from the Siberian margin to the Lomonosov Ridge demonstrates that the strong regional unconformity at the base of the hemipelagic sedimentary unit. The entire sedimentary section and the acoustic basement can be clearly followed from the margin along the Ridge. The continuity of sedimentary and crustal units is confirmed on the coincident wide angle seismic reflection/refraction profile. Magnetic data at the intersection of the Ridge with the North American margin reveal the edge of the Pearya Terrane extending from Ellesmere Island onto the Lomonosov Ridge. Furthermore, with the Eurasia Basin closed the magnetic anomalies associated with Early Cretaceous dyke swarms can be traced from Franz Josef Land via the Lomonosov Ridge to the Alpha Ridge and from the North American polar margin to the Alpha Ridge. The distribution of the dykes suggests that since their emplacement the Lomonosov Ridge has been stable with respect to the North American margin and remained in close proximity to the Barents Sea margin until separation of the North American and Eurasian plates, as predicted by plate reconstructions based on magnetic lineations. The geomorphological and geophysical data presented in the paper do not support earlier interpretations of the Lomonosov Ridge as a separate microcontinent.

INTRODUCTION

The Lomonosov Ridge, approximately 1700 km long, has a sinuous shape (Fig.1). The Ridge is named after the Russian polymath Mikhail Vasilyevich Lomonosov. It was first mapped by the Russian high latitude air borne surveys of 1948. In 1954 it was shown on the bathymetric map of the Arctic Ocean (Burkanov 1954). The first bathymetric measurements on the Lomonosov Ridge available in western literature were made close to the pole during the First (1967) and Second (1969) Canadian North Pole expeditions (Weber 1983; Weber and Sweeney 1985).

The Lomonosov Ridge width varies between 50 and 200 km. Its flanks rise steeply from the 3900 - 4200 m deep basins on each side to a depth of typically 1000 - 1300 m below sea level (Weber 1979; Bjork et al. 2007). The steep sides and the saw-toothed crest of the Ridge are typical of continental block faulting. Seismic reflection profiles that show an angular unconformity in the sedimentary section on the Ridge beneath the drilled Tertiary section (Jokat et al. 1992) have a distinct continental character. The refraction velocities on the Ridge are comparable with those on the Barents and Kara seas shelves (Forsyth and Mair 1984), and gravity models controlled by wide angle reflection/refraction (WAR) profiles (Weber and Sweeney 1985) also indicate a continental origin of the Ridge. In addition, the fit of the Lomonosov Ridge morphological configuration with that of the conjugate Eurasia Basin margin suggests that the Ridge is a continental sliver separated by seafloor spreading from the Barents-Kara seas crustal block (e.g. Srivastava and Tapscott 1986).

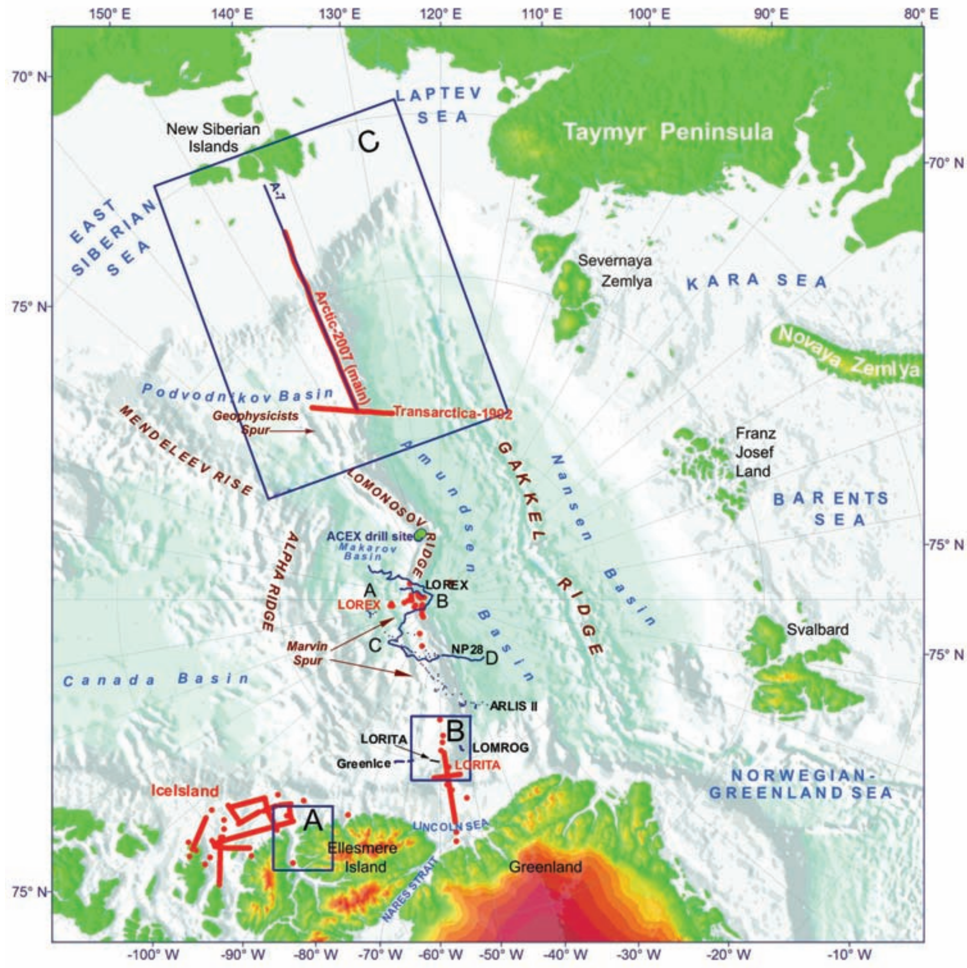


Fig. 1. Bathymetric map of the Arctic Ocean showing the location of seismic reflection lines in black and wide angle reflection/refraction lines in red described in the text. The black boxes labeled A and B are the position of the magnetic surveys shown in Figure 10. The black box labeled C is the location of gravity and magnetic surveys presented in Figure 11.

The Lomonosov Ridge divides the Arctic Ocean into two major deep basins (Fig. 2a): the Eurasia and the Amerasia basins. It has been called a double-sided continental margin (Jokat et al. 1992). The Eurasia Basin with its two sub-basins, the Amundsen and Nansen basins (Fig. 1), was created by Cenozoic sea floor spreading revealed by lineated seafloor spreading anomalies. This is due to the difficulties in interpreting chaotic high amplitude magnetic anomalies associated with the Alpha-Mendeleev ridges, the weak magnetic lineations in the Canada Basin and the scarcity of bedrock samples. Several different geodynamic models have been suggested for the Amerasia Basin, such as rifting of Alaska from the Lomonosov Ridge requiring transform motion along the Queen Elizabeth Islands margin of North America (e.g. Ostenso 1974). Another transform model has the Siberian margin rifted from the Queen Elizabeth Islands with shearing along the Alaska margin and Lomonosov Ridge (e.g. Herron et el. 1974). The rotational model for the opening of the Amerasia Basin with Alaska rifted away from the Queen Elizabeth Islands margin was first suggested by Carey (1958) and continues to be the option supported by the majority of researches (e.g. Cochran et al. 2006). The rotational model is consistent with paleomagnetic data from Alaska (Halgedahl and Jarrard 1987) and restores Mesozoic geology of the Queen Elizabeth Islands with that on the Alaskan margin (Embry 1990). The rotational option predicts that the Amerasia Basin side of the Lomonosov Ridge is a sheared margin.

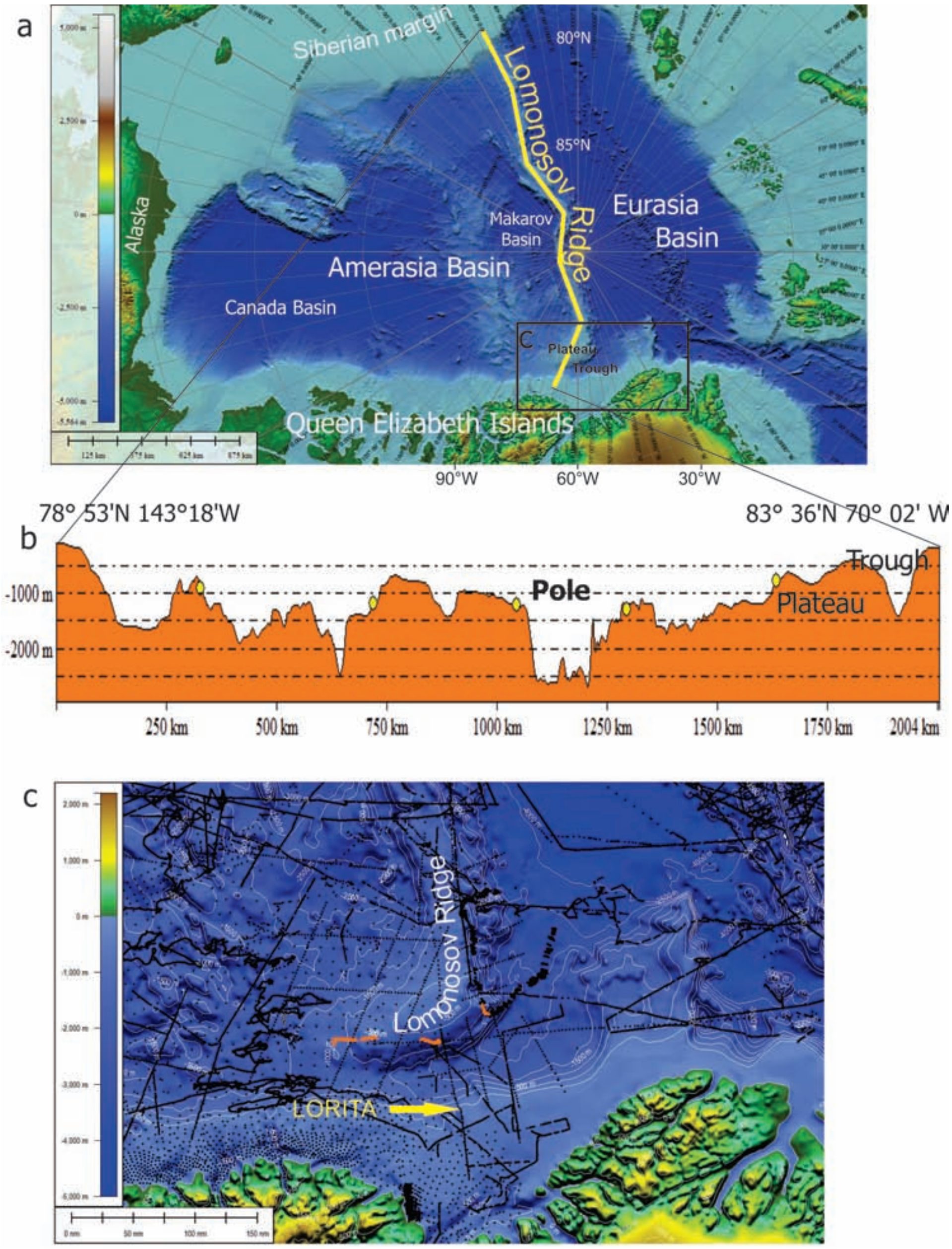


Fig. 2. Bathymetric map of the Arctic Ocean (section 'a') with the yellow line along the length the Lomonosov Ridge indicating the position of the bathymetric profile presented in section 'b'. The black box labeled 'c' indicates the region of detailed bathymetric surveys. The dots on section 'c' are the locations of spot soundings. The north-south line with closely spaced dots is the location of the LORITA wide angle reflection/refraction profile. The orange short lines are the location of seismic reflection profiles.

Significant new data collected by agencies in Canada, Denmark and Russia over the Lomonosov Ridge (Fig. 1) are presented that provide information on the continental affinities of the Ridge and its transition to the adjacent continental margins. A major question addressed is whether the geophysical data can be explained by plate reconstructions with the Lomonosov Ridge remaining fixed with respect to the continental margins of North America and Siberia, or whether displacement of the Ridge relative to the margins along major transform faults is required.

In 1992 for the first time, the Polar Marine Geosurvey Expedition (PMGE) under the auspices of the Ministry of Natural Resources and Environment of the Russian Federation carried out WAR observations over the Lomonosov Ridge and the adjacent Amundsen and Podvodnikov-Makarov basins (Fig. 1). In addition, aeromagnetic mapping in a belt 100 km wide was acquired along the WAR profile.

In 2007, VNIIOkeanologia and the Marine Arctic Geological Expedition (MAGE) were charged by the Federal Agency for Mineral Resources of the Russian Federation (Rosnedra) to perform integrated geological and geophysical investigations on the Lomonosov Ridge and the adjacent Siberian Shelf. The range of scientific observations included WAR measurements, multichannel seismic reflection profiling and potential field (gravity and magnetic) measurements in a belt 100 km wide along the WAR line.

The Geological Surveys of Canada (GSC) and Denmark and Greenland (GEUS) acquired WAR data and limited reflection profiling over the junction of the Lomonosov Ridge with the Greenland and Ellesmere Island continental margin in 2006. In 2007 and 2009 on LOMROG I and II ship-based programs, seismic reflection profiles on the Lomonosov Ridge were collected by GEUS that are also shown here.

In this paper the Lomonosov Ridge will be described from the continental shelves towards the North Pole through successive data sets beginning with bathymetry and continuing with data that investigate the sedimentary and crustal structure.

BATHYMETRY

The contours on the International Bathymetric Chart of the Arctic Ocean (IBCAO version 2.0) (Jakobsson et al. 2008) are developed from data gridded at a 2 km interval (Fig. 1). The data distribution is irregular and care must be taken assigning confidence to the mapped features. Due to the perennial ice cover, the bathymetric data on the Lomonosov Ridge adjacent to Greenland and Ellesmere Island consists of spot soundings augmented by sparse submarine single beam profiles and ship based multibeam data. The distribution of recent transects with spot soundings ensures that the representation of the major features in this region is realistic (Fig. 2c).

The bathymetry data reveal several distinct zones from the shelf adjacent to Ellesmere Island along the Lomonosov Ridge towards the North Pole. The shelf is characterized by water depths of less than 500 m. Further seaward a bathymetric trough that reaches a maximum depth of 2300 m and width of 75 km at the position of the LORITA refraction line (Fig. 1 and 2) is distinct. Northward there is a plateau with a minimum water depth of about 500 m. At the 1000 m contour the plateau is about 200 km wide. Further north the Lomonosov Ridge has a width of about 70 km at the 1500 m contour. On a bathymetric profile (Fig. 2b) slightly westward of the location of the LORITA profile, the topography across the trough and over the plateau is not significantly different from the regional variations observed along the length of the Lomonosov Ridge. For instance, greater water depths are observed near the Pole where there is an internal valley in the Ridge or towards the Siberian margin (at about 700 km on figure 2b) where one limb of the sub-parallel ridges that form the Lomonosov Ridge is crossed.

The transition from the Siberian margin to the Lomonosov Ridge (Fig. 1 and 2) is smooth for the first 200 km from the shelf. The water depth increases steadily from about 200 m to 1750 m over about 200 km. Further northward the Lomonosov Ridge is made up of a complex of ridges and basins as seen in the rugged topography. A consistent feature of this region of the Lomonosov Ridge is a series of parallel ridges with a width of over 200 km extending south to at least 82°30’ N and, based on gravity data, perhaps to the Siberian Margin (Cochran et al. 2006).

SEISMIC REFLECTION DATA

Near the North American margin

The ice cover in the Arctic Ocean hinders shipping. This is a particular problem for vessels towing seismic reflection equipment. In order to acquire seismic reflection data, a number of different platforms have been used that include drifting ice stations and icebreakers. The data coverage of the Lomonosov Ridge, adjacent to Greenland and Ellesmere Island, where the ice is the thickest and under compression, is limited. Only three seismic reflection profiles have been acquired in this area: the GREENICE and LORITA profiles from drifting ice camps and the ship based LOMROG 1 experiment (Fig. 3).

The length of the profiles varied from 55 km, 32 km to 22 km respectively. The seismic sections from drifting ice camps show that the sedimentary cover increases in thickness with distance away from the centre of the plateau. This is clearly seen on the GREENICE profile (Fig. 3). Near the crest of Lomonosov Ridge (550 m water depth) a thin veneer (0.05 s) of unconsolidated sediments overlies the acoustic basement that displays occasional dipping reflections. The sedimentary section thickens westward. On the LORITA reflection profile, 70 km to the east of the GREENICE profile and closer to the centre of the plateau (Jackson and Dahl-Jensen et al. 2010), and on the LOMROG profile, the sedimentary section is thin to absent, while basement reflection characteristics are similar to those observed on the GREENICE profile. On all three profiles coherent dipping reflections are visible only near the top of acoustic basement with a velocity of 5.9-6.5 km/s (Jackson and Dahl-Jensen et al. 2010). The limited seismic penetration beneath the thin sedimentary cover is consistent with high velocity rocks. Possible geological interpretations for the acoustic basement are calcareous or basaltic rocks. If calcareous, the dipping units would be due to fault blocks; however there is no indication of faults. The dipping reflectors observed in all the profiles could also be volcanic flows. When the seismic profiles are viewed in conjunction with the associated high frequency magnetic anomalies, it suggests that the basement is composed of volcanic rocks (Jackson and Dahl-Jensen et al. 2010).

The location of seismic reflection profiles between the plateau and the Pole is shown in Figures 1 and 4. The data were collected by the drifting ice camps NP28 (Langinen et al. 2008) and ARLIS II (Ostenso and Wold 1977) which zigzagged from the Amundsen Basin to Makarov Basin across the Ridge crest. The ARLIS II seismic section shows a flat top of the Lomonosov Ridge with sedimentary thickness of about 500 m thinning toward the Pole where bedrock pierces the seafloor in two locations (Weber and Sweeney 1985). Close to the Pole, steps in the seabed topography suggest block-faulting.

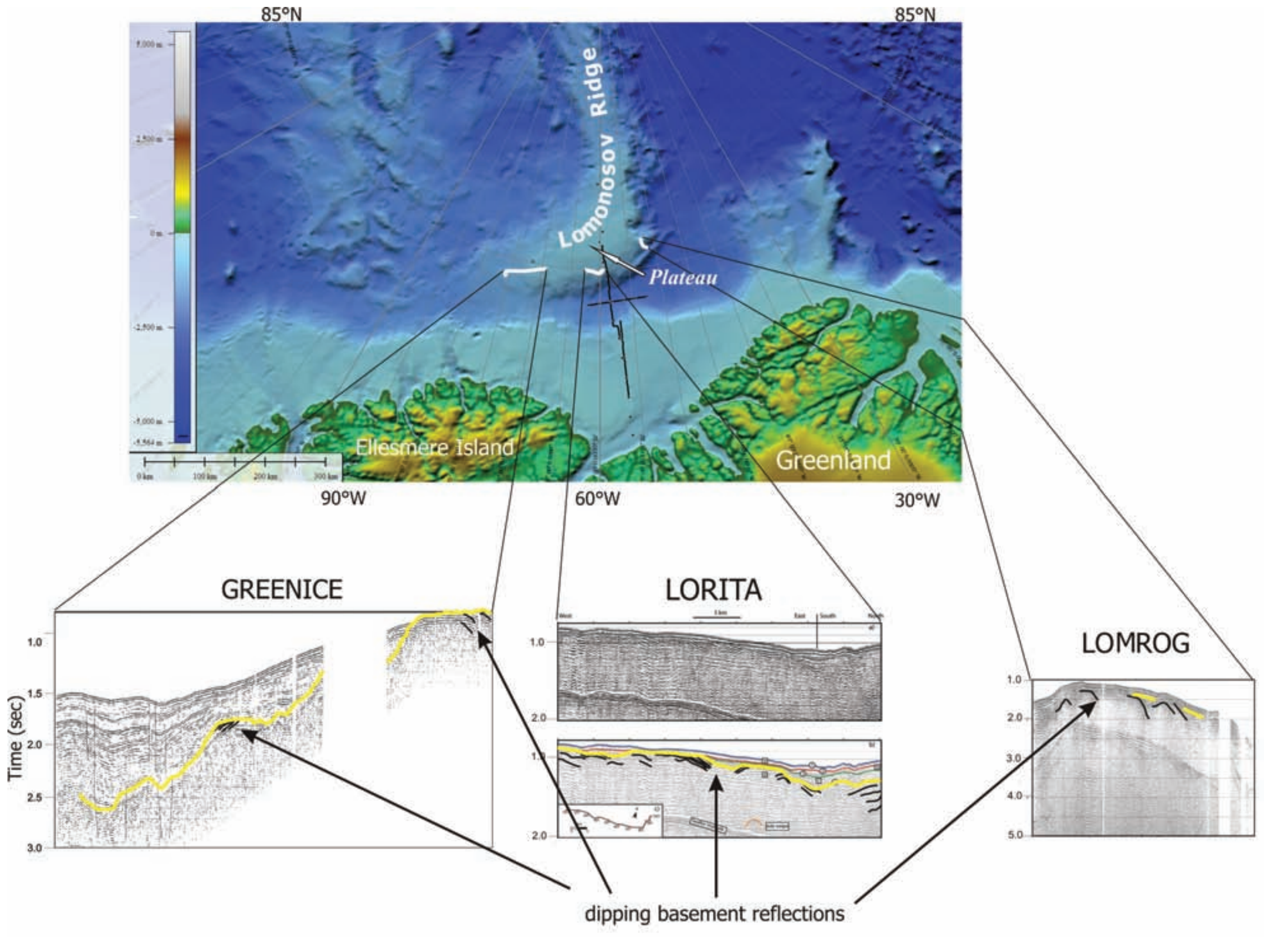


Fig. 3. Location of seismic data on the Lomonosov Ridge plateau and next to the Ellesmere Island and Greenland. The short white lines are the reflection profiles GREENICE (modified from Kristoffersen and Mikkelsen 2006), LORITA (after Jackson and Dahl-Jensen et al. 2010) and LOMROG (data from the LOMROG I experiment).The black line and dots are the position of the receivers and shots from the LORITA refraction profile.

The most continuous reflection data (Fig. 4) were obtained by the drifting ice camp NP28 (Langinen et al. 2008). The drift track crossed the Lomonosov Ridge three times between 88°N and the major bend in the Ridge near the Pole. The steeper continuous slope of the Lomonosov Ridge towards the Makarov Basin contrasts with the several ridges that step down to the Amundsen Basin. On the NP 28 seismic profiles as described by Langinen et al. (2008), a prominent flat-lying composite reflection package is seen from the seafloor to a depth of a few hundred meters. The base of this reflection package is often accompanied by a sharp increase in P-velocity and defines a major discontinuity, called the Lomonosov Unconformity (LU). The underlying reflections are variable in intensity and in dip. Between the LU and acoustic basement there is a variety of units, some highly reflective (with reflections concordant or discordant to the upper units), while others are sporadically reflective. The thickness of these units varies greatly not exceeding 1.5 km.

Marvin Spur

Marvin Spur is a linear ridge 20-50 km wide in the Makarov Basin (Fig. 4). The Marvin Spur is sub parallel to the Lomonosov Ridge at a distance of about 50 km from it on the Amerasia Basin side. The bathymetric depression between the Spur and the Ridge narrows toward the North American polar margin. Seismic lines that cross both the Lomonosov Ridge and Marvin Spur (Langinen et al. 2008, Fig. 4) illustrate their similar sedimentary stratigraphy. Fine-layered sediments, up to 0.5 s (two-way travel time) are visible on top of the Spur that have the same reflection characteristics as identified on the Lomonosov Ridge. Equally low or slightly greater thickness of sedimentary cover was recorded on the Spur by Polarstern-1998 seismic data (Jokat, 2005). On the profile C to D (Langinen et al. 2008) the basement is of variable depth and not well imaged but seems to have a blocky topography. The Spur, on the NP 28 data, appears as an opaque block with no consistent internal seismic structure. The Oden seismic reflection profile crosses the Marvin Spur at its extremity in the northernmost Makarov Basin (Fig. 4). The line is located slightly more distant from the Lomonosov Ridge than point A of the NP 28 profile. The LOMROG profile (Hopper et al. 2009) indicates normal faults in the basement, as well as stratigraphic reflectivity below the basement. The character of the reflectivity implies a continental origin of the crust (Hopper et al. 2009). Gravity data (Cochran et al. 2006) and limited seismic evidence (Langinen et al. 2008) suggest that the Marvin Spur continues in the Makarov Basin beneath the sedimentary section. We believe that the parallel continental feature of the Marvin Spur was formed by fragmentation of the North American section of the Lomonosov Ridge. Towards the North American margin the Marvin Spur merges with the Lomonosov Ridge further supporting a common geological development.

The Lomonosov Ridge from the Pole toward Russia

Due to the lighter ice conditions, from the North Pole to the Siberian margin, more continuous seismic reflection profiles are available, including a lengthy high-resolution line ‘A-7’ that followed the WAR profile (Fig. 1). From the North Pole towards the Siberian margin, especially between 89°N and 85°N, there are noticeable changes in trend and differences in elevations of blocks in a series of en echelon horsts and grabens oblique to the main ridge (Lomonosov Ridge complex) (Kristoffersen 2001).

Multichannel seismic reflection data ‘A-7‘

The ‘A-7’ line (832 km) extended from the New Siberian Islands to 83.5º N (Fig. 1). A Sercel Seal seismic work station and Sercel streamer with an active length of 8,100 m were used as the recording equipment. Bolt airguns with a total volume of 3400 in^3 were the seismic source. The recording parameters were: number of channels 648; group length 12.5 m; streamer depth 9 m; geophone group interval 12.5 m; record time 12 s; sample rate 2 ms. Source parameters: shot point spacing 37.5 m; airgun submersion depth 6 m. CDP fold – 108. Navigation was accomplished using the GPS Spectra system with the accuracy of at best 2 m.

The principal feature of the sedimentary cover along the entire line is a unit with distinct hemipelagic reflection characteristics overlying a strong unconformity. This unconformity is associated with the major depositional hiatus recorded in ACEX core data (Backman et al. 2006) and separates the Middle Eocene shallow-water rocks rich in

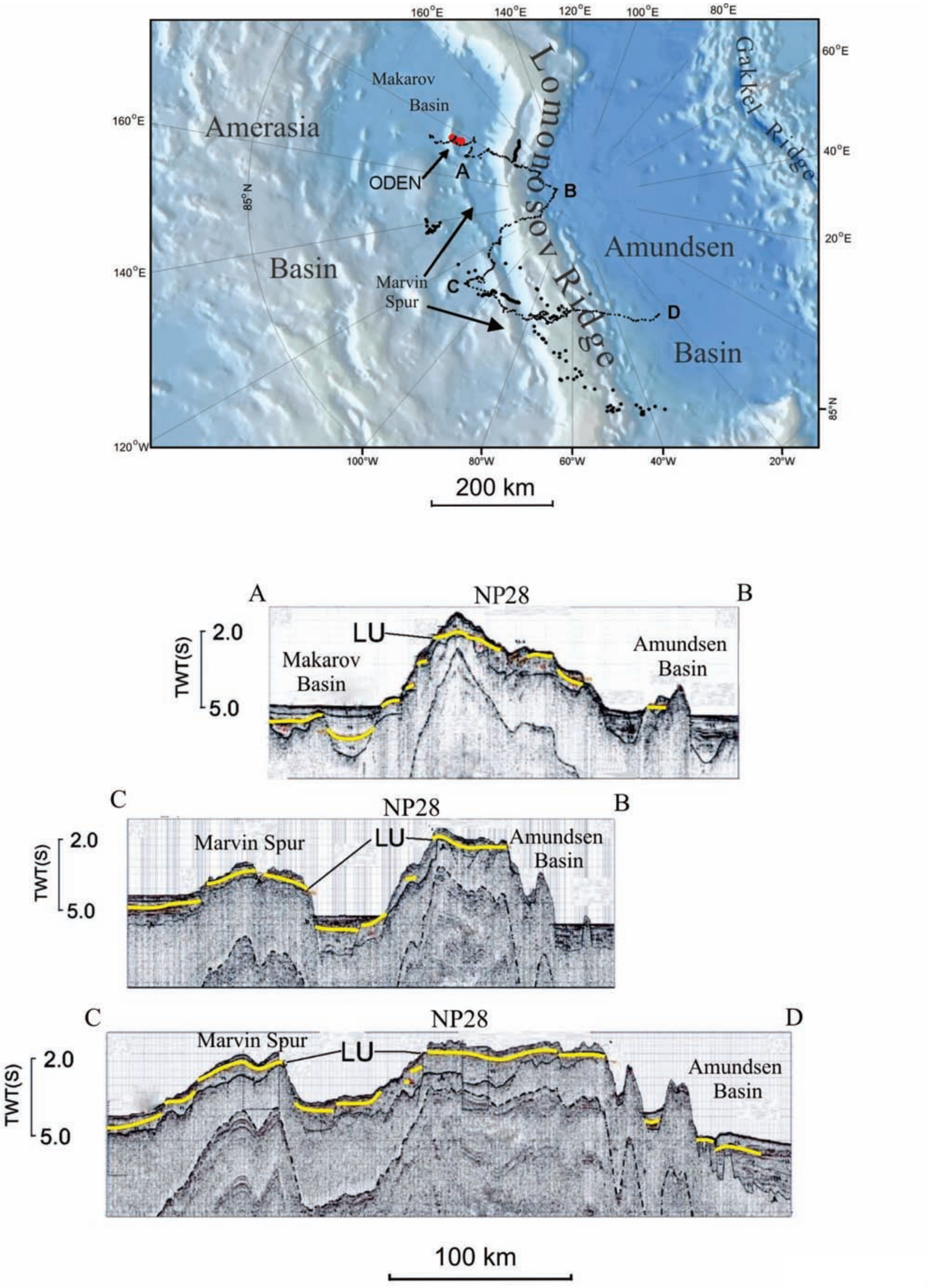


Fig. 4. Location of seismic reflection lines that cross the Lomonosov Ridge north of the plateau. Seismic sections AB, BC and CD are the portions of the NP 28 profile modified from Langinen et al. (2008). The position of the 'Oden' (LOMROG) seismic reflection profile is marked in red (Hopper et al. 2009). LU - the Lomonosov Unconformity.

biogenic material from the Early/Middle Miocene hemipelagic deposits with only minor amount of biogenic remains. This seismic boundary is recorded throughout much of the Central Arctic as a regional pre-Miocene unconformity RU (Butsenko and Poselov 2006) (Fig. 5 and 6a). An older unconformity also observed on 'A-7' line is believed to be related to post-Campanian depositional break (PCU). Such identification is based on correlation with the AWI 91090 profile which was tied to the ACEX core data (Bruvoll et al. 2010).

Southward along the Lomonosov Ridge and downslope to the Makarov Basin these unconformities merge, while the character of overlying Miocene-Quaternary hemipelagic unit remains similar to that observed in the northernmost part of 'A-7' line. At the approach to the Laptev Sea shelf the merged unconformities are again divided (Fig. 5 and 6a) and can be correlated with unconformities LS1 and LS2 on the Laptev Sea shelf (Franke et al. 2001).

Stratigraphic subdivision of the sedimentary cover along the 'A-7' line is based on the age of these major unconformities and enables recognition of 5 units (Fig. 5): (1) pre-Upper Cretaceous, (2) Upper Cretaceous, (3) Paleogene, (4) Miocene and (5) Pliocene-Quaternary. On the Lomonosov Ridge the Neogene-Quaternary deposits virtually rest on the Upper Cretaceous formations.

Continuous tracing of the Cretaceous-Cenozoic sedimentary units from the Siberian shelf to the Lomonosov Ridge through the transition zone and the persistence of seismostratigraphic and seismic facies characteristics are consistent with the lack of observable displacement in the acoustic basement (Fig. 6b). We interpret this as evidence of the absence of any major structural boundary in the transition zone.

WIDE ANGLE REFLECTION/REFRACTION

North American polar margin

A summary of a WAR survey along the margin near Ellesmere Island (Fig. 1) by Forsyth et al. (1998) is included for comparison with the data on the Lomonosov Ridge. The Ice Island surveys were conducted southwest of the junction of the Lomonosov Ridge with the margin in 60-km segments with 5-km recorder spacing. The data were modeled by ray tracing. Five velocity units were determined. The shallowest, a 1.9-3.4 km/s unit of unconsolidated to lightly compacted sedimentary rocks interpreted to be clastics of Tertiary age (Forsyth et al. 1998). Beneath this unit is a 4.3-5.2 km/s unit that could be an equivalent of an onshore

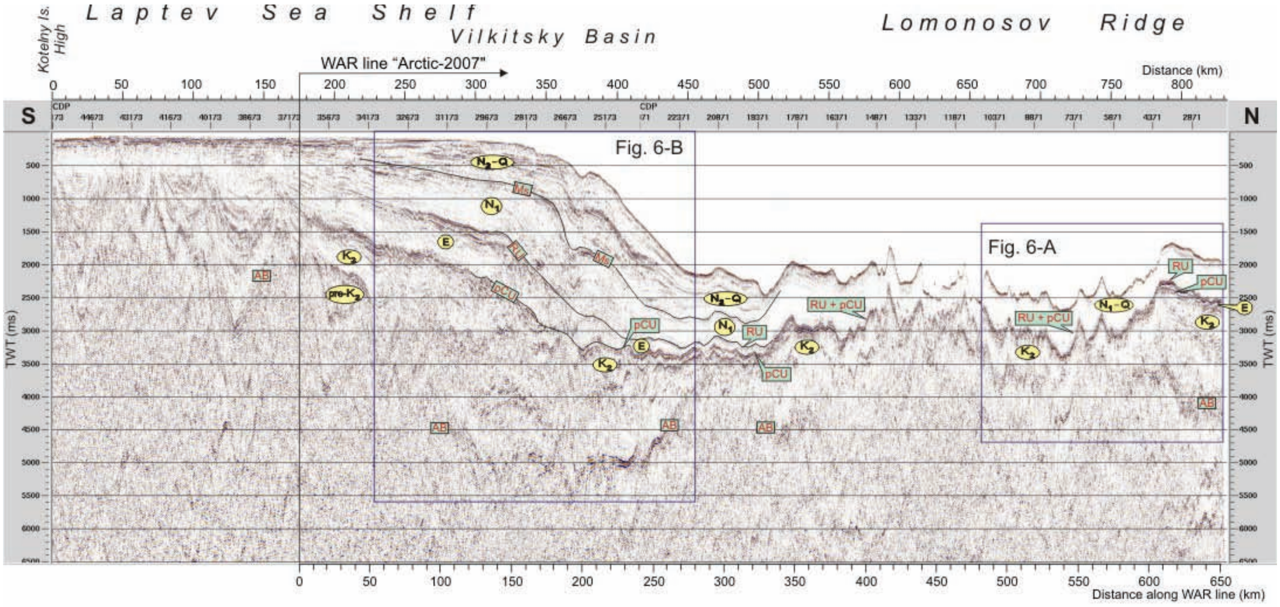


Fig. 5. A-7 multichannel migrated seismic reflection section. AB – acoustic basement, pCU – post-Campanian unconformity, RU – regional pre-Miocene unconformity, Ms – Messinian regression. The unconformities pCU, RU and Ms correspond to LS1, LS2 and LS3 of Franke et al. (2001), respectively. Boxes indicate the sections enlarged in Figure 6.

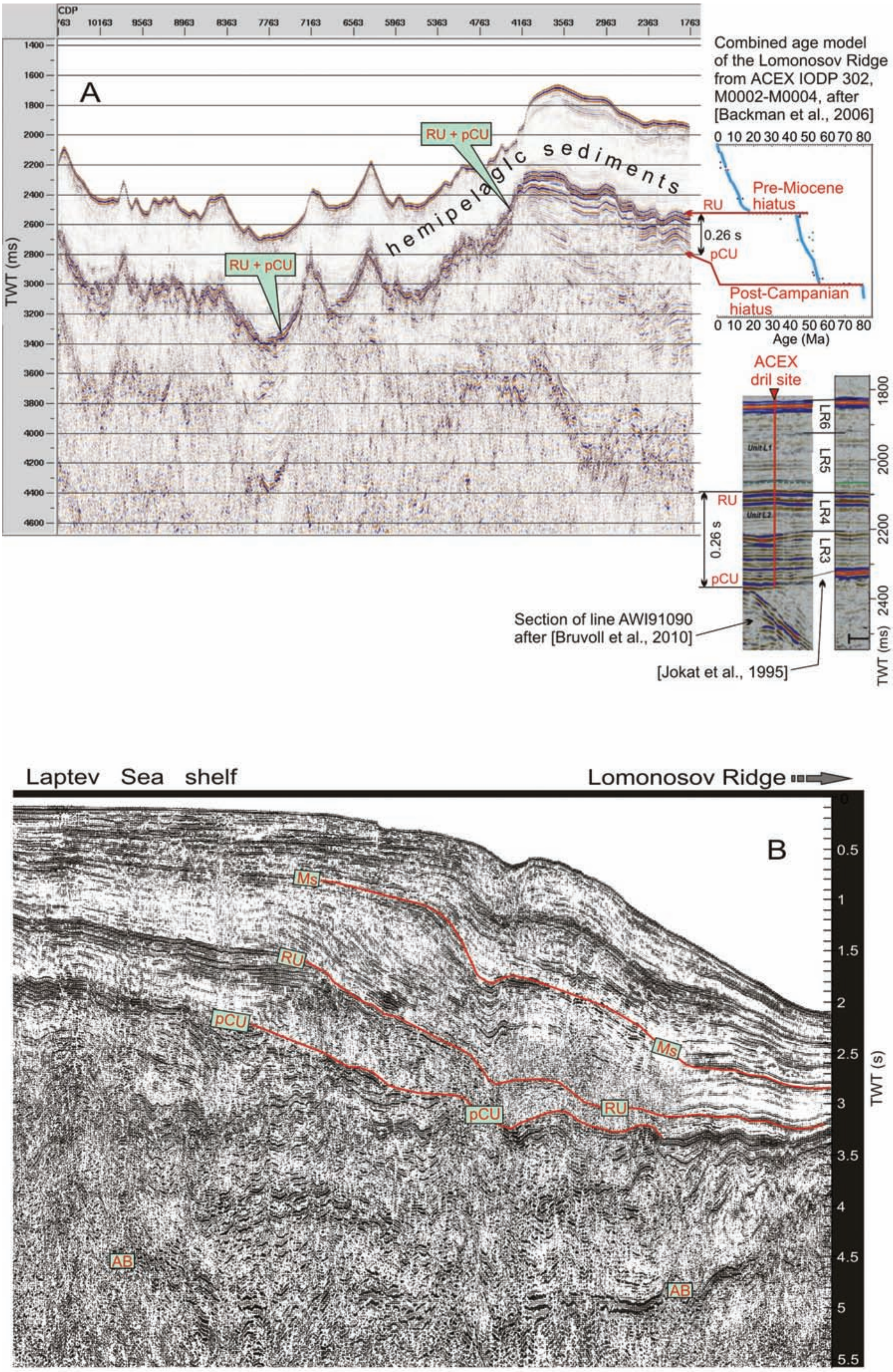


Fig. 6. Enlarged segments of A-7 multichannel seismic reflection profile (see Fig. 5): A – ties of major unconformities to the ACEX core, B - tracing major unconformities from the Lomonosov Ridge to the Laptev Sea shelf. Designation of unconformities is the same as in Fig. 5.

sedimentary sequence in the Sverdrup Basin (Sørensen et al. 2011). A 5.9 km/s unit that may be highly deformed and indurated clastics, carbonates and volcanics of Late Proterozoic to early Paleozoic age overlies a 6.6-6.8 km/s unit interpreted to be the crystalline lower crust (Forsyth et al. 1998). An upper mantle velocity of 8.2 km/s was measured at a depth of 20-25 km.

From the North American Margin to the Plateau of the Lomonosov Ridge

The results of the LORITA experiment are extracted from Jackson and Dahl-Jensen et al. (2010). The 440 km long north-south WAR profile crosses the continental shelf from the Lincoln Sea onto the Lomonosov Ridge. A 110 km east-west profile was run in the trough crossing the north-south line (Fig. 1). On the north-south line 181 receivers were spaced at 1.3 km and a total of 13 shots were fired. The WAR data were used to constrain two dimensional P-wave velocity models. The P-wave models were generated using the ray-tracing code RAYINVR and accompanying inversion and amplitude modeling code (Zelt 1999).

The modeling of the north-south WAR line identified three sedimentary units on the southern section of the line. The upper two layers with velocities of 2.1-2.2 km/s and 3.1-3.2 km/s are correlated with the Arctic continental terrace wedge. Below a seaward dipping interface predicted to be a regional unconformity, velocities in the range 4.3-5.2 km/s similar to those in the Mesozoic to Paleozoic Sverdrup Basin onshore have been determined. A layer with a velocity of 5.5-5.9 km/s underlies the inferred sedimentary strata on the continental shelf and can be traced seaward until it pinches out at a basement high on Lomonosov Ridge. This velocity is consistent with metasedimentary rocks of Late Proterozoic to early Paleozoic age seen in the onshore Sverdrup Basin at the same stratigraphic level (Jackson and Dahl-Jensen et al. 2010).

On the plateau of the Lomonosov Ridge (Fig. 2 and 3), the sediment cover is <1 km. The basement velocities are 5.9-6.5 km/s (Jackson and Dahl-Jensen et al. 2010). Consistent with the WAR results, the short seismic reflection profiles (Fig. 3) penetrated only a thin veneer of sediments overlying basement with internal dipping reflections. This seismic data in combination with the associated high frequency magnetic anomaly pattern suggests basaltic rocks near the surface (Jackson and Dahl-Jensen et al. 2010).

The crustal velocities flanking the basement high are in the range of 6.4-6.7 km/s. The information on the gradients is dependent on the depth of the penetration of the diving waves. Diving rays at about 15 km depth and at a range of 350 km indicate subtle changes in the crustal velocities northward. On the north end of the line, unreversed diving waves reach a maximum depth of 16.5 km that also constrain the top of the lower crust beneath the high. The Moho depth varies substantially from 20 to 27 km shallowing beneath the trough and deepening towards the continent and the plateau.

Near the North Pole

A WAR profile called LOREX (Fig. 1) was completed with 6 shots and 10 seismic recorders that were deployed on both a cross and a strike line on the Lomonosov Ridge near the North Pole (Mair and Forsyth 1982; Forsyth and Mair1984). The location of the shots and receivers were verified with water wave arrival times. The shot-to-recorder distances are accurate to 500 m. Ray tracing was done on the cross line and synthetic models were computed on the strike line. Due to the small number of shots and receivers and the 10-20 km spacing between them, there is little velocity control on the sediments at the seafloor. The reversed arrivals along the strike of the Lomonosov Ridge were modeled with two layers: a 5 km thick velocity layer of 4.7 km/s underlain by a 15-20 km thick velocity layer of 6.6 km/s (Mair and Forsyth 1982). An upper mantle velocity of 8.3 km/s was indicated by a few arrivals. The modeling of the cross line suggests Moho depth of about 28 km with a steeper slope on the Makarov Basin side than on the Eurasia Basin side.

The Pole to the Siberian margin

Wide-angle refraction/reflection data 'Transarctica-1992'

The 280 km long 'Transarctica-1992' WAR line crosses the Lomonosov Ridge from the Amundsen Basin to the Podvodnikov-Makarov basins at about 83.5ºN (Fig. 1). The observations were made using twenty 'Taiga' analogue recorders placed on the ice at 4-6 km intervals. The energy was sourced from

TNT charges between 100 and 1200 kg, depending on the position of shot points relative to the recorders. The average distance between shots was 40 km. The maximum offset reached 200 km.

Analogue WAR data were digitized at 8 ms sample rate and processed using ProMAX 2D software. To improve the data quality, true amplitude recovery and minimum-phase bandpass filtering of 1-2-7-9 Hz were applied. Interpretation of the data was based on ray-tracing, and modeling of synthetic wave field. For these purposes, RAYINVR and the accompanying amplitude modeling software TRAMP (Zelt, 1999) were used.

The results of WAR data interpretation along the 'Transarctica-1992' line are presented (Fig. 7). Ray-tracing of seismic waves from selected shot points, synthetic wave fields generated from segments of the final model, the corresponding seismic records with superposition of calculated time-distance curves of reflected and refracted waves, and seismograms without interpretation of the wave field are shown (Poselov et al. 2012). Errors bars for picking of the arrivals are shown in Table 1.

Several groups of waves were discerned and interpreted on seismic records: P-waves reflected from the intra-mantle boundary (Pm1P), from the Moho discontinuity (PmP) and from the top of the upper crust (PBP), and P-waves refracted in the upper mantle (Pn), in the upper crust (Pg) and in the layer PMS that occupies an intermediate position between the crystalline crust and the uppermost sedimentary layer.

The top of this "in-between" layer forms the acoustic basement on the reflection profile A-7 and also throughout the greater part of the Alpha-Mendeleev Ridge and Podvodnikov-Makarov Basin area. The layer occupying similar position in crustal section and demonstrating comparable seismic characteristics was identified in the southern section of LORITA WAR profile and interpreted as a metasedimentary unit correlative to Franklinian assemblages (Jackson, Dahl-Jensen et al., 2010).

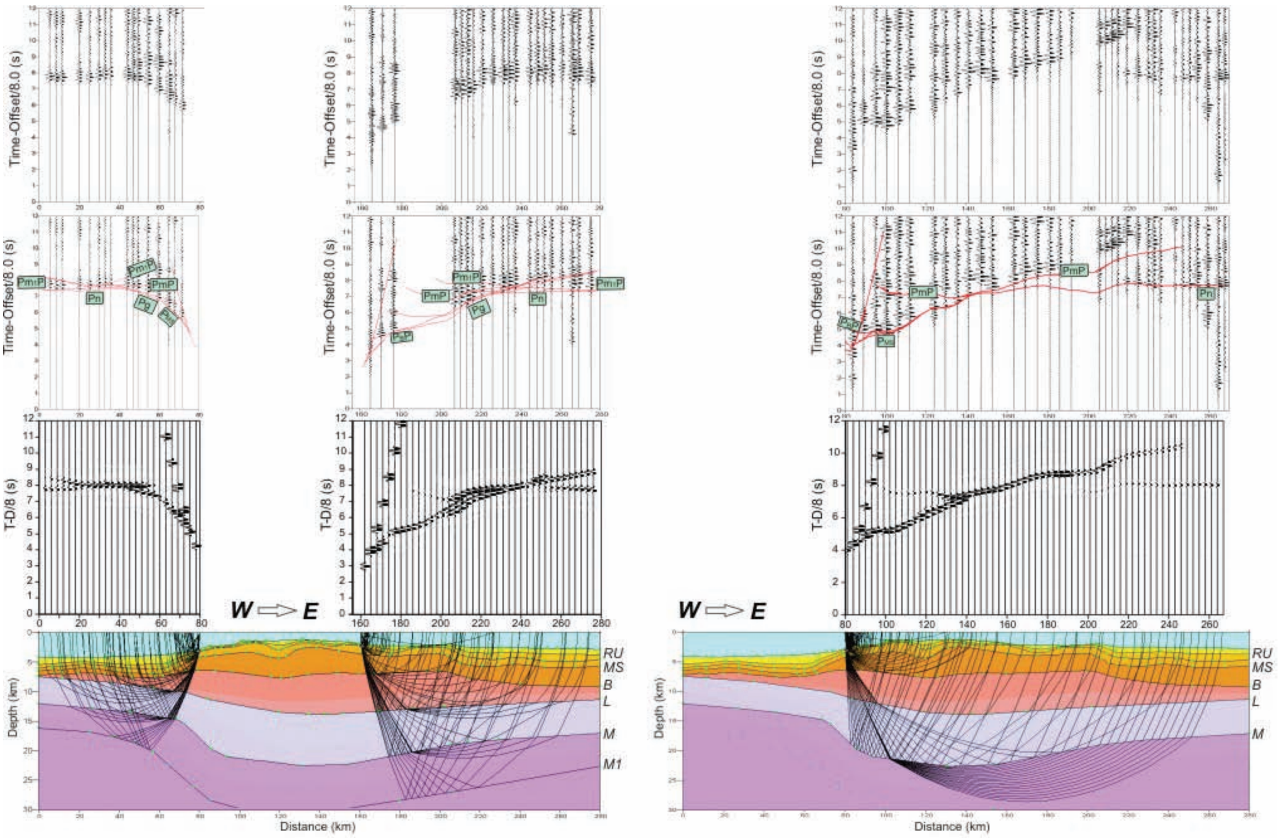
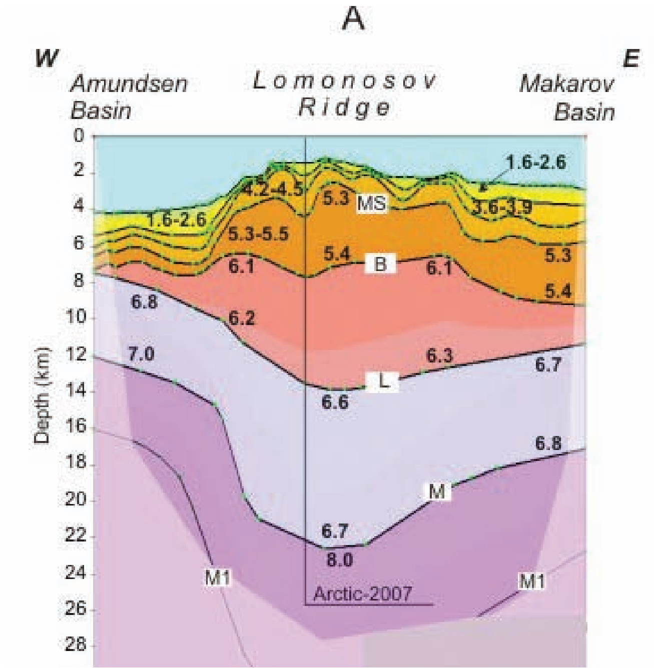


Fig. 7. Transarctica-1992 wide angle reflection/refraction profile, ray tracing and synthetic modeling. Major boundaries: RU - Regional unconformity, IL - Top of Intermediate layer, B - Top of Upper crust, L - top of Lower crust, M - Moho, M1- intra-mantle boundary

Conceivably, the seismic parameters of this layer may at different locations correspond to folded and mildly metamorphosed sedimentary units, or undeformed but highly compacted sedimentary rocks (e.g. quartzitic sandstones, dolomites), or sediments interleaved with volcanic flows or sills. Until the nature of that layer in the Pole to Siberia segment of the Lomonosov Ridge is understood with better confidence, we shall tentatively apply the definition proposed in LORITA model and refer to this unit as presumably Paleozoic to Early Mesozoic in age and 'metasedimentary' in composition (ms unit).



The main feature of the wave field is the presence of atypically strong Pn waves which may be due to their interference with Pm1P waves (as indicated by the synthetic modeling). The resulting velocity model of the Earth's crust along the 'Transarctica-1992' line is presented in Figure 8a.

Three sedimentary sequences, of which two upper ones are separated by a regional unconformity, are identified in the model. The upper sequence is characterized by i.e. velocities 1.6-2.6 km/s; the middle one, by i.e. velocities 3.6-3.9 km/s and the lower one, by i.e. velocities 4.2-4.5 km/s. Total thickness of the sequences reaches a maximum of ~3 km over a subsided block of the Lomonosov Ridge. On the top of the Ridge, it does not exceed ~1 km. The crust below the sedimentary sequences consists

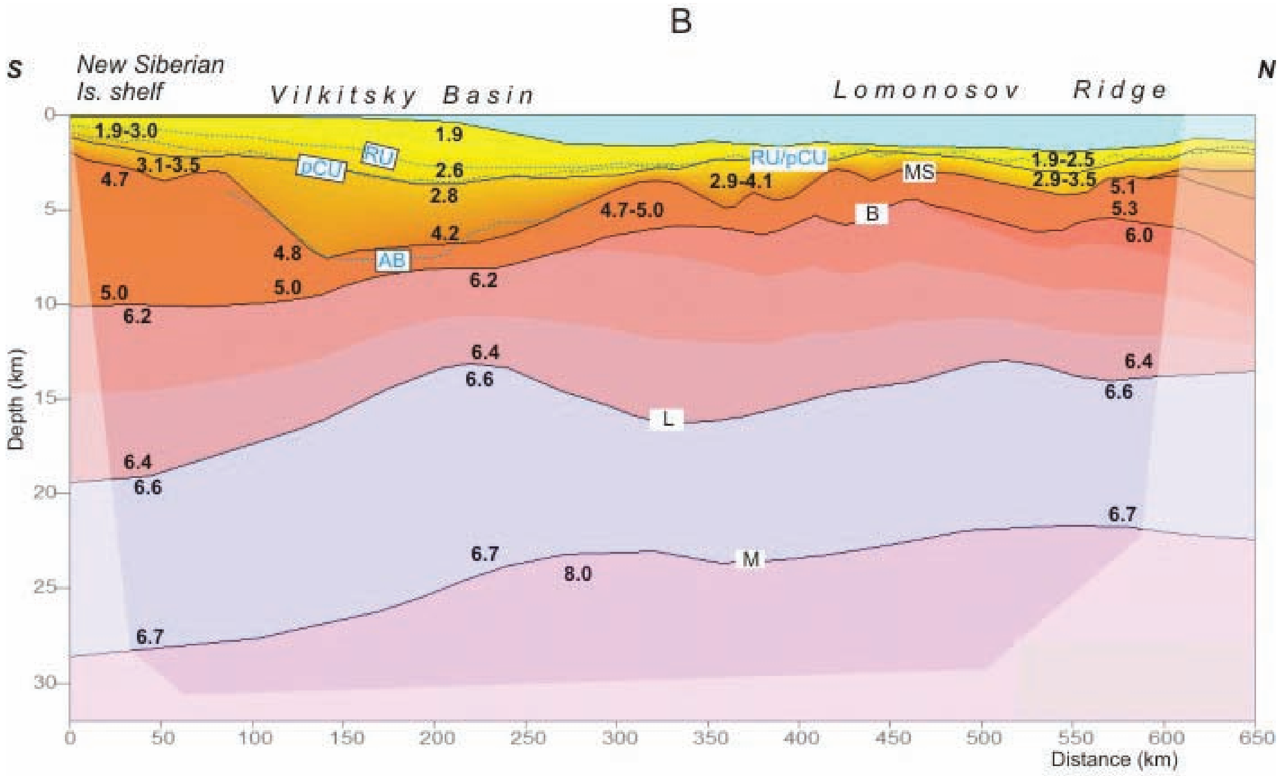


Fig. 8. Velocity models of the crust: (a) along Transarctica-1992 wide angle reflection/refraction profile, (b) along A-7 multichannel seismic reflection line and Arctic-2007 WAR profile. Major boundaries: MS - top of "metasedimentary" layer, B - top of upper crust, L - top of lower crust, M - Moho, M1- intra-mantle boundary. Bold digits – P-wave velocities (km/s), blue dotted lines – position of unconformities time/depth converted from A-7 multichannel seismic reflection profile (see Fig. 5 for designations).

of three velocity layers. Velocity parameters of the 'metasedimentary' layer (MS) are characterized by 5.3-5.5 km/s. Its thickness varies from ~1 km under the Amundsen Basin to ~4.5 km across the Lomonosov Ridge. In the Makarov Basin, it reaches a thickness of 3.0-3.5 km. The upper crust is characterized by velocities of 6.1-6.3 km/s and a thickness of between 6 and 7 km across the Ridge. Velocities in the lower crust do not exceed 6.7 km/s. The thickness of the lower crust varies within 7-9 km across the Ridge. Depth to the Moho discontinuity ranges from ~22 km at the Lomonosov Ridge crest to ~17 km and ~12 km beneath the Makarov and Amundsen basins, respectively. The intra-mantle reflections are coming from a depth of greater than 30 km under the Ridge, and from ~23 km and ~15 km in the Makarov and Amundsen basins, respectively.

WAR data 'Arctic-2007'

The 650 km long 'Arctic-2007' WAR line was shot along the Lomonosov Ridge from 83.5°N to the Siberian shelf north of the New Siberian Islands (Fig. 1). Data were recorded from ice stations. Thirty recording instruments were spaced at intervals of 5 km. TNT charges weighed from 200 to 1000 kg. The average spacing between shot points was 50 km. The maximum offset reached was 250 km.

Digital WAR data (sample rate 8 ms) were processed by using ProMAX 2D software. To improve data quality, true amplitude recovery for the offset and minimum-phase bandpass filtering of 2-3-6-8 Hz were applied. The approach to the interpretation of WAR data was similar to that applied for 'Transarctica-1992' line. The resulting model is presented in Figure 8b.

The results of WAR data interpretation along the 'Arctic-2007' line are shown in figure 9. The ray-tracing of seismic waves from selected shot points, synthetic wave fields generated by the final model, the corresponding seismic records superimposed with the calculated time-distance curves of reflection and refraction waves, and seismograms without interpretation of the wave field are presented. In addition, errors bars for picking of the arrivals are shown in Table 1.

On the seismic records, P-wave refractions in the upper crust (Pg), refractions in the upper mantle (Pn), reflections from the Moho discontinuity (PmP) as well as shot lineups of P-waves reflected from the top of the upper (PBP) and lower (PLP) crust are interpreted. A common feature of the WAR data is the lack of refraction waves passing through the lower crust in the first arrivals, as a result of which the velocities in the lower crust were estimated only from PmP waves.

The resulting 'Arctic-2007' velocity model (Fig. 8b) was controlled by multichannel seismic reflection data. Two sedimentary sequences are separated by a regional unconformity. The upper sequence is characterized by velocities from 1.9-3.0 km/s on the shelf to 1.9-2.5 km/s on the Lomonosov Ridge; the lower one, by velocities from 3.1-3.5 km/s on the shelf to 2.9-4.1 km/s on the Lomonosov Ridge and 2.9 to 3.5 km/s farther to the North Pole. Total thickness of the sequences reaches the maximum of ~7 km in the depocentre of the Vilkitsky Basin; on the Lomonosov Ridge, it does not exceed ~2 km. Consolidated crust consists of three velocity layers: 'MS', upper and lower crust. Velocity parameters of 'MS' are characterized by a lateral variability from 4.8-5.0 km/s on the shelf to 5.1-5.3 km/s on the Lomonosov Ridge. Thickness of the layer varies laterally from ~7 km on the shelf to ~1.5 km under the shelf edge; on the Lomonosov Ridge, it reaches a thickness of 3.5 km. The upper crust is characterized by velocities of 6.0-6.4 km/s and the thickness is 6-7 km. Velocities in the lower crust do not exceed 6.7 km/s. The thickness of the lower crust varies within 9-12 km. Depth to the Moho discontinuity ranges from 28 km on the shelf to 22-23 km on the Lomonosov Ridge.

According to the WAR data, all sedimentary sequences and consolidated crustal layers are continuous from the outer shelf of the Laptev - East Siberian Seas to the Lomonosov Ridge.

POTENTIAL FIELD DATA

Near North America

Of particular interest is the magnetic signature associated with the plateau of the Lomonosov Ridge and its onshore extension (Miles 2002; Damaske and Estrada 2006; Oakey et al. 2012) (Fig. 10). The linear magnetic anomalies highlighted in white on Figure 10b are present from near shore to the plateau. Oakey et al. (2012) have interpreted them as Cretaceous intrusives. These linear anomalies terminate against

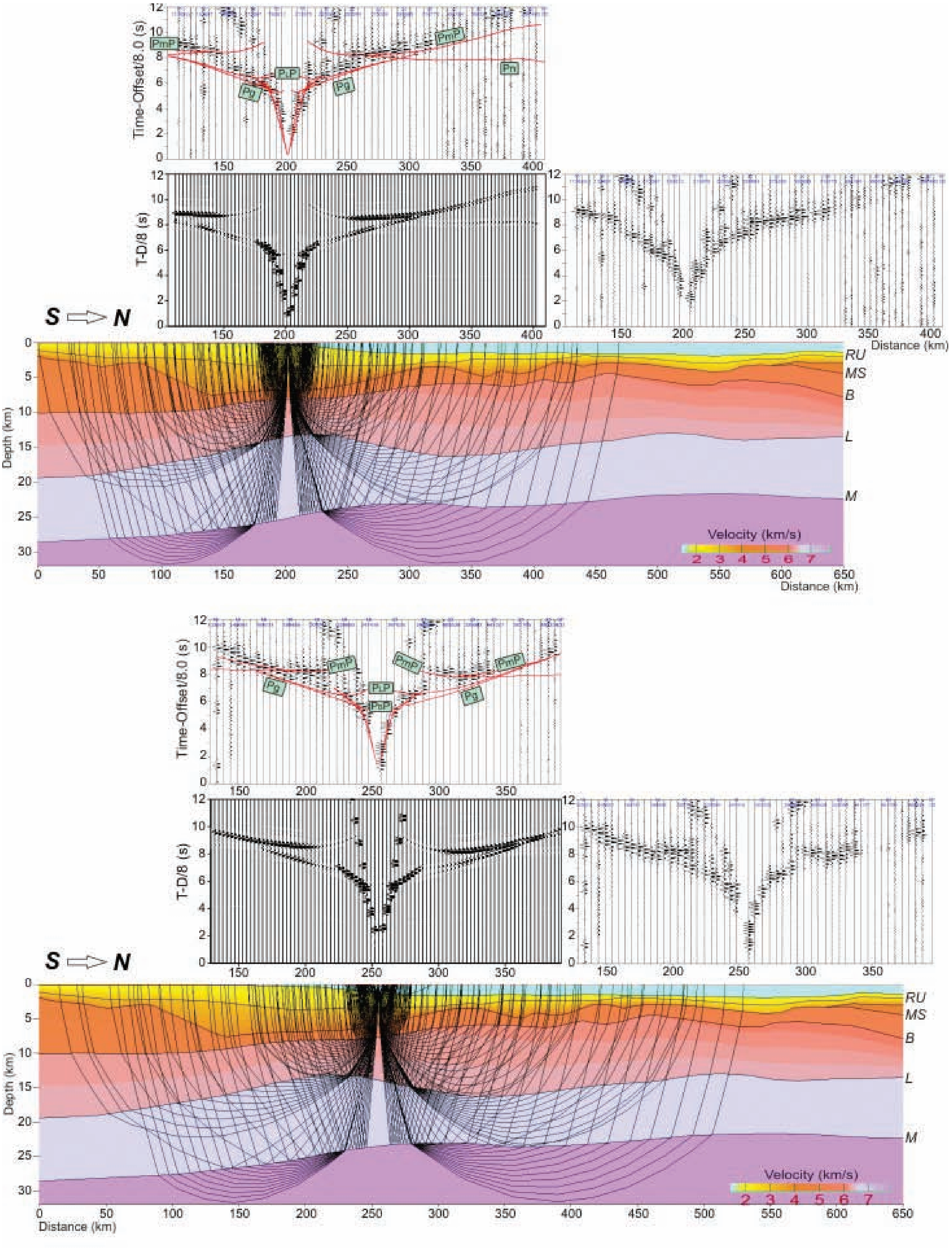


Fig. 9. Arctica-2007 wide angle reflection/refraction data: ray tracing and synthetic modeling. Major boundaries: RU-Regional Unconformity, IL - Top of Intermediate layer, B - Top of Upper crust, L - top of Lower crust, M – Moho.

Table 1. Number of observations (no. of shots, no. of picks), RMS misfit between calculated and picked arrival travel times, dominant phases for individual waves.

Line/Wave	No. of shots	No. of picks	RMS misfit(s)	Phase(s)
Transarctic-1992 line (digitized analog data)				
Sed. refractions	6	9	0.179	0.10
Metased. refractions	9	29	0.120	0.10
Upper Crust top reflections	7	22	0.160	0.10
Upper Crust refractions	12	40	0.116	0.10
Lower Crust top reflections	6	15	0.111	0.10
Lower Crust refractions	5	23	0.091	0.12
PmP	12	60	0.121	0.14
Pn	11	63	0.103	0.13
All observations (shots/traces)	14/280	261		
Arctic-2007 line (digital data)				
Sed. refractions	6	22	0.121	0.12
Metased. refractions	9	15	0.115	0.12
Upper Crust top reflections	11	34	0.095	0.12
Upper Crust refractions	18	120	0.114	0.13
Lower Crust top reflections	18	70	0.102	0.13
Lower Crust refractions	0			
PmP	20	167	0.111	0.17
Pn	14	48	0.106	0.16
All observations (shots/traces)	23/690	476		

a series of SSW-NNE trending magnetic highs that can be traced from Clements Markham Inlet (CMI) on Ellesmere Island to the southeastern edge of the Lomonosov Ridge. Oakey et al. (2012) suggest that this bounding feature marks the easternmost extension of the Pearya Terrane. Onshore, the Pearya Terrane (Trettin 1991) has a limited geographical extent of 300 km on Ellesmere Island.

The magnetic data show additional onshore/offshore correlations (Fig. 10b). There is a high amplitude positive circular anomaly (marked with a 'V' in a yellow circle) about 25 km in diameter surrounded by shorter wavelength linear anomalies (shown in yellow on Figure 10b). The circular anomaly is enclosed by the 500 m contour, and the linear anomalies by the 1000 m bathymetric contour. Onshore Ellesmere Island at the westernmost extent of the Pearya Terrane, there is a similar magnetic pattern (Fig. 10a and 10d) that is known to be caused by the Hansen Point Volcanic complex. The onshore volcanic complex is a 1000 m thick sequence of flows, pyroclastic rocks, and intercalated fluvial and marine clastic sedimentary rocks and coal (Trettin and Parrish 1987). The igneous rocks are bimodal, partly alkaline (Estrada et al. 2006). A WAR experiment offshore of the Hansen Point Volcanic complex (Asudeh et al. 1989) measured a value of 5.0 km/s at the seabed overlying a 5.8 km/s unit that is described as basement. These high velocities near the seafloor were unlike the lower velocities obtained

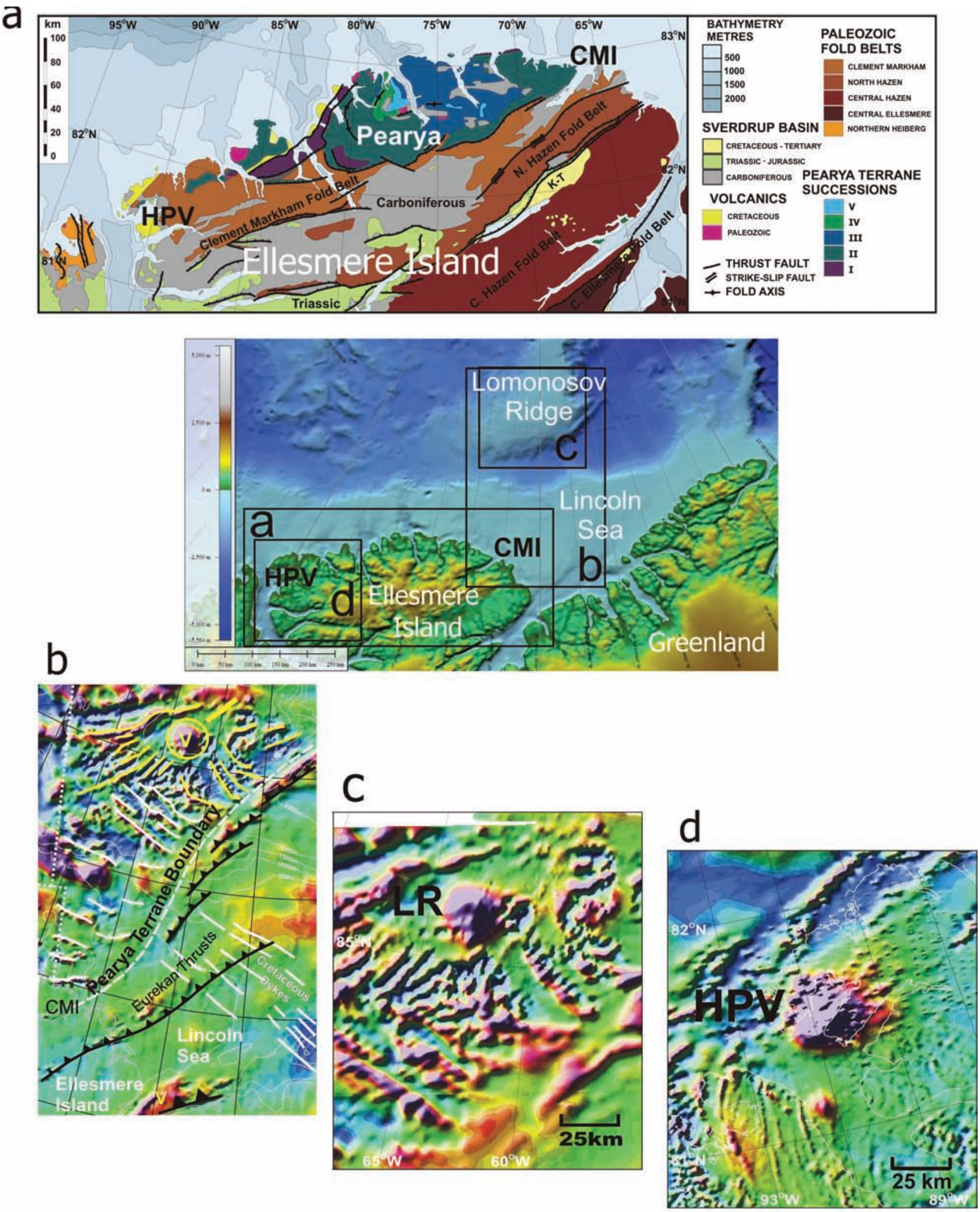


Fig. 10. Geological and bathymetric maps with 3 enlargements of magnetic surveys near the junction of the Lomonosov Ridge with the North American margin. Figure 10a illustrates the geology of northern Ellesmere Island for comparison with the magnetic anomalies. The black boxes labeled ‘a’, ‘b’, ‘c’ and ‘d’ on bathymetric map indicate relative positions of the geology map and the magnetic maps. CMI-Clements Markham Inlet, HPV- Hansen Point Volcanics, LR-Lomonosov Ridge, V-Volcanics

elsewhere on the margin at this depth. On the plateau of the Lomonosov Ridge near the circular magnetic anomaly, velocities of 5.9 km/s were recorded at the seafloor.

By analogy, based on the similar unique magnetic signatures of the plateau and the Hansen Point Volcanic complex, the consistent refraction velocities, and the proximity of the Pearya Terrane, we suggest that the plateau on the Lomonosov Ridge was caused by a magmatic event similar to the Hansen Point Volcanic complex modifying older continental crust.

High amplitude long wavelength magnetic anomalies associated with the Lomonosov Ridge to the north of the plateau are similar to those observed over the southern Makarov basin and the adjacent Alpha Ridge. Kritoffersen and Mikkelsen (2006) mention two sets of reflectors on the plateau of the Lomonosov Ridge and another set 600 km to the North along the Ridge (Kristoffersen 2001) at a depth of 600 m below the seabed that were interpreted as basaltic flows. Døssing et al. (2013) are able to trace magnetic anomalies from the edge of this section of the Lomonosov Ridge to the Alpha Ridge. We suggest that the magmatic event that is associated with the Alpha Ridge also affected the Lomonosov Ridge from the Pole to the margin of North America.

Near The Siberian Margin

Potential field data coverage in the area of transition from the Lomonosov Ridge to the Siberian margin is irregular (Fig. 11). Line spacing during airborne magnetic surveys conducted here between 1962 and 2007 varied dramatically, as well as RMS observation and navigation errors (Fig. 11a). Gravity information was also merged from different available data sources characterized by unequal accuracy (Fig. 11b). The best quality data were obtained within

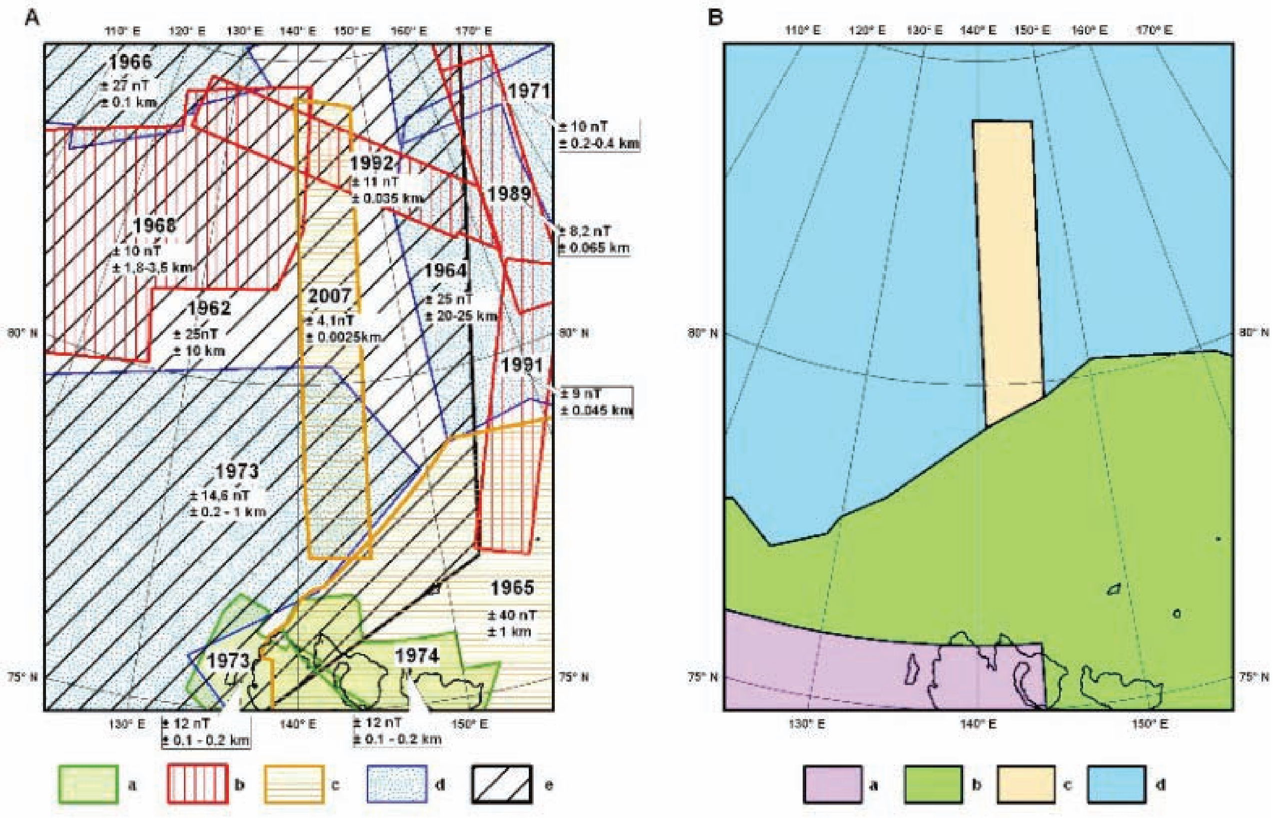


Fig. 11. Potential field data coverage near the junction of the Lomonosov Ridge with the Siberian margin. A) Airborne magnetic surveys with track line spacing: a) 2-5 km, b) 5 km, c) 10 km, d) 20-40 km, e) 40-50 km; the year of activity, RMS observation error (nT) and navigation error (km) are indicated for each survey. B) Gravity data sources: a) State free-air gravity anomaly map of the USSR at scale 1: 1,000,000; b) geophysical database to the State geological map of Russia at scale 1:1,000,000; c) results of 2007 airborne gravity survey; d) Arctic Gravity Project (Kenyon et al., 2008; http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm96/egm96.htm).

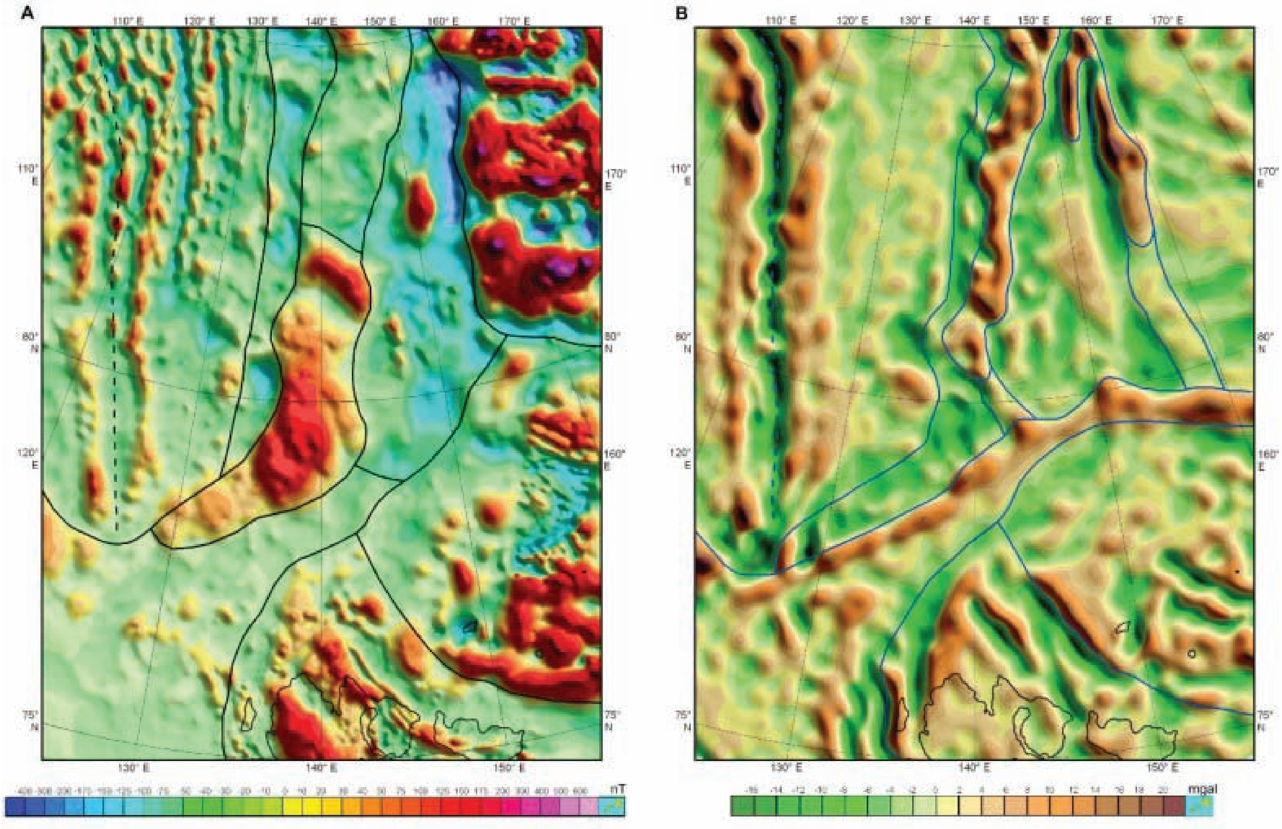


Fig. 12. Magnetic anomalies (A) and local Bouguer gravity anomalies (B) in the area indicated by box ‘C’ in Figure 1. Boundaries of potential field domains are shown by solid lines. The Gakkel Ridge axis is marked by a dashed line.

the corridor surveys performed along WAR lines ‘Arctica-2007’and ‘Transarctica-1992’ described above.

All available magnetic and gravity information was processed, adjusted and converted to grids of magnetic and free-air gravity anomalies with cells size of 2×2 and 3×3 km. Bouguer gravity anomalies were calculated using IBCAO grid (Jakobsson et al. 2008). Local Bouguer anomalies were computed as the difference between Bouguer gravity anomalies and their upward continuation to 20 km. Several grids of magnetic and Bouguer gravity anomaly transformations, such as vertical and total horizontal gradients, tilt-transformations, upward continuations were computed as additional tools for potential fields interpretation.

Analysis of the above information was carried out manually using GIS ArcMap v.9.2. Magnetic and gravity datasets were first considered independently and then correlated on the basis of sketch maps of magnetic and local Bouguer anomalies each showing the respective main features of potential fields zoning expressed as boundaries of differing domains (Fig. 12). The boundaries whose positions appeared matching or closely comparable on both maps were interpreted as reflecting the limits of major tectonic provinces and/or morphostructural features which are shown in figure 13 taking into account the above considered seismic evidence and available geological data.

The oceanic Eurasia Basin stands out for displaying a linear magnetic and gravity signature symmetrical relative to the Gakkel Ridge spreading axis. Between anomaly 24 and the base of the Lomonosov Ridge marked by distinct magnetic and gravity gradients, this signature fades out indicating the ocean-continent transition zone.

The crest and eastern spurs of the Lomonosov Ridge are clearly reflected in the gravity field, whereas the magnetic signature over the Lomonosov Ridge and the Laptev Sea shelf is rather flat and inexpressive, except the area around 80o N with intensive positive anomalies. The origin of these anomalies is unknown. Their interpretation may, perhaps, be facilitated by the notion of a similar pattern of the magnetic field on the conjugate side

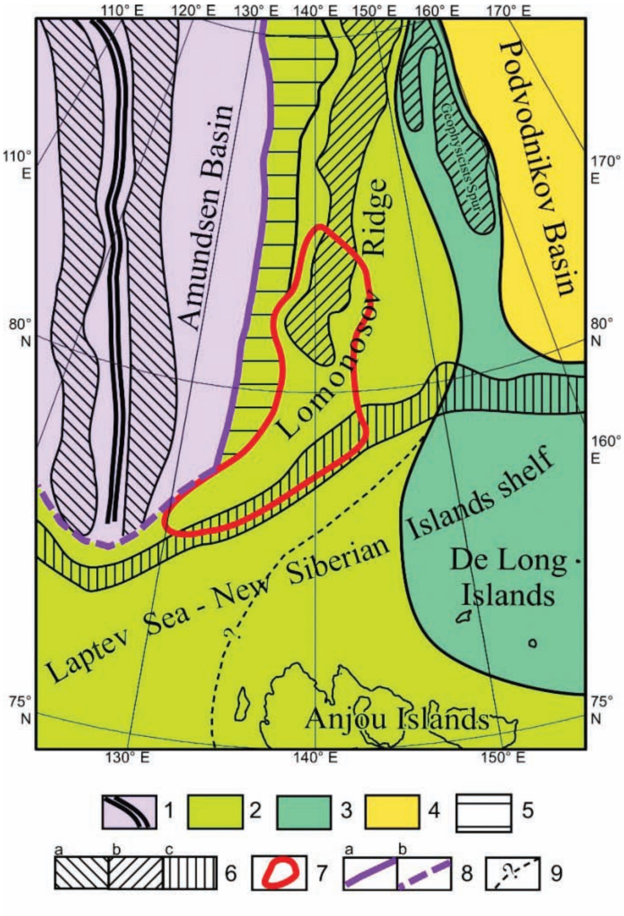


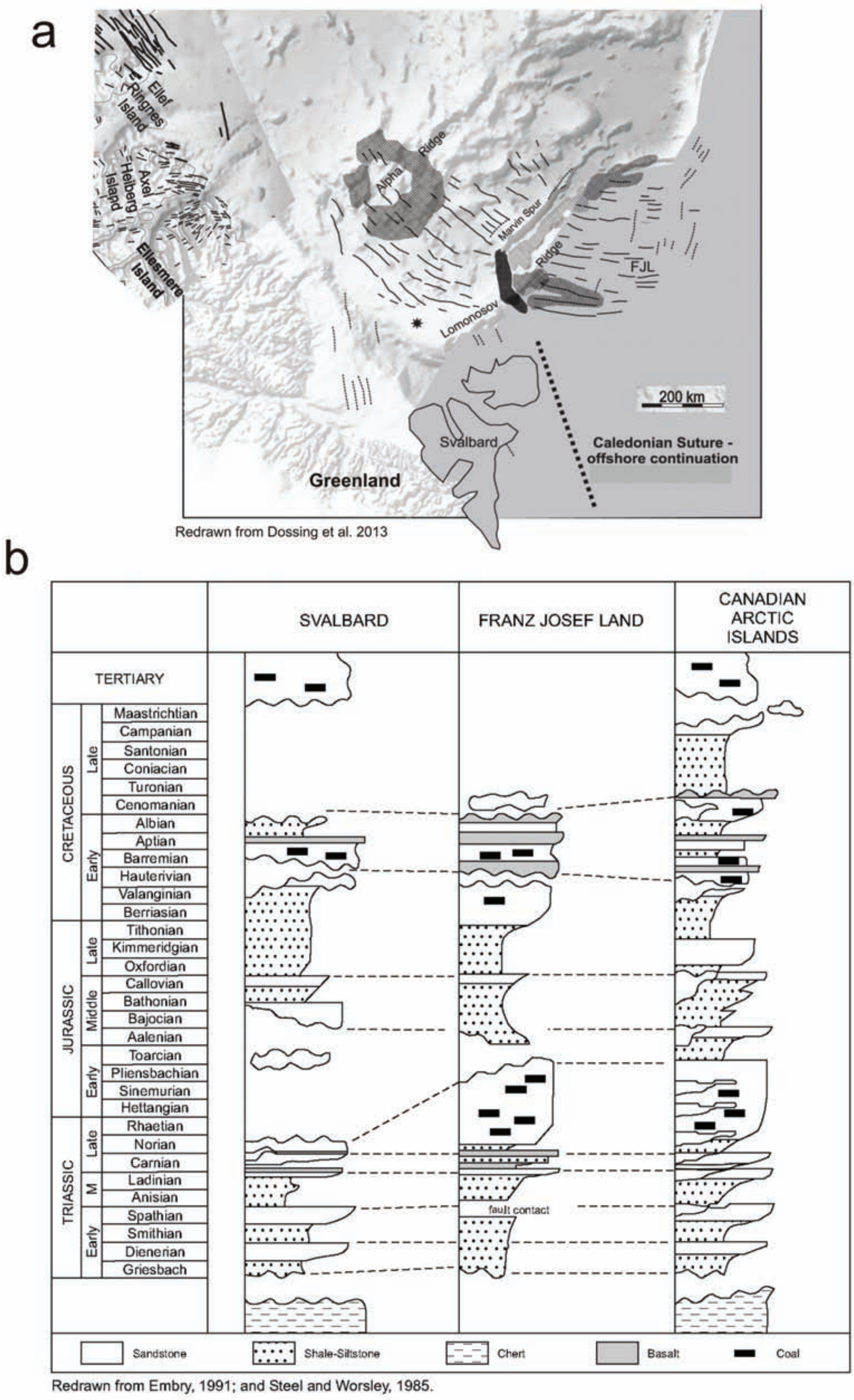
Fig. 13. Structural provinces and features near the Siberian margin. 1 – Cenozoic oceanic crust and the Gakkel Ridge spreading axis; 2-5 – rifted continental crust: 2 – Anjou Islands and its inferred continuation in the Laptev Sea and on the Lomonosov Ridge, 3 – De Long Islands province and its inferred continuation to the Geophysicists Spur, 4 – Podvodnikov Basin province, 5 – continent-ocean transition zone; 6 – linear gravity highs associated with a) the Gakkel Ridge, b) crestal parts of the Lomonosov Ridge and adjacent spurs, c) shelf edge effect; 7 – outline of prominent positive magnetic anomalies in the southern Lomonosov Ridge; 8 – position of the continent-ocean boundary a) as defined by Chron 24, b) speculative; 9 – potential field gradient interpreted as internal fault boundary within the Anjou Islands province.

of the southern Eurasia Basin at the submarine prolongation of the Taymyr structures.

The "Severny Transfer", or "Khatanga-Lomonosov Fracture Zone", etc. postulated in many works (e.g. Franke et al. 2001; Drachev et al. 2003; Engen et al. 2003) coincides with a narrow gravity high that evidently follows the Siberian shelf edge. For that reason we interpreted this high as resulting from "shelf edge effect" whose expression in local Bouguer anomalies may be mainly caused by insufficient accuracy of the IBCAO grid.

The area of New Siberian Islands and the surrounding shelf is characterized by general similarity of magnetic and gravity anomaly patterns. The discordance that can be observed between the Anjou Islands and the De Long Islands potential field domains (Fig. 13) is consistent with the different ages of these provinces (Mesozoic and Late Neoproterozoic-Early Paleozoic, respectively). Based on geological and geochronological evidence from the near-Pole Lomonosov Ridge (Backman et al. 2006; Grantz et al. 2001) and the Geophysicists Spur (Grikurov et al., this volume), we interpret both these provinces to extend northward from the Siberian shelf as shown in figure 13. We also assume that potential field gradients that appear to restrict the Anjou Islands block on the west do not manifest a division between different structural terranes but rather mark an internal boundary within a single tectonic province underlain by the Mesozoic fold basement which is exposed on Anjou Islands but rifted and subsided in the Laptev Sea Basin.

The Podvodnikov Basin domain is remarkable for contrasting magnetic signature which is expressed in alternating high-amplitude positive and negative anomalies that strike almost orthogonally to the Lomonosov Ridge. An explanation of such a strong magnetic signal in a deep-water basin with subsided, intensely stretched and thinned high-velocity crustal layers (Lebedeva-Ivanova et al. 2011) is not readily available. At present it can only be assumed that the anomalies are caused by deeply submerged very strongly magnetized magmatic sources whose formation must have occurred in extensional environment and could be associated with, or independent of the emplacement of HALIP.



Redrawn from Dossing et al. 2013

Redrawn from Embry, 1991; and Steel and Worsley, 1985.

Fig. 14. a) Plate reconstruction at anomaly 25 with the position of the Lomonosov Ridge relative to Franz Josef Land (FJL), Svalbard, Greenland and Ellesmere, Axel Heiberg and Ellef Ringnes islands. Circular region of high intensity long wavelength anomalies marked in dark gray on the Alpha Ridge is the focus of radiating linear magnetic anomalies shown by black lines and interpreted as dykes based on their onshore correlations. The star on the Lomonosov Ridge is the position of the circular magnetic anomaly shown in figure 10b and c. The darkest gray area that reaches from the Marvin Spur across the Lomonosov Ridge to the margin north of Svalbard traces a broad magnetic low. b) Mesozoic stratigraphy of the Svalbard, Franz Josef Land and Canadian Arctic Islands illustrating the similarity of volcanic-sedimentary sections and the age of unconformities.

DISCUSSION

Plate reconstructions for the Arctic and the North Atlantic oceans have been published on extensive magnetic and morphological data bases that define the magnetic anomalies and fracture zones (Srivastava and Tapscott 1986; Rowley and Lottes 1988; and Gaina et al. 2002). The reconstructions place the Lomonosov Ridge adjacent to the Barents and Kara margins prior to sea floor spreading in the Eurasia Basin (Fig. 14a). These reconstructions were performed with the Lomonosov Ridge remaining fixed to the North American plate. Because the pole of rotation for the North American and Eurasian plates is not accurate enough to be a point but is determined within an error ellipse, the motion of the Lomonosov Ridge relative to the North American and Siberian margins, if any, is less than the available constraints.

Gaina et al. (2002) calculate 600 km of extension in the Laptev Sea which is consistent with the width of the central Eurasia Basin but probably is an overestimate for its narrowing continuation on the Siberian shelf. The evidence for the extension in the Laptev Sea is predicted by the plate reconstructions as summarized by Pulvertaft and Dawes (2011), and numerous extensional features in the area (rifts, extensional faults) are documented by geological and geophysical observations (e.g. Drachev 2000; Franke et al. 2001; Sekretov 2001) suggesting the propagation of the Gakkel Ridge speading axis into continental crust that underlies the Laptev Sea. The rift activity has occurred over a long period from at least the Maastrichtian to present (e.g. Engen et al. 2003). Recent mapping indicates that the main rift underlying the Laptev Sea lies off-line from the Gakkel Ridge, and there is the possibility that 150-200 km of displacement between the Gakkel Ridge and the landward focus of extension may be accommodated by rift transfer (Engen et al. 2003) which took place beneath the shelf along a strike-slip fault within continental crust. We presume that the separation of continental crust due to seafloor spreading in the Eurasia Basin was manifested as a stretching regime on the continental margin of the Laptev Sea. Here the extension appeared sufficient to match the width of immediately adjacent oceanic opening in the southernmost Eurasia Basin, and the Siberian segment of the Lomonosov Ridge developed in geological uniformity with the adjacent part of the Siberian shelf. The absence of movement of the Lomonosov Ridge relative to the Siberian margin is indicated by the lack of present-day seismic activity in their junction zone (Engen et al. 2003).

Moore et al. (2011) interpret the Lomonosov Ridge as a microcontinent on the assumption that it is separated from the Siberian margin by a fault that would be difficult to detect because of the more than 1 km of Cenozoic sedimentary cover. However, the reflection profile ‘A-7’ that extends from the Lomonosov Ridge to the shelf penetrates well below the Cenozoic cover and shows that the sedimentary cover and acoustic basement are continuous across the transition zone. This is confirmed by the coincident WAR profile that also shows the continuity of the crustal layers.

A transform fault is also predicted (Moore et al. 2011) at the junction of the Ridge with the North American margin based on the bathymetry profile from the margin to the Ridge and the interpretation of a short WAR profile with a poorly constrained lower crust (Forsyth et al. 1994); the authors also ignore the results of the more detailed WAR (Jackson and Dahl-Jensen et al. 2010) that shows continental crust beneath the trough. Furthermore, Oakey et al. (2011) clearly show the magnetic lineations (Fig. 10) that are not displaced by a fault boundary and can be traced from onshore across the shelf, the trough and the plateau of the Lomonosov Ridge.

In addition, Døssing et al. (2013) describe magnetic anomalies that radiate from the Alpha Ridge onto the Queen Elizabeth Islands (Ellesmere Island, Axel Heiberg and Ellef Ringnes islands) and towards Greenland, and from the Alpha Ridge to Franz Josef Land and Svalbard (Fig. 14a). Based on the onshore continuation of the linear magnetic anomalies, they are interpreted to be caused by dykes formed in the Early Cretaceous. The pattern of the dykes establishes the position of the margins prior to seafloor spreading in the Eurasia Basin and prior to or early in the opening of the Amerasia Basin. Reconstructed dyke swarms are accurate indicators for the position of continents prior to sea floor spreading because they provide piercing points that can be matched (Buchan and Ernst 2006). Thus, Moore et al. (2011) suggestion of a transform fault between the Lomonosov Ridge and the Queen Elizabeth Islands margin is not supported by the available magnetic and geological data.

Mair and Forsyth (1982) correlated the velocity structure of the Lomonosov Ridge with that of the Barents Sea at 76°N and the Kara Sea at 78°N and 82°N. The velocity section of Franz Josef Land based on seismological data shows the sedimentary layer (3.2 km/s) on top of crustal layers 4.7-4.8 km/s, 5.7 km/ and 6.6-6.7 km/s with depth to Moho in the range 22-28 km (Dibner 1998). The 5.7 km/s layer recorded on Franz Josef Land is missing in the LOREX section on the Lomonosov Ridge, possibly due to the geometry and low resolution of the LOREX refraction profile. However, the 5.7 km/s layer is observed on the LORITA WAR velocity model, and the velocities of 5.3-5.5 km/s and 4.8-5.3 km/s are recorded on Transarctic-1992 and Arctic-2007 WAR profiles, respectively. Thus, the velocities of the crustal layers and depth to Moho are similar on the conjugate margins and are consistent with the plate reconstructions predicting that the Lomonosov Ridge was rifted from the Barents and Kara seas margin.

Also of interest are the lower crustal velocities that do not exceed 6.8 km/s along the length of the Lomonosov Ridge or on the adjacent margins. This velocity limit is typical of Paleozoic continental crust (Holbrook et al. 1992). The depth to Moho for the Lomonosov Ridge varies from 22 to 28 km and is also consistent with the crustal thickness range of other continental margins.

The plate reconstructions indicate that prior to seafloor spreading in the Eurasia Basin the Lomonosov Ridge was in proximal position to the Queen Elizabeth Islands, Greenland, Svalbard and Franz Josef Land (Fig. 14a). Before the plate reconstructions were well established, striking lithological similarities were observed in the Late Paleozoic to Mesozoic sections of the Sverdrup Basin, northeast Greenland, Franz Josef Land and Svalbard (Embry 1994; Harland 1997, Nassichuk and Davies 1980; Fig 14b). Thus, the plate reconstructions in context of the circum Arctic geology predict that the Lomonosov Ridge was a part of the Paleozoic to Mesozoic basin continuous between the Barents-Kara seas and the North American margins.

CONCLUSIONS

The improved bathymetric data for the Lomonosov Ridge accompanied by seismic reflection profiles indicate that the Ridge consists of a number of elongated sub-parallel continental fragments; for example, the Marvin Spur between the Pole and the North American margin and the en echelon ridges from the Pole towards the Siberian margin. An exception to this morphological character is observed near the margin of Ellesmere Island and Greenland where the widest part of the Ridge is occupied by a plateau. Based on tracing the Clements Markham Fault offshore and the occurrence of similar circular magnetic anomalies onshore and offshore, the plateau is interpreted as a geological counterpart of the Pearya Terrane affected by volcanic activity. The position of the Lomonosov Ridge relative to the Ellesmere Island margin is thought to be stable based on magnetic anomalies attributed to dykes. On the reconstruction at anomaly 25 these dykes can be traced from the Queen Elizabeth Islands and from Franz Josef Land to the Alpha Ridge.

On the Siberian margin a seismic reflection profile that extends from the shelf along the Lomonosov Ridge is interpreted with seismic reflectors continuing from onshore to offshore without faulting. Furthermore, the accompanying WAR velocity model shows that sedimentary and crustal velocities can be followed across the margin onto the Ridge. The presence in Bouguer anomalies of shelf edge effect can be explained by insufficient accuracy of the bathymetric grid and does not necessitate the existence of a sharp structural junction. The lack of present-day seismicity indicates the absence of active faulting, and plate reconstructions are readily accomplished without a transform fault between the Ridge and the margin.

The upper crustal velocities on the Lomonosov Ridge near the North Pole are similar to those observed on Franz Josef Land. The lower crustal velocities from the Queen Elizabeth Islands margin along the Lomonosov Ridge to the Siberian margin all show values of 6.8 km/s or less typical of rifted lower continental crust. This is consistent with plate reconstructions that would place the Lomonosov Ridge prior to seafloor spreading in the Eurasia Basin against the margins of the Barents and Kara seas. The plate reconstructions also show the proximity of the

North American and the Barents-Kara seas margins which is substantiated by the similar stratigraphy of the Queen Elizabeth Islands, Svalbard and Franz Josef Land from the Carboniferous to the late Cretaceous time.

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