Main Structural Elements of Eastern Russian Arctic Continental Margin Derived from Satellite Gravity and Multichannel Seismic Reflection Data

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Abstract - This paper presents an analysis of the altimeter derived marine gravity data and available multichannel seismic reflection profiles of the northeastern Siberia continental margin to provide a preliminary delineation of its geologic structure. Both data sets allow making a suggestion that the continental margin was strongly affected by the rifting process since mid of Mesozoic. The main rift zones extend south- and southeastward from the shelf edge toward the mainland. These are the Laptev Rift System, New Siberian and Vil'kitskii rifts in the East Siberian Sea, and North Chukchi rift basin in the Chukchi Sea. These structures may represent both active and aborted rifts related to extension episodes in the Arctic Ocean, namely: initial rifting in the Canada Basin (Middle Jurassic to Hauterivian), opening of the Makarov Basin (53-80 Ma ?) and spreading in the Eurasia Basin (0-56 Ma). Thus it is suggested that the spreading migrated westward during the Cretaceous-Cenozoic time and led to separation and fragmentation of the continental blocks (Lomonosov and Mendeleev ridges, Chukchi Plateau) and subsidence of the rift basins on the eastern Russian Arctic continental margin.

Introduction

The Arctic Ocean is unique among the oceans of the world in that half of its area is underlain by continental shelf, primarily the wide European and Siberian continental shelves. The Laptev, East Siberian and Chukchi seas overlie the extensive shelf of northeaster Russia which is up to 800 km wide and totals about 2,000,000 km^2 in area (Figure 1). To the north, this continental margin is bordered by the Eurasia and Amerasia oceanic basins which contain large submarine ridges and plateaus including: the Gakkel, Lomonosov, Alpha-Mendeleev and Chukchi Borderland.

The structure and tectonic history of the shelf are very poorly known and are primarily a postulated extension of the terrestrial geology of the New Siberian, De Long and Wrangel islands and the mainland (Vinogradov et al., 1977; Vinogradov, 1984; Fujita and Cook, 1990; Kos'ko, 1984; Kos'ko et al., 1990). Of the three seas, the Laptev Sea is better known as the result of the Russian seismic reflection studies which have defined the rift basins (Ivanova et al., 1990; Drachev et al., 1995a). The structural pattern and geological history of the remainder of the continental margin are still largely unknown and there are as many points of view as there are investigators. Since beginning of the 1970s, the Russian airborne magnetic data were the primary available means of deciphering the geology of this region (for more detail see Fujita and Cook (1990) and references contained therein). Also the northwestern part of the Chukchi Sea is crossed by eight U.S. Geological Survey multichannel seismic reflection (MCS) profiles (Grantz et al., 1986, 1990). In 1989, 1990, and 1993-1994 several seismic lines were acquired

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in the western part of the East Siberian Sea by Russian and German research institutes (Sekretov, 1993a; Drachev et al., 1995b; Roeser et al., 1995). In this paper we present our hypothesis on the structure of the eastern Russian Arctic continental margin (ERAM) and its relationship to the evolution of the Arctic oceanic basins, based on combining of the recently obtained satellite altimeter gravity data with the results of the offshore MCS surveys.

Tectonic setting

The ERAM occupies an area where the Siberian Craton, Early Mesozoic Taimyr Fold Belt, and Late Mesozoic New Siberian-Chukchi and Verkhoyansk-Kolyma fold belts come together (Figure 1). The latter two are divided by the narrow and highly deformed Lyakhov-South Anyui ophiolitic suture which has been suggested by Savostin et al. (1984b), Parfenov and Natal'in (1986), Drachev and Savostin (1993) to be a zone of collision between northeastern edge of the Laurasia supercontinent and New Siberian-Chukchi microplate in the mid Cretaceous time. The deformed Paleozoic and Mesozoic complexes of these large tectonic elements form a poorly known heterogeneous basement overlain everywhere with a sharp angular unconformity by almost undeformed clastic sequences of Late Cretaceous to Cenozoic in age. These sequences fill the extensive offshore sedimentary basins which are believed to be initially originated by rifting and post-rift thermal subsidence during the opening of the Arctic oceanic basins. The Laptev Sea rifts reveal a strong link to sea-floor spreading axis (Gakkel Ridge) in the Eurasia Basin (Grachev, 1982; Drachev et al., 1995a; Roeser et al., 1995). The kinematics of the opening of this basin is well understood because it contains a readily decipherable sea-floor magnetic pattern suggesting that sea-floor spreading may have begun as early as 54-64 Ma (Karasik, 1968; Karasik et al., 1983; Kovacs et al., 1983; Savostin et al., 1984a). The poorly studied rifts of the East Siberian Sea and northwestern part of the Chukchi Sea probably originated in the similar tectonic conditions in response to earlier spreading episodes in the Amerasia Basin.

Satellite derived altimeter data

Satellite radar altimetry is the means to derive marine gravity field through accurate measurement of the average sea surface topography. The ERS-1 satellite, launched in 1991, provided the first altimetric observations of the Arctic Ocean to latitudes of 82° N.

However the ERAM suffers coverage by both seasonal and, in some areas, permanent sea ice cover. Satellite altimeter data over sea ice areas are normally excluded from global marine gravity fields as the onboard estimates of surface height suffer greatly increased noise due to changes in the return echo waveform (Laxon, 1994). To overcome this problem, techniques have been developed to reprocess the individual return echoes in order to significantly reduce noise and allow marine gravity anomalies to be extracted in the usual manner (McAdoo and Marks, 1992). This process was used to derive the first satellite marine gravity field of the Arctic Ocean from a single 35-day repeat cycle of ERS-1 giving an unprecedented view of its tectonic fabric (Laxon and McAdoo, 1994).

The gravity field presented in this paper supplants that first Arctic field. This new, higher resolution field is derived from much more data including data from the ERS-1 geodetic mission whose a 168-day repeat cycle yielded a dense grid of observations with a spacing of less than 4 km at altitudes above 60° N. The resolution of this new gravity field, estimated by comparisons with airborne gravity data, is approximately 30-35 km (Laxon and McAdoo, 1998).

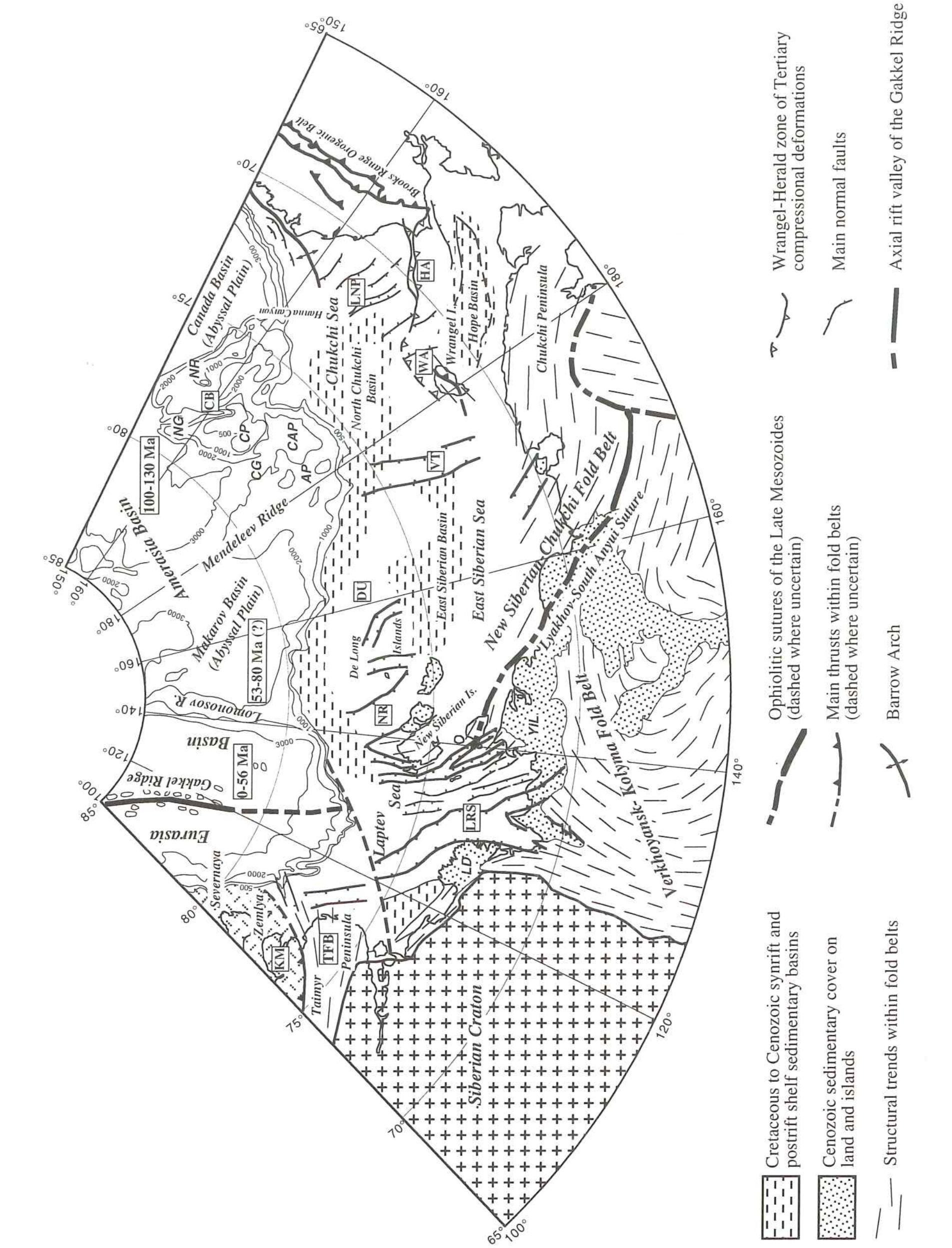

Figure 1: Geographical features and the main structural elements of the eastern Russian Arctic continental margin and adjacent regions. Polar stereographic projection. The italic capital letters show location of the physiographical features: LD - Lena Delta, YIL - Yana-Indigirka Lowland, AP - Arlis Plateau, CAP - Chukchi Abyssal Plain, CG - Charlie Gap, CP - Chukchi Plateau, NG - Nautilus Gap, NR - Northwind Ridge. Outlined bold capital letters denote the structural elements: KM - Kara Massif, TFB - Taimyr Fold Belt, LRS - Laptev Rift System, NR - New Siberian Rift, DU - De Long Uplift, VT - Vil'kitskii Trough, WA - Wrangel Arch, HA - Herald Arch, LNP - Listric-normal faults province, CB - Chukchi Borderland. Outlined bold numbers denote the time of the spreading events in the Arctic oceanic basins in millions of years.

Laptev Sector (Laptev Sea and southern Eurasia Basin)

This sector of ERAM is bounded by the Taimyr Peninsula and Severnaya Zemlya Archipelago on the west and New Siberian Islands on the east (Figure 1). It contains the southern termination of the Gakkel spreading ridge and thus its geologic structure is the result of a continental margin/spreading ridge interaction. The new gravity data (Figure 2) confirm the map-view geometry of the main elements of the rift system, which were previously mapped by MCS surveys (Drachev et al., 1995a), and provide more details where the seismic profiles are lacking.

The Laptev Rift System consists of several deep subsided rift basins and uplifted or high-standing blocks of the basement (Figures 2 and 3). From the west to the east there are: the West Laptev and South Laptev rift basins, Ust‘ Lena Rift, Stolbovoi and East Laptev horsts, Bel‘kov-Svyatoi Nos and Anisin rifts. The structural pattern of the central and eastern parts of the shelf are clearly expressed in the gravity field with the low-to-high variations from -35 mGal over the rifts to 50 mGal over high-standing blocks. The Ust‘ Lena, Bel‘kov-Svyatoi Nos and Anisin rifts are particularly prominent. The total preliminary estimated thickness of the rift-related sediments varies between 4 and 8-9 km while on the horsts the sedimentary cover is significantly reduced and its thickness does normally not exceed 2-2.5 km. The rift sedimentary fill contains several seismic stratigraphic units predicted to be of Late Cretaceous to Early Pliocene in age and its internal structure reflects the different stages of the spreading ridge/continental margin interaction (Figure 3). The whole shelf is covered by uppermost seismic unit. Onshore stratigraphy supports the Late Pliocene to Holocene age for them. This succession probably reflects a deceleration of the rifting during the last reorganization of the North American/Eurasian plates interaction about 2 Ma as shown by Cook et al. (1986) who calculated the present-day Euler Pole of the Eurasian/North American plates to be near the coast of the Laptev Sea.

The rifts strike SE-NW from the coast toward the shelf edge. The Bel‘kov-Svyatoi Nos Rift contains a long and narrow axial horst in the southern part that divides it into two parallel grabens continued on the land. To the north this rift merges the Anisin Rift reaching the shelf edge at about 77° N 130° E. The northern part of the rift is seismically active (Fujita and Cook, 1990; Avetisov, 1993) and can be considered present-day manifestation of the extension axis of the Gakkel Ridge on the shelf. The Ust‘ Lena Rift and South Laptev Rift Basin, however, are not continuous across entire shelf but are terminated by a NE-SW structural line which is well-expressed in the gravity field. This line is coincident with the continental slope of Amundsen Basin, then follows previously outlined Severnyi (Northern) Graben (Vinogradov, 1984) and extends further toward the Khatanga Bay between Taimyr Peninsula and the mainland (Figure 2). The existence of such lineament was inferred by Fujita et al. (1990) who described it as Severnyi Transfer. In our opinion this lineament which we call the Northern Fracture could have acted as a transform fault during some stage of opening of the Eurasia Basin and displacement of the Lomonosov Ridge relative to the Laptev Shelf.

The decrease of the rift sedimentary fill as one moves eastward from 10-12 km in South Laptev Basin to 4-5 km in Bel‘kov-Svyatoi Nos Rift and simplification of the structure as a whole suggest migration of the rifting in an eastward direction. The West Laptev and South Laptev rift basins may represent failed rifts associated with beginning of the rifting prior the continental breakup and initiation of sea-floor spreading at about 58 Ma. Such migration of the rifting could take place since the spreading axis in the Eurasia Basin had to migrate eastward with respect to the Barents-Kara continental margin.

The structural pattern of the Eurasia oceanic basin and Gakkel Ridge southward of 80° N is not morphologically expressed as they are buried under a thick sedimentary cover. The first MCS data were acquired there in 1990 by the Russian Marine Arctic Geologic Expedition

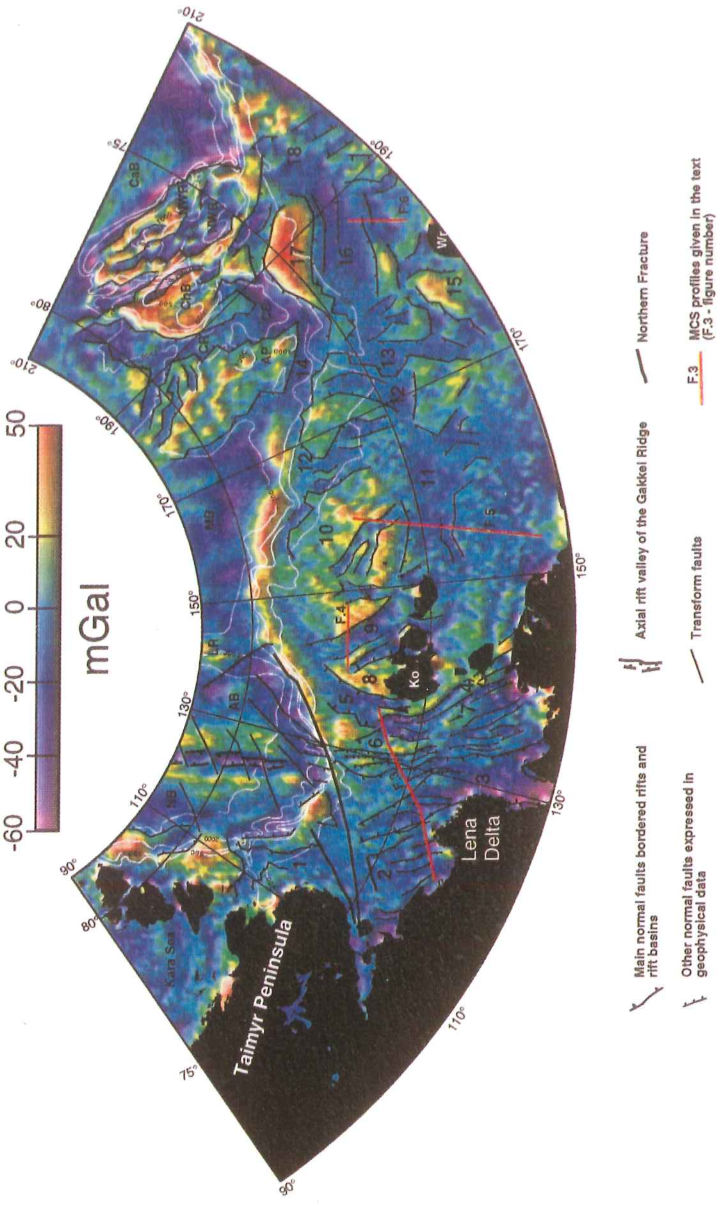

Figure 2: Altimeter derived marine gravity field and main structural elements of the eastern Russian Arctic continental margin. Polar stereographic projection. The bold numbers denote the geological structures on the continental shelf: 1 - West Laptev Rift Basin, 2 - South Laptev Rift Basin, 3 - Ust' Lena Rift, 4 - Bel'kov-Svyatoi Nos Rift, 5 - Anisin Rift, 6 - East Laptev Horst, 7 - Stolbovoi Horst, 8 - Kotel'nyi Uplift, 9 - New Siberian Rift, 10 - De Long Uplift, 11 - East Siberian Basin, 12 - Vil'kitskii Rift System, 13 - Vil'kitskii Trough, 14 - Toll' Rift, 15 - Wrangel Block (Arch), 16 - North Chukchi Rift Basin, 17 - North Chukchi Uplift, 18 - Listric-normal faults province. The capital bold letters show the structural features of the oceanic areas: NB - Nansen Basin, AB - Amundsen Basin, LR - Lomonosov Ridge, MB - Makarov Basin, AP - Arlis Plateau, CB - Chukchi Basin, CR - Charlie Rift, ChB - Chukchi Borderland, NWB - Northwind Basin; NWR - Northwind Ridge, CaB - Canada Basin. The white letters are: Ko - Kotel'nyi Island, Wr - Wrangel Island.

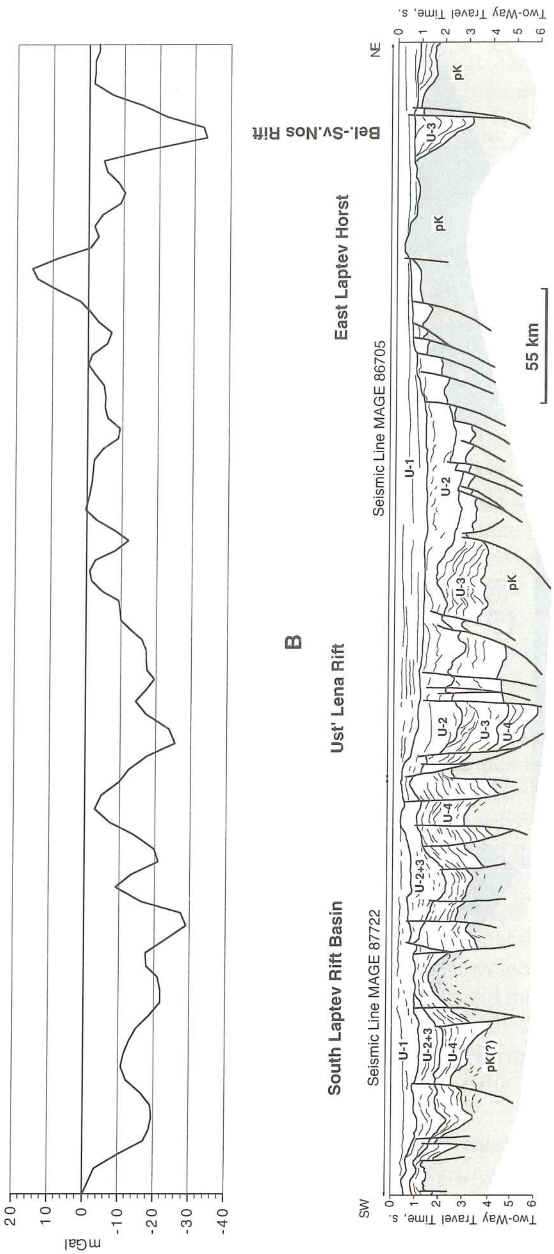

Figure 3: Free air gravity chart (A) and line drawing of the MCS profiles MAGE 87722 and 86705 by Marine Arctic Geologic Expedition (B) showing inferred geologic structure and stratigraphy across the Laptev Rift System (see Figure 2 for location). U-1 to U-4 denote the seismic stratigraphic units of following predicted age: U-1 - Late Pliocene to Holocene, U-2 - Oligocene to Pliocene, U-3 - Late Paleocene to Eocene, U-4 - Late Cretaceous to Paleocene (within the South Laptev Rift Basin this unit might be older (Cretaceous ?) than in the Ust' Lena Rift), U-2+3 - Eocene to Late Miocene (within the South Laptev Basin only).

(Sekretov, 1993b) but they are not published yet. The new gravity data give an unique insight into structure of this very interesting spreading ridge/continental margin conjugation.

The Gakkel Spreading Ridge is sharply displayed in the gravity field by a narrow low about -20 to -50 mGal and surrounding gravity highs of 10 to 30 mGal, which reflect an axial rift valley and both uplifted flanks of the buried ridge correspondingly. The rift valley is traced onto the continental slope up to 78° 30' N 126° 15' E, where it is cut by a set of oblique lineaments which appear to be transform-like fractures. Several transform faults can also be recognized within the ridge. They segment the ridge but do not reveal a visible offset and can be considered zero-transform faults.

The southern Eurasia Basin has been crossed by several MCS profiles in 1990 (Sekretov, 1993b). These data show a thick (about 5-8 km) sedimentary sequence suggested to be a Late Cretaceous to Cenozoic in age. The Gakkel Ridge is buried under its upper (Miocene to Holocene) part.

East Siberian Sector (East Siberian Sea and Southern Makarov Basin)

This sector is located between 140° and 180° E and thus is the central part of the ERAM. There is a limited amount of available MCS and seismic refraction data obtained by the Russian and German scientists in 1989-1994 in the western part of the East Siberian shelf, mainly northward of New Siberian Islands (Gramberg et al., 1993; Sekretov, 1993a; Drachev et al., 1995b; Roeser et al., 1995). Satellite altimeter data give us the opportunity to extend the structural contours, localized previously by seismic surveys, and to provide a preliminary delineation of the structure of the seismically unstudied areas (Figure 2).

The 500 km long and 100-120 km wide New Siberian Rift is a most prominent negative gravity feature of the East Siberian shelf. It occurs between the De Long and Kotel'nyi uplifts extending NW-SE toward central part of the shelf where it merges with the East Siberian sedimentary basin. The triangle-shaped Kotel'nyi Uplift separates the New Siberian Rift from the Laptev Rift System and consists of folded Paleozoic to Mesozoic clastic and carbonate complexes covered with thin, less than 1 km of thick, Upper Cenozoic sediments. The northern part of the rift was studied by joint German-Russian geophysical survey in 1993 (Roeser et al., 1995). It includes two deep subsided parallel grabens divided by a narrow horst, as shown on Figure 4. These features are well distinguished in the gravity field (Figure 4A). The preliminary estimated thickness of the Cenozoic sediments within the rift exceeds 5 km.

De Long Uplift, the large ellipsoid-shaped positive feature of the region, occurs between 145° and 175° E extending northward of 75° N up to the shelf edge. It comprises high-standing block of the folded basement (Bennett and Henrietta terranes; for more details see Fujita and Cook, 1990) covered by subaerial Cretaceous (Albian) and Late Cenozoic basaltic flows and Upper Cenozoic sediments. The boundaries and internal structural pattern of the uplift are clearly expressed both in gravity (Figure 2) and magnetic (Macnab, 1993; Verhoef et al., 1996) fields. The latter reveals a pattern typical for a volcanic plateau consisting of high amplitude short wavelength anomalies. Gravity and MCS data show small grabens and horsts which complicate the internal parts of the plateau (Drachev et al., 1995b; Roeser et al., 1995). In the northeast the uplift is bordered by the Vil'kitskii Rift System, whose western branch enters the uplift and merges with the East Siberian Basin. The northeastern slope of the uplift has been crossed by Marine Arctic Geologic Expedition MCS profile (Sekretov, 1993a). According to these data, the thickness of the sediments in the area of the continental slope northward of the uplift reaches 6-8 km and their age is predicted to be Aptian to Cenozoic.

In the area between 150° and 160° E the New Siberian Rift joins the East Siberian sedimentary basin. The latter occupies the central part of the East Siberian Shelf, bordering the De Long

Uplift on the south. The MCS profile LARGE 8901 (by Laboratory of Regional Geodynamics, Moscow) crosses this area and provides more details about internal structure and relationship between structural elements displayed in the gravity field (Figure 5). The southwestern part of the shelf is occupied by a structural terrace that represents a gently northward dipping of the acoustic basement and seismic reflectors toward the East Siberian Basin. Previously this area was suggested to be the deep subsided Blagoveshchensk sedimentary basin underlain by thinned continental or even oceanic crust and separated by a linear basement uplift (Anzhu Ridge) from the New Siberian Basin (Fujita and Newberry, 1982; Kos'ko, 1984; Fujita and Cook, 1990). Our data show neither Blagoveshchensk Basin nor Anzhu Ridge in this area.

The East Siberian Basin is bounded by the normal faults both from the shelf terrace and De Long Uplift (Figure 5B). The marginal parts of it are the deeper with the top of the acoustic basement at a depth of 3.5 s TWT, whereas in the central part of the basin the basement is occurred at 2.0-2.3 s TWT and affected by the numerous low-amplitude near-vertical normal faults (Figure 5B). A boundary between the De Long composite terrane and the rest of the basin basement is well expressed in the MCS data. It is a narrow (about 5 km) zone consisting of several anticline-shaped folds accompanied by thrusts and reverse faulting within the lowermost part of sedimentary cover. It can be considered either a compression or transpression fracture. The sedimentary cover of the basin is composed of 5 to 7 seismic stratigraphic units which were suggested to be Cretaceous to Holocene in age (Drachev et al., 1995b). The two uppermost units form an uninterrupted cover while others were deposited by both northward (from the mainland) and southward (from the De Long Uplift) sediment transport.

The eastern part of the East Siberian Shelf is occupied by the Vil'kitskii Rift System comprised of several NE-SW trending rifts. It has not been studied by offshore MCS profiling but can be delineated by satellite gravity and airborne magnetic data (Figure 2; for magnetic field see Macnab, 1993; Verhoef et al., 1996). The previously delineated Vil'kitskii Trough (Vinogradov, 1984; Fujita and Cook, 1990) is one of the most prominent members of the rift system and represents a natural boundary between East Siberian and Chukchi sectors of ERAM. There are no data to infer the age of the sedimentary fill of this rift system and the nature of the basement. However, by an analogy with the East Siberian Basin, we suggest the former to be of a Cretaceous (Middle to Late Cretaceous ?) to Quaternary age and the latter to be composed of deformed complexes of the Late Mesozoic New Siberian-Chukchi Fold Belt.

The southern Makarov Basin appears gravitationally as a smooth, low area, outlined by the 2000 m isobath (Figure 2). It does not reveal any clear structural zonality and is probably underlain by a thinned continental crust covered with a thick (8-9 km) sedimentary cover as it shown by seismic refraction and MCS data (Gramberg et al., 1993; Sekretov, 1993a). The southeastern wedge-shaped end of the basin separates the continental margin and Arlis Plateau (southern part of the Mendeleev Ridge). Further to the southeast, there is a prominent linear gravity low in the area of the continental slope. We consider this feature to be an expression of an extensional structural feature that we call the Toll' Rift (Figure 2). This rift is structurally bounded by the Arlis Plateau on the NE and De Long Uplift on the SW and merges the Vil'kitskii Rift System on the shelf.

Chukchi Sector (Northwestern Chukchi Sea and Chukchi Borderland)

The Chukchi Sector spans the eastern part of the ERAM and adjacent territories of the Alaskan continental margin, surrounded on the north by high-standing submarine blocks of the Amerasia Basin: Arlis Plateau and Chukchi Borderland (Figures 1 and 2). The principal source of the present-day geological understanding of this area is the ice- and aircraft based geophysical measurements carried out during many years by U.S.S.R., US and Canadian

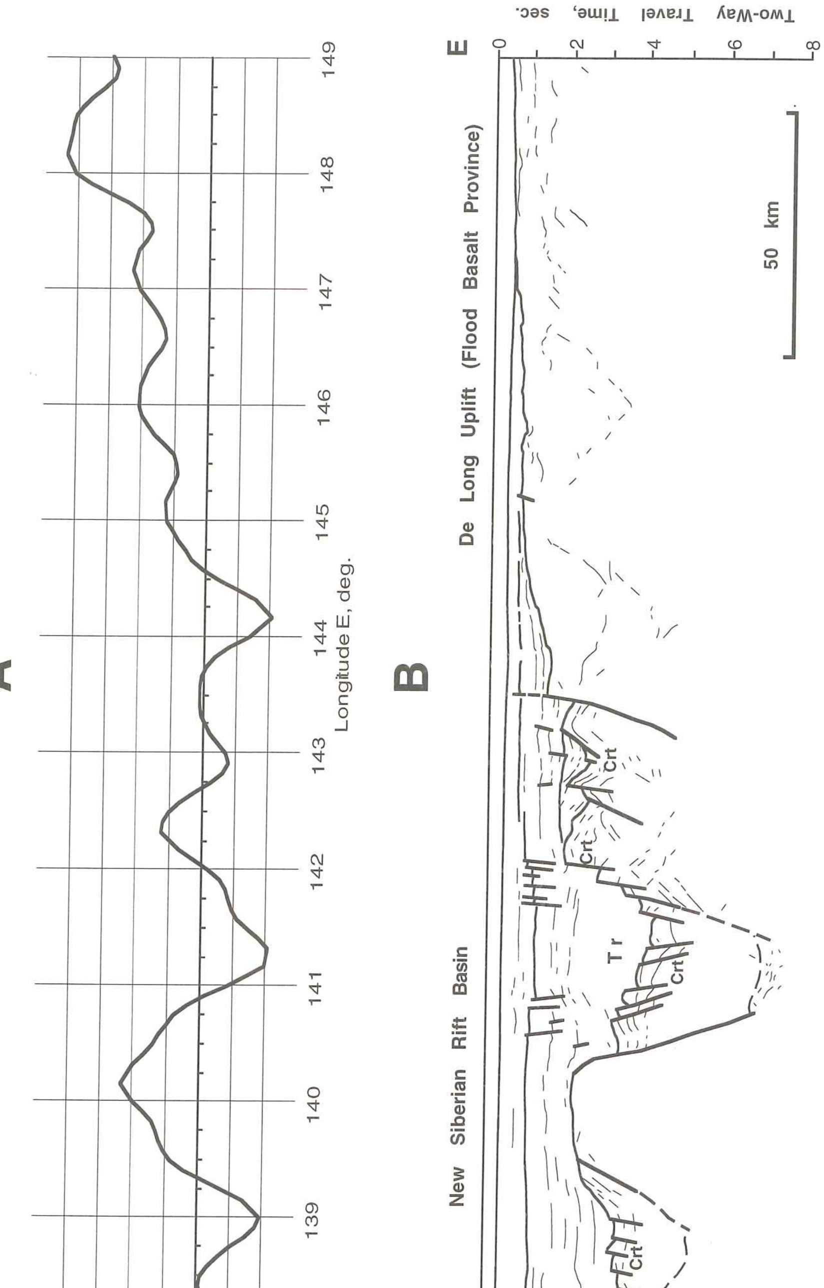

Figure 4: Free air gravity chart (A) and line drawing of the MCS profile BGR93-012 (after Roeser et al., 1995) (B) across the New Siberian Rift (see Figure 2 for location). Tr - Tertiary seismic unit, Crt - Cretaceous seismic unit.

institutes and published MCS data from the northwestern part of the Chukchi Shelf, gained by US Geological Survey (Grantz et al., 1986 and 1990). The surface observations of the gravity field were compiled by Sobczak et al. (1990), and the latest tectonic synthesizes were published by Hall (1990) and Grantz et al. (1990). The satellite gravity data shed more light on structure of the region.

The sector has the clear structural boundaries in the northwestern Chukchi Sea. These are the Vil'kitskii Rift System on the west and eastern limit of the Listric-normal faults province on the east. The latter was delineated by Grantz et al. (1990) and is located along the apparent shelf continuation of the Northwind Escarpment. The Wrangel Block, North Chukchi rift basin and North Chukchi Uplift represent the main structural elements of the shelf area which are well-expressed in the gravity field (Figure 2).

The Wrangel Block represents an uplift (Wrangel Arch by Grantz et al., 1990) of the folded basement. Recently it was studied on the Wrangel Island by Russian and Canadian geologists (Kos'ko et al., 1993) who reported the island to be composed of pentratively deformed complexes of Upper Proterozoic metamorphic rocks, Paleozoic (Late Silurian to Permian) and Triassic clastic, carbonate and flysch strata, overlain by undeformed of tens of meters thick Tertiary and Quaternary sediments. The main thrust-and-fold deformations are suggested to have occurred during a Middle Jurassic to Early Cretaceous orogeny. The gravity data suggest the Wrangel Arch extends northerly and northwesterly of the Wrangel Island up to 73° N.

The 500 km long and 200 km wide North Chukchi rift basin lies north of Wrangel Arch and represents one of the main negative structural features of the ERAM. It extends nearly W-E from 180° E toward Barrow Arch and Chukchi Platform of the Alaskan continental margin (Grantz et al., 1990). The MCS data show this basin is filled with a very thick, as much as 12-14 km, sequence of marine and shelf marine strata, interpreted to be of probable Cretaceous to Quaternary age (Figure 6B). However, the U.S.G.S. profiles are located on the southern slope of the basin just southwest of its most subsided part, marked by a gravity low of -40 to -60 mGal around 73° N, 170° W (Figure 6A). This suggests that the sediment thickness is even higher in the basin depocenter and supports the hypothesis of Grantz et al. (1990) that an oceanic or very highly thinned continental crust is present in the base of the North Chukchi Basin. The northern flank of the basin is marked by a steep gravity gradient. This feature was noted by Sobczak et al. (1990) and probably reflects some asymmetry in basin's structure with a gently sloping southern side and a steep, fault related (?), northern side.

The eastern part of the basin is affected by an array of northerly-striking listric normal faults, predicted to be of latest Cretaceous or earliest Tertiary age (Grantz et al., 1990). This Listric-normal fault province is well-expressed in the gravity data and obviously represents a shelf continuation of the extension-related structures of the Chukchi Borderland.

The North Chukchi Uplift occurs in the outer northwestern Chukchi Shelf (Figure 2). It is marked by one of the highest gravity peaks, which is as much as 50 mGal in intensity, and separates structurally the North Chukchi Basin and western part of the Chukchi Borderland (Chukchi Cap). This structure has not previously been described and there are no data to infer its geology. We only can suggest some similarity between this feature and Chukchi Cap (Plateau) since both structures display a similar gravity pattern.

The Chukchi Borderland has the most spectacular expression in the gravity field (Figure 2). Morphologically it represents an ensemble of the N-S trending narrow ridges and basins, divided by the steep gravity gradients and marked by gravity highs (40-50 mGal) and lows (-40 to -60 mGal), correspondingly. Such a characteristic pattern has previously been established and has been said to reflect rift-related structure of the borderland (Hall, 1990).

There are two main crustal blocks, which differ significantly in their gravity field. The more solid western block is represented by the Chukchi Plateau, whose top part consists of a 25 km wide N-S trending graben, delineated previously (Hall and Hunkins, 1968; Hall, 1990). The

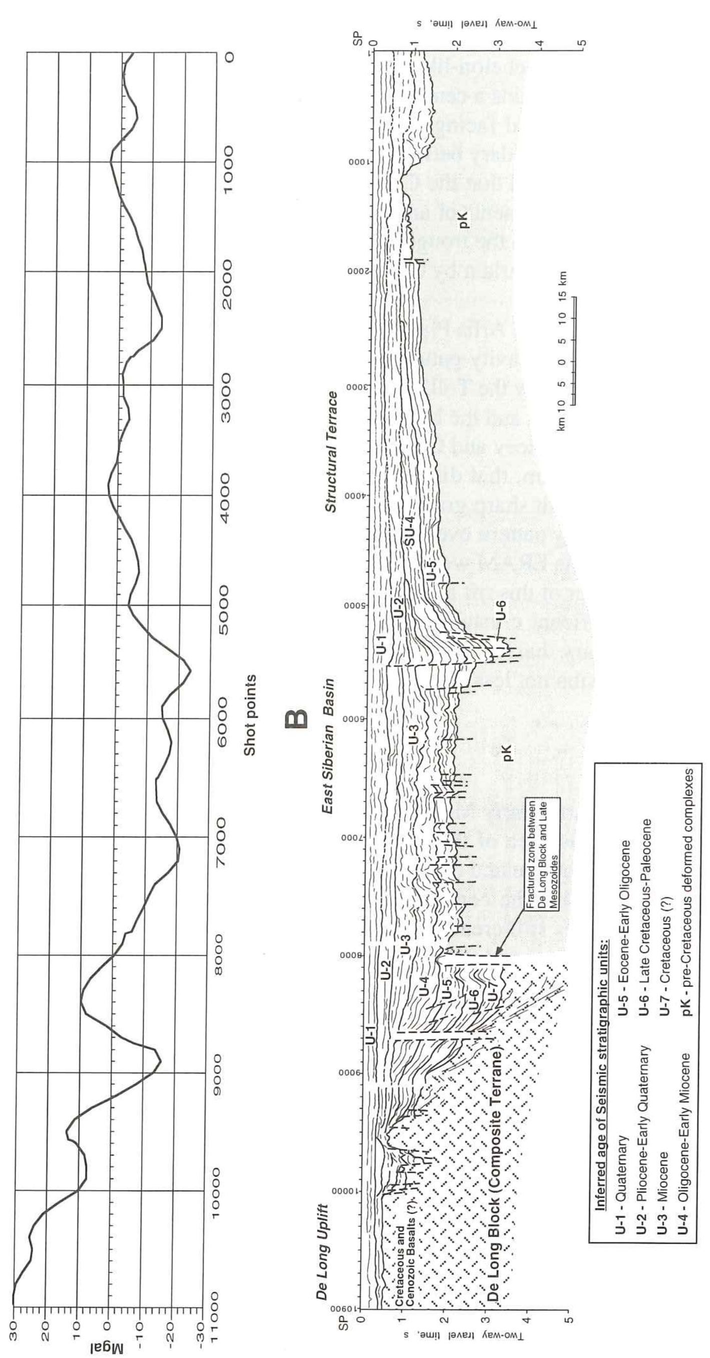

Figure 5: Free air gravity chart (A) and line drawing of the MCS profile LARGE 89001 (B) showing inferred geologic structure and stratigraphy across East Siberian Shelf (see Figure 2 for location).

eastern block reveals more complex ridge-to-basin structure and is composed of the Northwind Basin and Northwind Ridge. A boundary between the blocks is marked by a chain of narrow NE-SW and N-S trending echelon-like troughs, coinciding with the Nautilus Gap on the north. The Northwind Basin contains a central horst-like block, surrounded by several narrow steep-sided grabens. The eastward facing Northwind escarpment, marked by the sharpest gravity gradient, represents the boundary between the Chukchi Borderland and Canada abyssal basin.

It is now broadly accepted that the Chukchi Borderland is underlain by thinned continental crust, covered with the sediments of an uncertain age of less than 2 km thick on the uplifts and more than 4 km thick within the troughs (Hall, 1990). As it was shown by Grantz et al. (1993) the Northwind Ridge is underlain by continental crust from a Cretaceous continental margin or shelf basin.

The Mendeleev Ridge and Arlis Plateau appear in the gravity field as an unified block within the 2000 m isobath. The gravity pattern suggests some similarity with De Long Uplift, while both blocks are separated by the Toll‘ Rift.

The Chukchi Borderland and the Mendeleev Ridge are morphologically separated by Charlie Gap, that links the Mendeleev and Chukchi abyssal plains. This feature is shown in the gravity field by a linear minimum, that disintegrates into two orthogonal branches on the north and merges on the south with sharp gravity low about -50 mGal over the Chukchi Abyssal Plain. To compare this gravity pattern over the Charlie Gap with the similar ones over the other MCS studied structures of the ERAM we suggest it is a manifestation of an extension structure called Charlie Rift. A merger of this rift and the Toll‘ Rift in area of the Chukchi abyssal plain appears to have led to significant crustal thinning and formation over this junction a deep subsided Chukchi sedimentary basin. The latter, based on gravity data, might be filled with a sedimentary succession not less than 8 to 9 km in thickness.

Summary

New geophysical, particularly MCS and satellite marine gravity data collected during the last decade over the broad area of the ERAM provide a good basis for revision of the previous hypotheses on the structure and tectonic genesis of the region. The data presented in this paper allow us to suggest that the continental margin was strongly affected by the rifting process which produced and is still creating rift systems and rift-related deeply subsided sedimentary basins which are: the presently active Laptev Rift System, the inactive New Siberian Rift and Vil‘kitskii Rift System in the East Siberian Sea, North Chukchi rift basin in the Chukchi Sea and several rifts and rift basins in the area of the continental slope and adjacent marginal plateaus (Toll‘ and Charlie rifts, Nautilus Trough, Chukchi and Northwind rift basins). The older rifts and rift basins which are now abandoned may have commenced activity as early as end of Jurassic to beginning of Cretaceous. The first episode of the oceanic related rifting probably took place in the Chukchi Sector in response to initial breakup between North American plate and North Alaska-Chukchi Block (Grantz et al., 1990; Embry and Dixon, 1994). This event resulted in formation of the North Chukchi Basin and movement of the Chukchi Borderland out of the Chukchi continental margin, as was suggested by Grantz et al. (1990). The East Siberia Basin may be a basin downwarped by the sedimentary load or an analogue of the Sverdrup Basin in northern Canada (Sweeney et al., 1990).

Next, in the Late Cretaceous to Early Tertiary time, the large extensional basins were formed in East Siberian Sector. We speculate this event to be connected with a crustal dilatation/sea-floor spreading in the Makarov Basin. It was also suggested by Grantz et al. (1990) that this "Laramide" (latest Cretaceous-earliest Tertiary) event created a system of the N-S trending ridges and basins of the Chukchi Borderland and province of the listric-normal faults in the

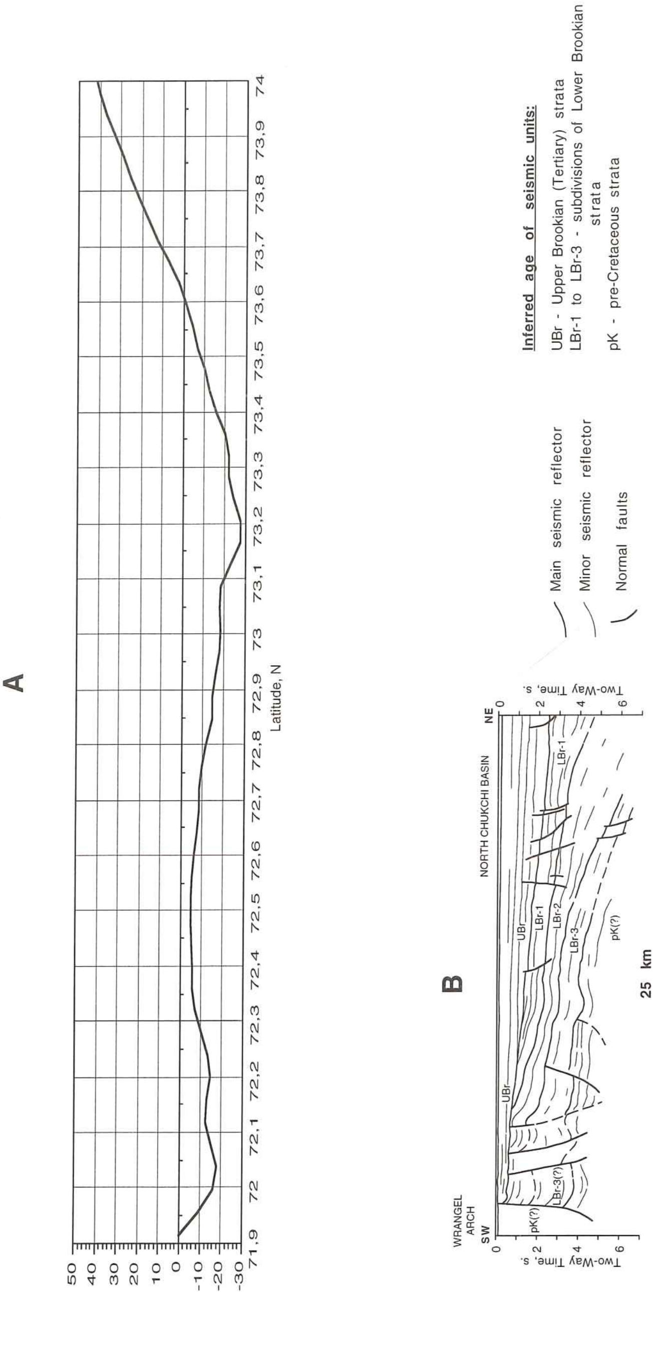

Figure 6: Free air gravity chart (A) and line drawing of the MCS profile U.S.G.S. 816 (from Grantz et al., 1990) (B) showing inferred geologic structure and stratigraphy across North Chukchi Basin (see Figure 2 for location).

eastern North Chukchi Basin. The main extension axis might be a continuation from the Mid-Atlantic Ridge via Baffin Bay and Makarov Basin toward the Mendeleev Ridge and Chukchi Borderland. We also speculate that in that time the southern part of the Mendeleev Ridge was rifted away from the De Long Block and the Toll' Rift, Chukchi Rift Basin and Charlie Rift were formed.

Finally, in the Tertiary to Quaternary time the Laptev Rift System was formed in response to the opening of the Eurasia Basin. This rifting started as early as 60-56 Ma or even earlier, and the main rifts were formed by the end of the Eocene since that period is characterized by the highest spreading rates (Savostin et al., 1984a). Present-day extension still occurs along Bel'kov Svyatoi Nos Rift but, probably, at a very low rate.

Thus we suggest that the spreading in the Arctic oceanic basins migrated westward during Cretaceous-Cenozoic time and led to rifting and subsidence of the sedimentary rift basins on the continental side as well as to separating and fragmentation of the marginal continental blocks: the Chukchi Borderland, the Mendeleev and Lomonosov ridges.

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