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Tectonic subdivision of the Chukchi and East Siberian Seas

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Abstract. A tentative tectonic subdivision for the Chukchi and East Siberian seas has been created based on the processing and analysis of new satellite altimetry and magnetic data and published materials that include information in electronic formats. The Chukchi Sea shelf is composed of correlatives of the Alaskan tectonic zones. The main Alaskan thrust does not stretch into Wrangel Island but is instead located in the region of the South Chukchi Sea Basin. Most part of the shelf is occupied by a zone of zero or slight deformation. The North Chukchi Sea Basin along with the Vilkitsky Trough and the region of maximum subsidence in the Colville Trough make a single entity, the Novosibirsk–Alaska Basin.

Introduction

The Arctic shelves of Russia became a focus of keen attention after large hydrocarbon fields had been discovered in the Barents and Kara seas and on land directly adjacent to the Laptev and Beaufort seas. In recent years, this has provided an incentive to create and publish new tectonic maps for all the Arctic seas of Russia, except for the East Siberian and Chukchi. These two seas are among Russia's least studied shelf areas because of the remoteness and severe natural and climatic conditions of this region.

However, the fact of discovery of some 40 oil and gas fields (including the giant Prudhoe Bay field) in northern Alaska, US, in immediate proximity to Russia's economic zone necessitates a more comprehensive study of the issue of tectonic subdivision of the eastern Russian Arctic (primarily, the Chukchi Sea), which is Russia's strategic energy resource.

The Chukchi and East Siberian seas are situated within the Arctic Ocean shelf (Figure 1). North of the shelf edge the Amerasia Sub-basin is located; it is subdivided into two provinces, one with undersea ridges and rises and the other (Canada Basin) topographically uniform [*Naryshkin,* 2001]. The former accommodates the Lomonosov Ridge and the Alpha, Mendeleev, Chukchi, and Northwind rises, which are linked with the Podvodnikov, Makarov, Stefansson, Mendeleev, Chukchi, and Northwind basins. All these morphostructures trend roughly N–S and are truncated by the shelf edge. The Chukchi and East Siberian seas are underlied with continental crust 30–35 km thick in the transition between the North American and Eurasian lithospheric plates [*Bird,* 1999]. This area is aseismic except for the southern Chukchi Sea and the vicinity of the Barrow Valley (Figure 2) [*CNSS...,* 2002].

The Canada Basin has depths of ca. 4000 m and is floored with oceanic crust, as evidenced by its pattern of magnetic lineations. The basin's mafic basement is overlain by sedimentary cover as thick as 2000 m, which increases to 9–10 km in the region of the Mackenzie delta [*Khain,* 2001].

West of the Canada Basin, as mentioned above, there lie the Northwind Ridge and Chukchi Plateau (often collectively referred to as "Chukchi borderland") and the Mendeleev Ridge, which all have continental crust. The Mendeleev Ridge [*Poselov,* 2002] displays a sedimentary layer whose upper part, judging by low acoustic velocities, is not lithified. The three lowermost layers with velocities of 2.8 to 5.5 km/s correspond to rocks with various degrees of solidification. The total thickness of the sedimentary cover in the axial part of the Mendeleev Ridge is ca. 2 km; further west, in the Podvodnikov Basin, it becomes up to 5 km or more. Solid crust is as thick as 31 km. Sampling (dredging, piston coring, etc.) of the ridge surface yielded fragments of four principal lithological types. Sharply prevalent are

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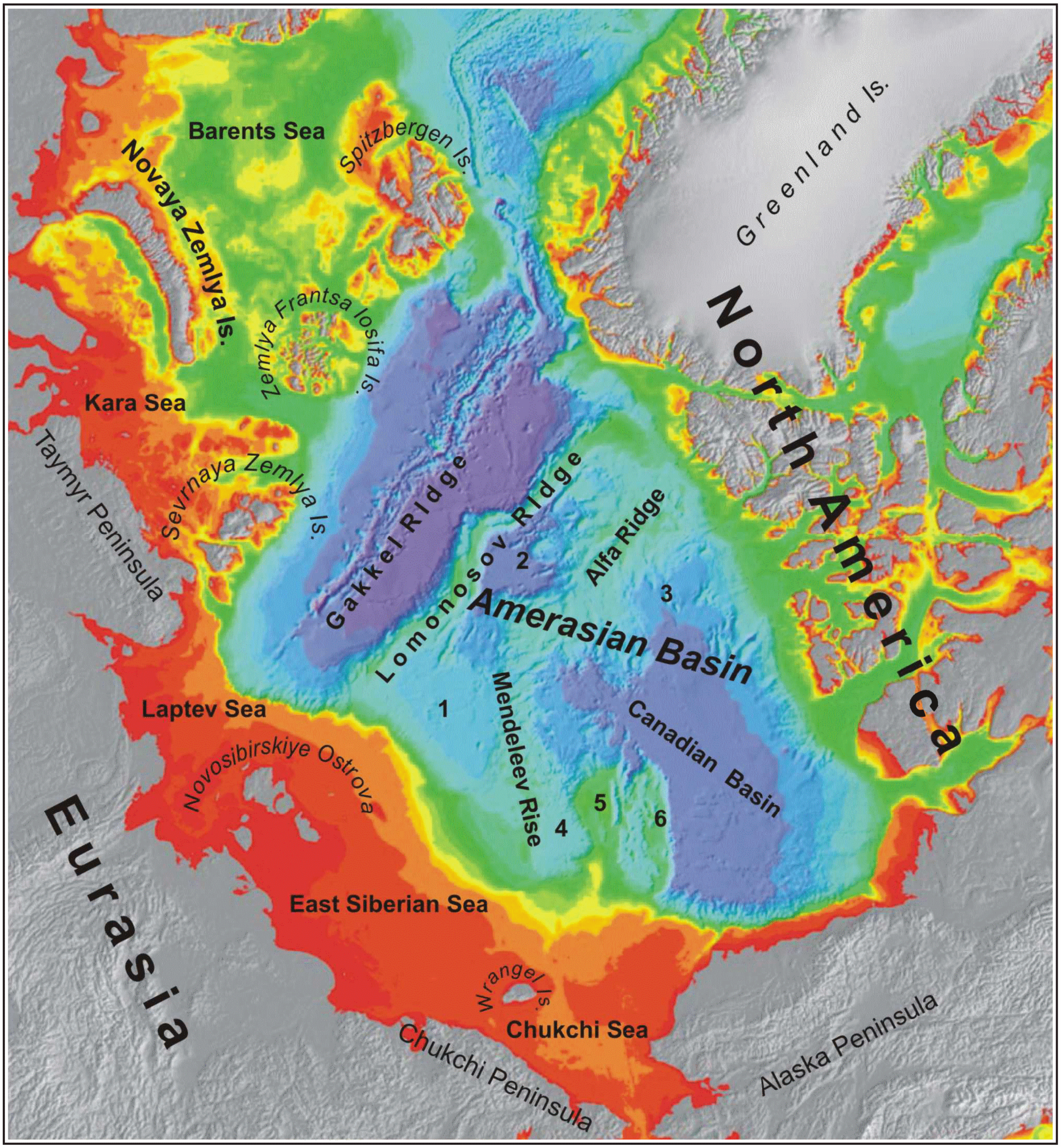


Figure 1. Principal physiographic features of the eastern Arctic sector. Numerals denote: Basins (1–4): 1 – Podvodnikov, 2 – Makarov, 3 – Stefansson, and 4 – Chukchi. Rises (5–6): 5 – Chukchi Plateau, Northwind Ridge. Topographic base, [*International...*, 2002], (http://www.ngdc.noaa.gov/mgg/bathymetry/arctic/arctic.html)

fragments of quartzose sandstone, siltstone, and dolomite. Less common are dolomite and cataclastic granite and diabase fragments. Limestones are encountered that contain conodonts and foraminifers of Devonian and Carboniferous age.

This paper embarks on creating a tentative tectonic subdivision for the Chukchi and East Siberian seas based on the processing and analysis of new satellite altimetry and magnetic data and published materials, which include information in electronic formats.

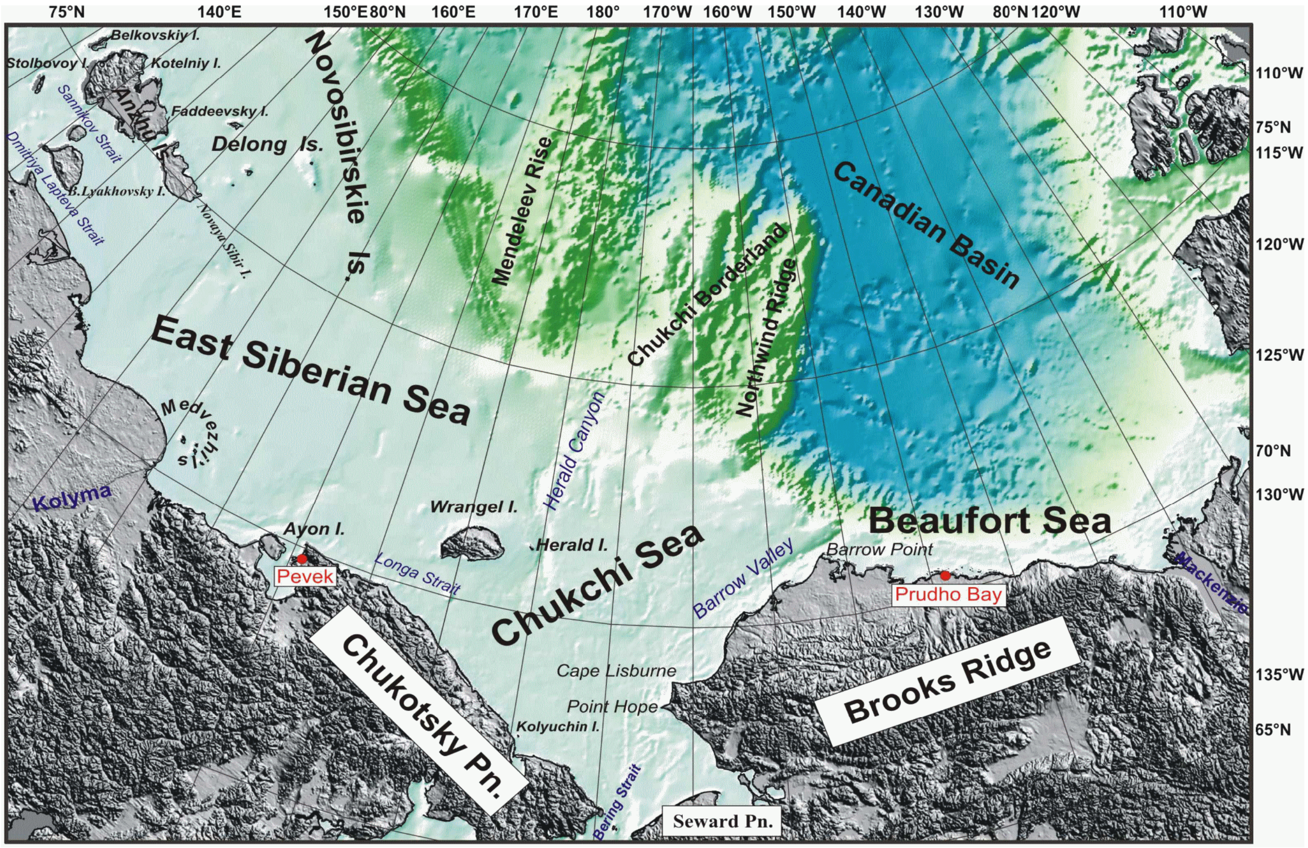


Figure 2. Relief and principal physiographic features of the Eastern Arctic sector. Topographic base, [*International...,* 2002].

Physico-Geographic Framework

Long standing echo sounding surveys conducted by Soviet/Russian, US, and Canadian researchers have brought detailed data on eastern Arctic bathymetry [*The Great...,* 1978; *International...,* 2002; *Naryshkin,* 2001]. In a very generalized form, Eastern Arctic physico-geographic setup is presented below (Figure 2).

The Chukchi Sea averages a depth of 77 m. Toward the shelf edge, water depth increases to 200 m or more, the maximum being 1256 m. The sea interior displays a rise that stretches in a roughly E–W direction with minimum water depths of ca. 20 m; on some maps, its eastern part is named "Hanna Shoal." This rise is separated from that of the islands of Wrangel and Herald by the Herald Canyon trending roughly N–S (approximately along 175°W). Another canyon or more exactly, valley (Barrow Valley) runs nearly parallel to Alaska's northwest coast.

Within the Chukchi Sea, the islands of Wrangel, Herald, and Kolyuchin are located. The former, which is of the greatest interest to comprehending the shelf tectonics, is 7300 km^2 in area [*The USSR Geology...,* 1970]. Its central part has mountainous landscape with a maximum elevation of 1096 m (Mt. Sovetskaya). The island's southern coast consists of scarps as high as 450 m. On the north, there occurs a gently sloping plain (Academy Tundra) with elevations below 50 m. Herald Island is a cliff that stretches approximately E–W and has elevations of up to 380 m [*The USSR Geology...,* 1970].

The East Siberian Sea is located between New Siberian Archipelago and Wrangel Island. On the west it bounds on the Laptev Sea, to which it is linked via Dmitry Laptev, Eterikan, and Sannikov straits and by a strait just north of Kotelny Island; on the east, it bounds on the Chukchi Sea, with which it communicates through Longa Strait and another strait north of Wrangel Island. The sea's northern limit stretches approximately along the 200 m depth contour. The sea averages a depth of 45 m, its maximum depth being 155 m.

The sea (Figure 2) has several archipelagoes (New Siberian and Medvezhi) and separate islands (Ayon and Shalaurov). New Siberian Islands incorporate De Longa Archipelago, which includes a number of small islands (Bennett, Zhokhov, Vilkitsky, Jeannette, and Henrietta). Anjou Archipelago is

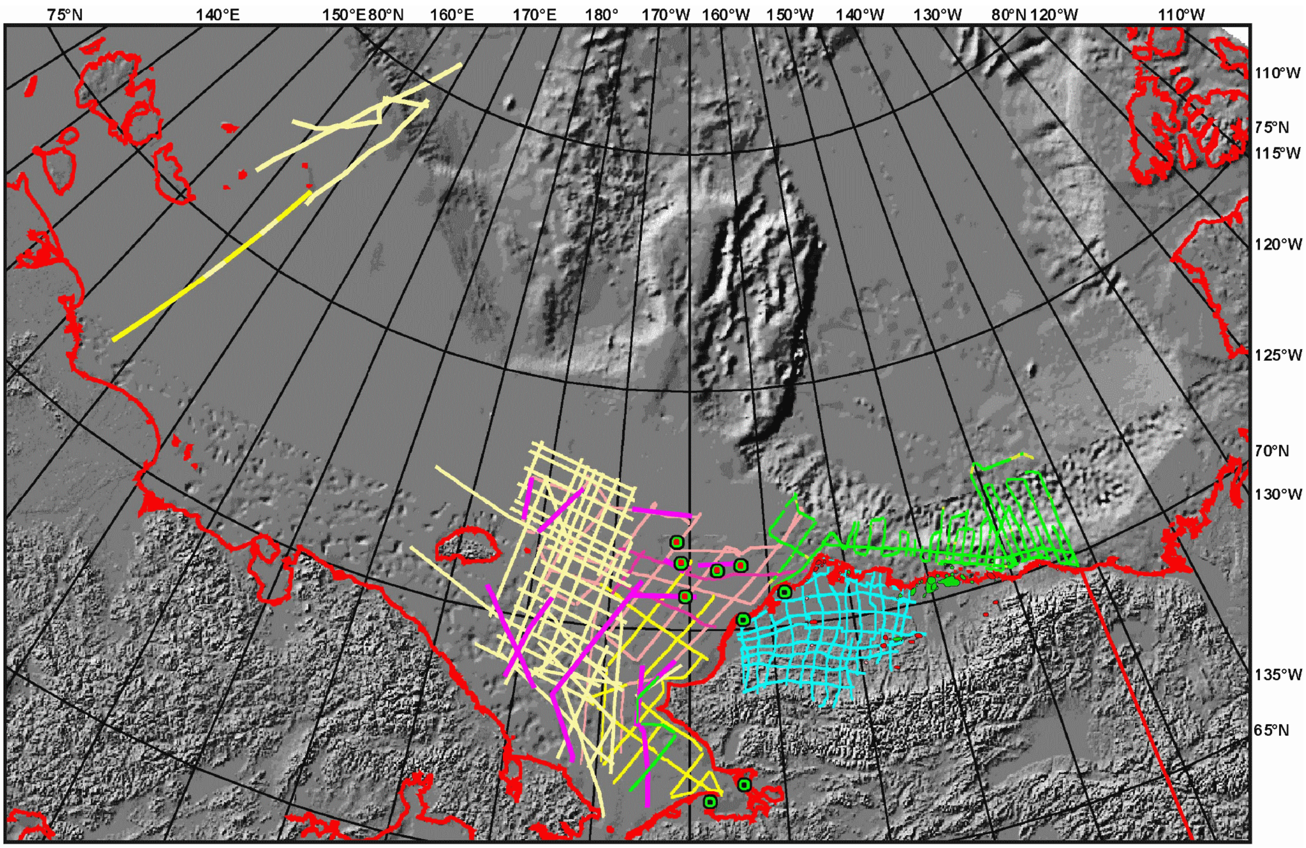


Figure 3. Location of seismic profiles in the Eastern Arctic sector and wells in the Chukchi Sea (based on published data).

comprised of the islands of Kotelny and Faddeyevsky with Bunge Land in-between (geographically, they all make a single island), Belkovsky Is., and Novaya Sibir Is. The southernmost part of the archipelago is known by the name of Lyakhovsky Islands and consists of Bolshoy Lyakhovsky Is., Maly Lyakhovsky Is., and Stolbovoi Is.

The entire region has an Arctic climate. Most of the time, the East Siberian and Chukchi seas are covered by perennial or seasonal ice (http://pafc.arh.noaa.gov/, http://www.aari.nw.ru/). Newly formed ice is in places as thick as 2 m.

Based on the data of the Pevek Weather Bureau, which is Russia's nearest to these seas (http://www.weather.com/), the mean monthly temperature from 13-year records ranges from −27°C (February) to +8°C (July). Over the same time interval, the highest recorded temperature was +20°C and the lowest, −50°C. The mean annual number of days with temperatures below 0°C (from 18-year observations) reaches 271.

It thus follows that oil and gas exploration in this region requires colossal investments, which cannot pay back in the foreseeable future unless giant fields are discovered. In this context, detailed tectonic analysis may provide the basis for exploration strategy.

A Synopsis of Previous Geological and Geophysical Studies of the Chukchi and East Siberian Seas

The geological and geophysical structure of the East Siberian Sea is understood rather poorly. No drilling was conducted there, and the available seismic lines are sparse [*Drachev et al.,* 2001; *Lazurkin and Pavlov,* 2002; *Sekretov,* 2001, 2002; *Shipilov and Tarasov,* 1998]; magnetic and gravimetric observations have been carried out (see below for details). Between 1965 and 1989, the East Siberian Sea was covered by extensive gravimetric observations from drifting polar stations [*Gramberg et al.,* 1997]. The southern East Siberian Sea was covered by 1:1,000,000 scale gravimetric surveys, but the more northerly regions were surveyed at 1:2,000,000 to 1:5,000,000 scales. Magnetic data acquisition began in 1964, yet systematic airborne magnetic surveys (at scales of 1:4,000,000 to 1:1,000,000) were initiated as late as 1990.

From 1965 to 1980 [*Drachev et al.,* 2001; *Sekretov,* 2001, 2002], several geophysical profiles were recorded by drifting stations (Figure 3); the results of their interpretation were published only in part. In 1991, a seismic profile 600 km long from the region of Zhokhov Island to the shelf edge was recorded. In 1990, the Marine Arctic Geological Expedition on board the R/V Professor Kurentsov shot more than 1000 km of multichannel seismic profiles in the area north of De Longa Islands.

In addition, certain information can be acquired by extrapolating on-land data into the shelf area. A considerable scope of on-land geological operations including shallow drilling [*Dorofeyev,* 1999] was conducted on New Siberian Islands and on the islands of Wrangel [*Byalobzhesky and Ivanov,* 1971; *Kos'ko,* 1992; *The USSR Geology...,* 1970; *Tilman et al.,* 1964; etc.] and Herald [*The USSR Geology...,* 1970].

The history of Soviet/Russian research in the Chukchi Sea was repeatedly discussed in literature [the latest reviews include: *Kim,* 2002; *Lazurkin and Pavlov,* 2002; *Sekretov,* 2002]. The earliest Soviet seismic surveys (Figure 3) in the Chukchi Sea were conducted in 1976 by the Polar Geophysical Expedition of NPO Sevmorgeo [*Kogan,* 1981] using the single channel reflection method. Two profiles of NE–SW direction just southeast of Wrangel Island totaling a length of 700 km were recorded, to pick four persistent reflectors identified with the tops of Neogene, Paleogene, and Upper Cretaceous beds. One reflector is interpreted as a lithologic boundary within the Cretaceous strata.

In 1978, an expedition under the leadership of A. Grantz on board the US R/V Samuel P. Lee surveyed the Chukchi Sea [*Grantz et al.,* 1990]. One of the survey methods used was 24-channel seismic profiling; several such profiles were shot in the region of the North Chukchi Basin, to resolving the upper Ellesemere, lower Brookian, and upper Brookian sequences (see below).

Comprehensive geophysical surveying (http://www.dmng.ru/) was conducted in 1990 by a joint venture of Dalmorneftegeofizika Trust and Haliburton Geophysical Services, to result in the recording of a total length of 8791 km of multichannel seismic profiles whose interpretation data remain unpublished.

Certain areas outside the Chukchi Sea shelf were also surveyed. Thus, in the Canada Basin, in addition to echo soundings and magnetic and seismic surveys, US workers on board the icebreaker Polar Star conducted geological studies on the Northwind Ridge in the eastern part of the Chukchi borderland. The three campaigns held in 1988, 1992, and 1993 recovered rock material whose processing [*Grantz et al.,* 1998] yielded age determinations from the Cambrian to the Neogene. Specialized studies have shown that the material recovered by piston corers was talus that had not undergone any perceptible transport and is thus informative of sedimentary lithologies of the Northwind Ridge and not ice rafting.

A higher degree of exploration (Figure 3) exists in the US sector of the Chukchi and Beaufort seas. This area was covered [*Bird,* 1999; *Bird and Houseknecht,* 2002; *Fujita and Cook,* 1990; *Grantz et al.,* 1990; *Kumar et al.,* 2002; *National...,* 1995; *Thurston and Theiss,* 1987; etc.] by extensive seismic/geological surveys in the Hope Basin northwest of Cape Barrow and by a dense profiling grid from the Alaskan coast to the Beaufort Sea shelf break. In the US sector of the Chukchi Sea, a number of prospecting wells (Klondike, Burger, Popcorn, Crackerjack, and Diamond) were drilled. Extremely extensive geological, prospecting, and geophysical operations and drilling were conducted on the so-called Northern Slope of Alaska.

However, the information acquired to date is not sufficient to create a reliable tectonic map for the Russian sector of the Chukchi and East Siberian seas. A considerable, if not pivotal role can be played by the comparison of geological data with results of remote sensing methods (satellite altimetry and airborne magnetic surveys).

Principal Stratigraphic Features of Alaska

To provide insight into the structure of the Chukchi Sea, we will use a composite stratigraphic division for northern Alaska, because all of its principal structural features extend offshore.

In the State of Alaska, the best studied regions occur on the north and comprise the so-called National Petroleum Reserve Area (NPRA), Arctic National Wildlife Refuge (ANWR), including region 1002 and the areas in-between, where the large oil and gas fields (Prudhoe Bay, etc.) were discovered.

Very generally, northern Alaska displays the following sequences spanning an age range from the Upper Proterozoic to Cenozoic inclusive: Franklinian (or pre-Devonian), Ellesemerian, and Brookian (Figure 4). These sequences exhibit essential lithological changes in lateral directions, but their fundamental features remain everywhere the same.

Franklinian Sequence

The sequence of pre–Middle Devonian age is best studied on the eastern Brooks Range. It is composed of metamorphosed sedimentary and volcanic rocks and intrusives [*Hanks,* 1989; *Kelley et al.,* 1992; *Mull and Anderson,* 1991]. Based on lithologic and petrographic features, recognized are several members: Cambrian mafic volcanics alternating with limestones (700–1300 m); Ordovician cherts and phyllites; black and greenish black–colored phyllites with isolated intercalations of limestones and thin- and cross laminated micaceous sandstones (700–1300 m); cherts, phyllites, and mudstones (over 1700 m); dark colored limestones, phyllites, mudstones, conglomerates, and sandstones (below 300 m); black and greenish gray–colored phyllites and cherts and sandstones of Early Cambrian to Late Ordovician age; limestones, stromatolitic and oolitic dolomites intercalated with mafic volcanics, lower Early Devonian in age (2500 m). Here, granites and quartz monzonites with radiometric ages of 380±10 Ma were also mapped.

Within the ANWR [*Petroleum...,* 1987], correlatives of the Franklinian Sequence are composed of metamorphosed sedimentary rocks with minor intercalations of volcanic and intrusive rocks. Some radiolarian cherts, limestones, mudstones, and graywackes are also attributed to this sequence.

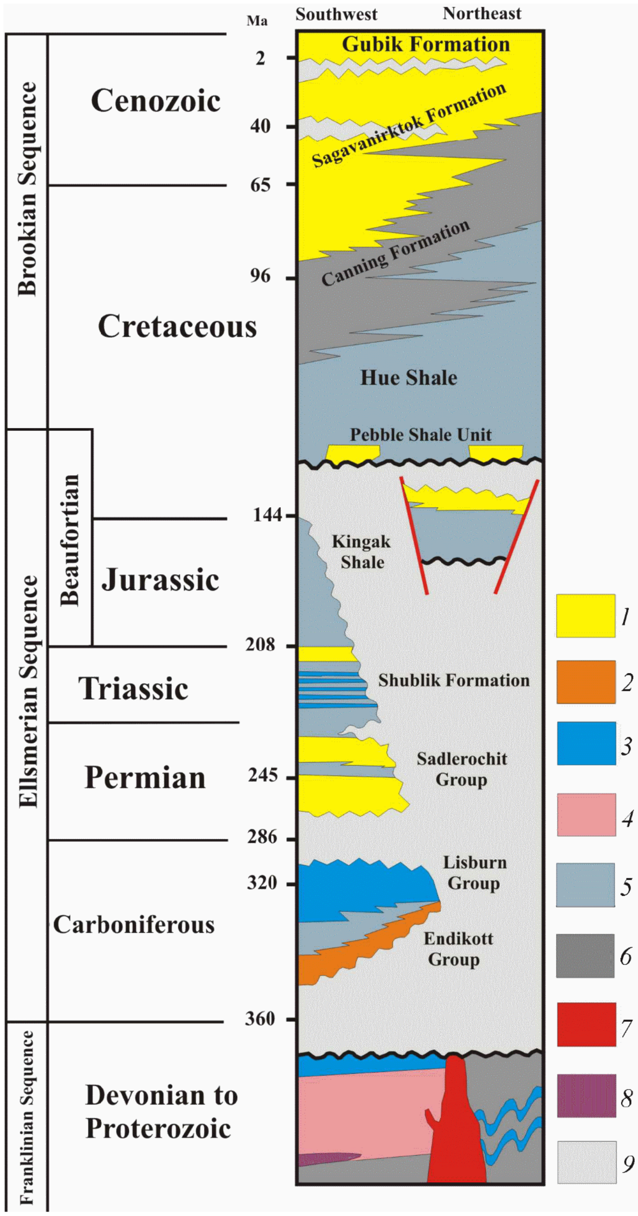


Figure 4. Composite stratigraphic column (schematized) for the ANWR region (see above). http://energy.cr.usgs.gov/OF98-34/ Terrigenous sequences of various origins (1, 2): (1) marine and (2) terrestrial. 3 – limestone; 4 – dolomite; 5 – clay dominated strata; 6 – mudstone; 7 – granite; 8 – basalt; 9 – nondeposition. Red lines, faults. Wavy lines, unconformities.

In western Alaska [*DGGS...,* 1993], southeast of Cape Hope, the correlatives of the Franklinian Sequence are composed of Ordovician–Devonian limestones, dolomites, marbles, phyllites, and terrigenous rocks (Nakolik Member) and coeval quartz–chlorite schists alternating with dark green metabasites, marbles, and metaconglomerates (Tukralerik Member). These are cut through by mafic dikes and metadiorite and metagabbro bodies, evidently of Mesozoic age. One more member recognized here is the Kallarihook Member, composed of garnet–mica–quartz schists, marbles, and gneisses intruded by leucogabbro, granite, and granodiorite bodies.

Within the Russian Arctic sector, a correlative of the Franklinian Sequence is established on Wrangel Island. It is composed [*Byalobzhesky and Ivanov,* 1971; *Kos'ko,* 1992; *Kos'ko et al.,* 1992; *The USSR Geology...,* 1970; *Tilman et al.,* 1964] of volcanics of felsic to intermediate composition, volcaniclastic deposits, phyllites, black shales, quartzites, and conglomerates totaling a thickness of ca. 2000 m (Wrangel Island assemblage). These deposits are intruded by quartzo-feldspathic porphyry, gabbro, and diabase bodies, felsite dikes and sills, and small granite bodies. The rocks of the assemblage are dated at 633–699 Ma.

Upper Silurian–Lower Devonian strata are represented by shallow water marine sandstones, siltstones, and carbonate rocks totaling ca. 700 m in thickness. These are overlain by clastic rocks of Devonian age, which onlap directly on Wrangel Island assemblage on the south of the island. Their total thickness is 1200 m.

In the eastern part of the Chukchi borderland, as mentioned above, rock material was acquired [*Grantz et al.,* 1992] that is similar to the Franklinian Sequence rocks. As pointed out in the same work, similar rocks were recovered from more than 40 drillholes in the Colville Basin in Alaska.

Therefore, the Franklinian Sequence and (or) its correlatives are developed over a large area from eastern Alaska to New Siberian Islands, and it can be interpreted as basement to depositional basins of the Chukchi Sea and a considerable part of the East Siberian Sea.

Ellesemerian Sequence

The Ellesemerian Sequence [*Pessel et al.,* 1990] was established in 1973 in Arctic Canada, where it was found to incorporate sedimentary rocks of Carboniferous–Jurassic age. In the US sector, this sequence also comprises Lower Cretaceous deposits. In northeastern Alaska it is composed of marine terrigenous and carbonate rocks. Assumedly, these sequences were formed along the periphery of a major continental mass, once situated on the site of what is now the Arctic Ocean.

In a number or regions in Alaska (in the vicinity of NPRA, just north of 69.5°N latitude [*Bird and Houseknecht,* 2002]), at the base of the Ellesemerian Sequence recognized is the Endicott Group (Figure 4) consisting of terrigenous deposits ca. 800 m in thickness [*Anderson,* 1993]. At its base, [*Robinson et al.,* 1992] identified the Keklktuk Conglomerate, in which the poorly rounded pebbles consist of cherts and quartzy sandstones of nearshore marine origin. Their thickness ranges 0–50 m. These are overlain by the Kayak Shale and its stratigraphic correlatives: dark colored carbonate siltstones with intercalations of sandstones of marine origin, as thick as 100 m.

In the northeastern foothills of the Brooks Range (in the vicinity of Gilead Creek) [*Pessel et al.,* 1990], the Ellesemerian Sequence comprises (from bottom to top): the Alapah and Wahoo Limestones of the Lisburne Group; the Echooka and Ivishak Formations of the Sadlerochit Group (Permian–Triassic); the Shublik Formation (Triassic); and the Kingak Shale (Jurassic–Early Cretaceous). According to some concepts [*Kumar et al.,* 2002], the Jurassic–Cretaceous portion of the stratigraphy is identified as the Beaufort assemblage (Figure 4).

Lisburne Group rocks are widespread in northern Alaska, including the Northern Slope and the northernmost Brooks Range [*Baesemann et al.,* 1998; *Wallace et al.,* 2001]. These rocks are represented by marine, dominantly carbonate deposits with isolated intercalations of cherts (dozens of meters in thickness) and siltstones. This sequence is the main region-wide basin for oil fields such as, in particular, Prudhoe Bay and Lisburne.

In the ANWR region the Lisburne Group is parautochthonous and in the central Brooks Range, allochthonous. Here, it is unconformably overlain by the upper portions of the Ellesemerian Sequence (quartzose sandstones, siltstones, and mudstones of the Sadlerochit Group).

The latter is subdivided into several members, mostly of terrigenous composition, which rest unconformably on the Lisburne Group [*Hakkila,* 1986; *Robinson et al.,* 1992]. At the base of the Sadlerochit Group, the Echooka Formation occurs, which contains some conglomerates and calcarenite sandstones. These are overlain by siltstones with intercalations of sandstone (Kavik Shale Member) a few dozens of meters in thickness, in turn overlain by sandstones (Ledge Sandstone Member) with a maximum thickness of ca. 120 m. The top of the Sadlerochit Group is composed of siltstone (Fire Creek Member) no thicker than 135 m.

The Triassic Shublik Formation [*Parrish et al.,*; *Robinson et al.,* 1992] is a sequence enriched in organic matter, phosphates, and glauconite with sporadic finds of marine vertebrates and mollusks. It is composed of: non-glauconitic sandstones, thin- to medium layered, quartzose, fine grained with carbonate or non-carbonate cement, and clayey sandstones; glauconitic (10% to $>$ 50% of glauconite grains) sandstones, clayey limestones, marbles, and siltstones; phosphate-bearing sandstones, thin- to medium layered; and black colored clayey limestones with phosphate concretions. Assumedly, the Shublik rocks were formed in a paleo-upwelling zone.

The Shublik Formation is conformably overlain by Jurassic–Neocomian shales (Kingak Shale) [*Robinson et al.,* 1992]. These are 45–365 m thick and consist of black non-carbonate soft clay, occasionally alternating with ferruginous sandstones.

The Kemik Sandstone member [*Robinson et al.,* 1992] of Hauterivian age is represented by pure quartzose fine grained sandstones. Their thickness is ca. 30 m.

The topmost strata of the Ellesemerian Sequence are composed of the Pebble Shale member [*Robinson et al.,* 1992] consisting of thinly laminated shales high in organic matter and with quartzite, quartz, and chert pebbles. These range in thickness from 70 to 100 m.

The Ellesemerian Sequence was drilled [*National...,* 1995] in many places in northern Alaska and in the Chukchi Sea (by the Klondike, Burger, Crackerjack, and Diamond wells).

Brookian Sequence

The Brookian Sequence consists of Cretaceous–Cenozoic deposits that are widespread both in Alaska and in shelf areas [*Robinson et al.,* 1992]. It is composed of thick marine and terrestrial terrigenous deposits subdivided into the Hue Shale (Aptian–Campanian or Maastrichtian), Arctic Creek facies (Jurassic–Campanian or Maastrichtian), Canning Formation (Campanian or Maastrichtian–Pliocene), and the Jago River and Sagavanirktok Formations. In the ANWR 1002 region, the Brookian Sequence has been subdivided into seven units. From south to north, the thickness of the rocks increases to 5000 or even 12,000 m [*Robinson et al.,* 1992].

The Hue Shale is composed of black, organic matter enriched, non-carbonate, fine grained terrigenous rocks alternating with sandstones. The Canning Formation consists of turbidite sandstones 1200–1800 m thick.

The rocks of the Brookian Sequence make up the dominant part of sedimentary cover within the Chukchi Sea [*National...,* 1995].

Analyzing the Gravity and Magnetic Fields of the East Siberian and Chukchi Seas

Analysis of the gravity and magnetic fields recorded through regional-scale surveys (1:1,000,000 or smaller scale) should be based on geophysical information from large enough territories. This approach involves intrinsic complications due to variable data density and accuracy and different instruments used in geophysical surveys. This creates ambiguities in correlating structures and interpreting the materials, because it is hard to tell with confidence whether the contrasting field patterns are due to structural changes or whether they are artifacts of poor fit between different systems and techniques of measurements. Given such a factual basis, the interpreter can locate and roughly delineate (with an accuracy proportionate to the average data density in the survey area) only very large structural features. This is illustrated in a study on shelf tectonics of the Chukchi and East Siberian seas [*Gramberg et al.,* 1997], which makes use of gravity measurement data with a density of one station per 200–250 km^2 and magnetic profiles 20–25 km apart.

Data acquired by means of satellite-based methods (altimetry, magnetometry) have the same reference level and are free of the effects produced by fitting together surveys of various types, densities, and countries. This creates a unique opportunity to study the tectonic setup after artifacts have been removed as thoroughly as possible.

Anomalous Magnetic Field

Information on the anomalous magnetic field was provided by the digital databases in GIS formats for Alaska,

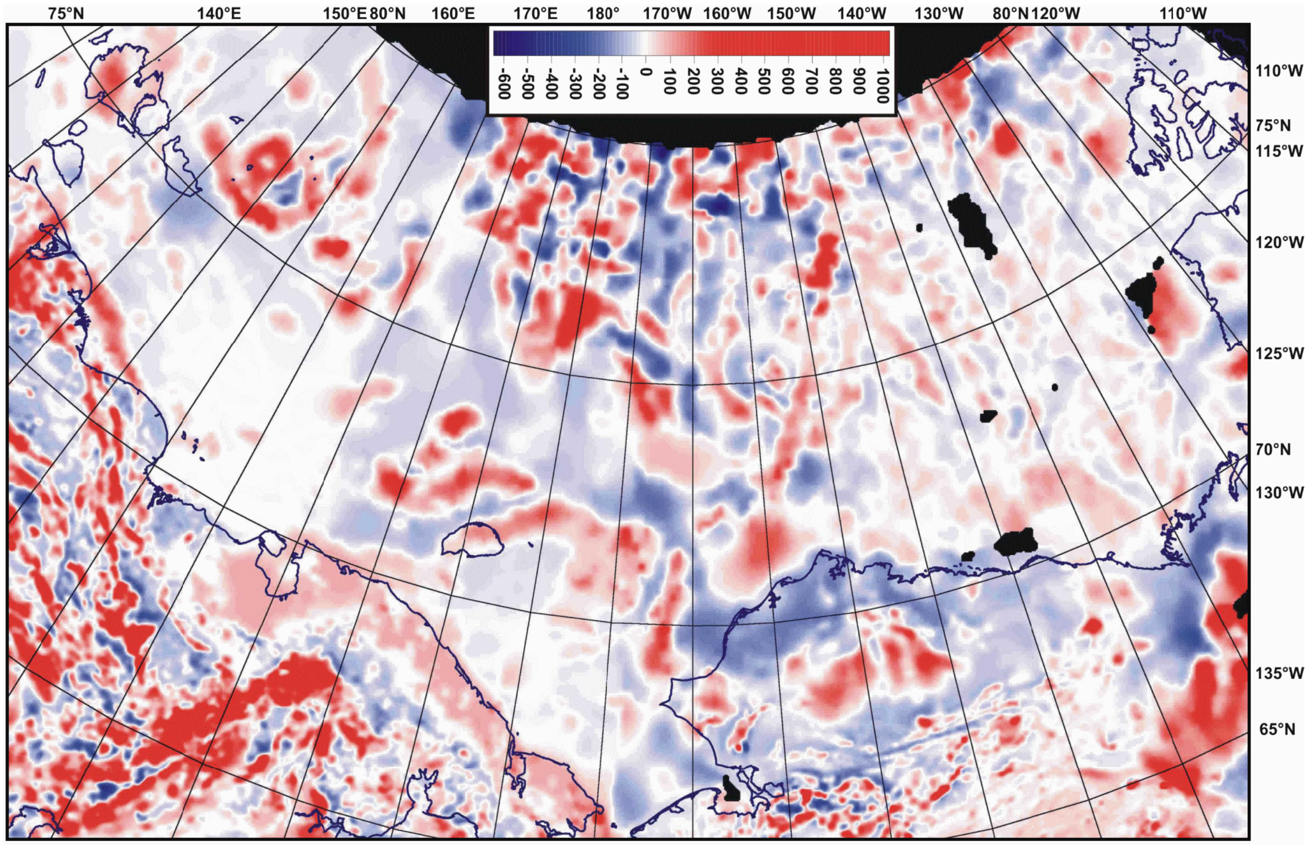


Figure 5. Anomalous magnetic field (nTl) of the Eastern Arctic sector.

northeastern Russia, and the Arctic [*GAMMAA5,*; *Macnab et al.,* 1995; *Racey et al.,* 1996; *Verhoef et al.,* 1996], included in USGS Open File Report 99-442 [*Greninger et al.,* 1999].

Note that data for the Alaskan region and northeastern Eurasia are essentially more detailed than for the eastern part of the northern Arctic Ocean as a whole. For this reason, in analyzing the anomalous field in the shelf zone, digital data were averaged within a radius of 24 km on a regular 4-km grid. This has ensured compatibility between the shelfal and continental parts of the field (Figure 5).

Our analysis of the anomalous magnetic field has shown that the Arctic region at large displays anomalous zones of three principal types: (i) oceanic, with a linear pattern of anomalies, (ii) continental, with anomalies in the form of strong highs clustering into large "cores," and (iii) shelf, with considerably lower values of the anomalous field as compared to the continental zone.

In the Canada Basin, magnetic lineations are barely discernible. Their analysis and exact identification to reconstruct seafloor spreading is thus hampered. Anomalies of the type tentatively defined above as continental "cores" make up the De Longa and Wrangel–Herald rises and the Brooks Range foothills, which jointly constitute a continuous zone. Anomalies of the same type feature the southern Mendeleev Ridge and Chukchi borderland. Their continental nature (crustal thickness from refraction data on Arctic 2000 Geotraverse being up to 33.5 km) is demonstrated in [*Poselov,* 2002]. This is a domain of strong anomalous values (up to 300 nTl) with a continuous chain of highs accompanied by gravity anomalies (see below). In all likelihood, this anomalous zone corresponds to metamorphosed rocks of Ellesemerian and, possibly, Franklinian age. Trough overthrusting, these rocks were uplifted closer to the surface, which enhanced their contribution to the anomalous field. The chain of highs just mentioned is accompanied on its north and south sides by similarly shaped chains of lows that perfectly mimic its outlines, including the bend along the Hanna Trough and Colville Basin. On the south, this system of anomalies is bounded by weakly anomalous values (ca. 100 nTl) corresponding to metamorphic basement of the Chukchi fold system. West of Wrangel Island, this system is limited by a zone of low values (±20 nTl) pertaining to the East Siberian Sea.

Hence, the pattern of magnetic anomalies in the study region is a coherent system modified by a bend near the Hanna Trough and marking the imbricate thrust system of the Wrangel–Brooks Range foothills and Paleozoic metamorphic rocks occurring near the earth surface.

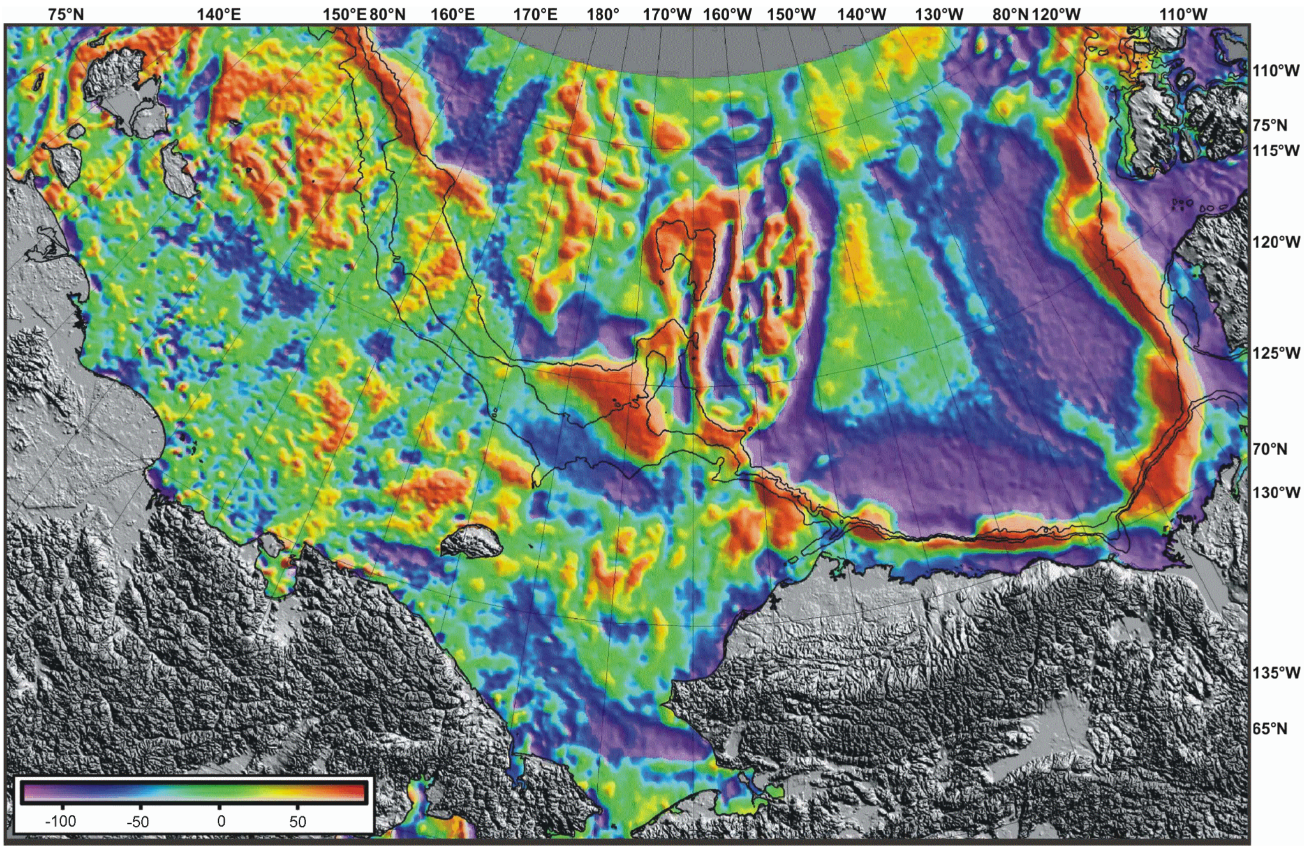


Figure 6. Free air gravity anomaly (mGal) of the Eastern Arctic sector [*Laxon and McAdoo,* 1998]. Shown are 100 m, 200 m, and 500 m depth contours.

Gravity Field and Its Transformations

The source of information on the gravity field of the Chukchi and East Siberian seas is satellite altimetry data. It is common knowledge that this method draws on satellite-based radar measurements of water-surface altitudes and subsequent conversion of this surface to free-air gravity anomalies. Until recently, the use of this method in polar regions was restricted by ice cover on the water surface. The way to cope with this problem is described in [*Laxon and McAdoo,* 1998; *McAdoo and Laxon,* 1997]. The removal of the ice-cover effect has resulted in the creation of digital coverage for the polar region up to 82° N latitude with gravity values on a grid of 1.4 nautical miles (ca. 2.5 km) with an accuracy of 4.8 mGal.

Employment of these data for further transformations of the gravity field is only possible given a comparable degree of detail of the digital coverege of seafloor relief. For relief imaging, we used the digital coverage from the International Bathymetric Chart of Arctic Ocean [*International...,* 2002] on a 2.5 km grid. Relief image for the on-land part of the region is based on GTOPO30 digital coverage on a 30 arc second grid (http://edcdaac.usgs.gov/gtopo30/gtopo30.html).

Free air anomaly. Our analysis of free-air gravity anomaly (Figure 6) shows the shelf to be separated from the oceanic domain by a distinct system of highs which correspond to sediments deposited along the shelf break without being compensated by basement subsidence. This system of highs virtually coincides with the 100 m, 200 m, and 500 m depth contours, which mark the transition from the shelf to continental slope. Departure from the standard relationships between the slope gravity highs and shelf-edge gravity highs is observable in two localities: along the shelf edge segments just southwest of the Chukchi borderland and southwest of the Mendeleev Ridge.

In the former case, the edge high stretches along the 500 m depth contour, which swings abruptly in direction (by ca. 40° to the north) away from the general trend of the shelf break in this region. The gap between the 200 m and 500 m depth contours is sharply widened here. Such a pattern of the shelf-break anomaly can be explained assuming that the depocenter migrated not along the normal to the shelf break, but at an angle of 50° to this normal. In the latter case, where the Mendeleev Ridge adjoins the shelf break, no edge highs whatsoever are located, and the 100 and 500 m depth contours are ca. 250 km apart, a value 10 times the analogous gradient of the upper slope part in the Canada Basin. This shift in sedimentation is likely to have occurred in re-

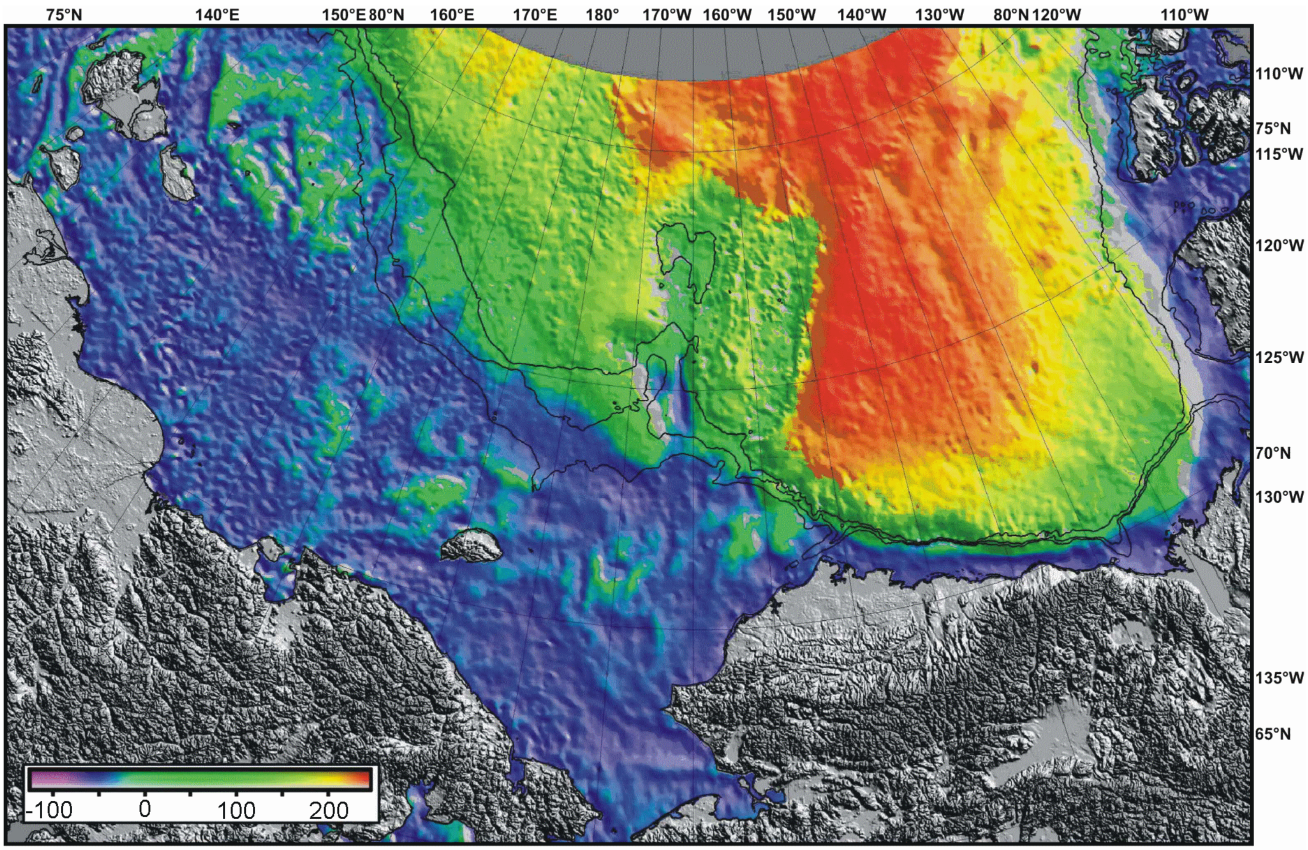


Figure 7. Bouguer anomaly (mGal) of the Eastern Arctic sector. Shown are 100 m, 200 m, and 500 m depth contours.

sponse to sediment accommodation space being opened as a result of horizontal tectonic movements.

The shelf area proper is represented by groups of positive anomalies that are induced by De Longa and Wrangel–Herald rises and that extend into the structures of the Brooks Range. A similar field pattern is developed on the Chukchi borderland and Mendeleev Ridge. The anomalies are offset by linear displacements of northeasterly trend due likely to dextral strike-slip motions.

On the shelf north and south of Wrangel Island, two systems of major NW-trending lows of the anomalous field are discernible. One system extends from New Siberian Islands to the North Chukchi Basin, where it becomes more distinct due to a maximum subsidence of basement under sedimentary cover, whose thickness exceeds 15 km here [*National...,* 1995]. Another major anomaly occurs just southwest of the Wrangel–Herald rise. It is sigmoid-shaped and extends to the east, into the fold-and- thrust belt of the Brooks Range.

Bouguer anomaly. The next phase in analyzing the gravity field of the Chukchi and East Siberian seas was to calculate the Bouguer anomaly using the classical method [*Gainanov and Panteleyev,* 1991]. In essence, this method consists in compensating the influence from relief on the anomalous field to discern the structure of crustal and mantle density inhomogeneities by adding the effect from missing water-column masses.

The calculation was performed assuming a crustal density of 2.5 g/cm^3, to make a stronger emphasis on the upper part of the crust. Because digital coverage is a matrix with field values in the nodes of a regular grid, the optimum calculation algorithm is approximation of the field by prisms. Integration was conducted within a radius of 166 km. A remarkable circumstance in calculating Bouguer anomaly on the shelf is that this procedure virtually does not affect the anomalous field structure where water depths are less than 200 m BSL. Only a minor correction is introduced to the relationships of Bouguer highs in local seafloor depressions. The most significant transformations that ensue are those suffered by the anomalies that are transitional from the shelf to the ocean. This involves disappearance of the shelf-edge high and emergence of a system of strong (300–400 mGal) anomalies induced by the denser oceanic crust and by mantle that occurs closer to the surface.

Analyzing the Bouguer anomaly shows (Figure 7) that the above treatment has left intact all the principal traits of the anomalous free-air field that reflected structural features of the shelf zone. The only difference that arises is a more distinct pattern of the extensive and local lows, which were discussed above.

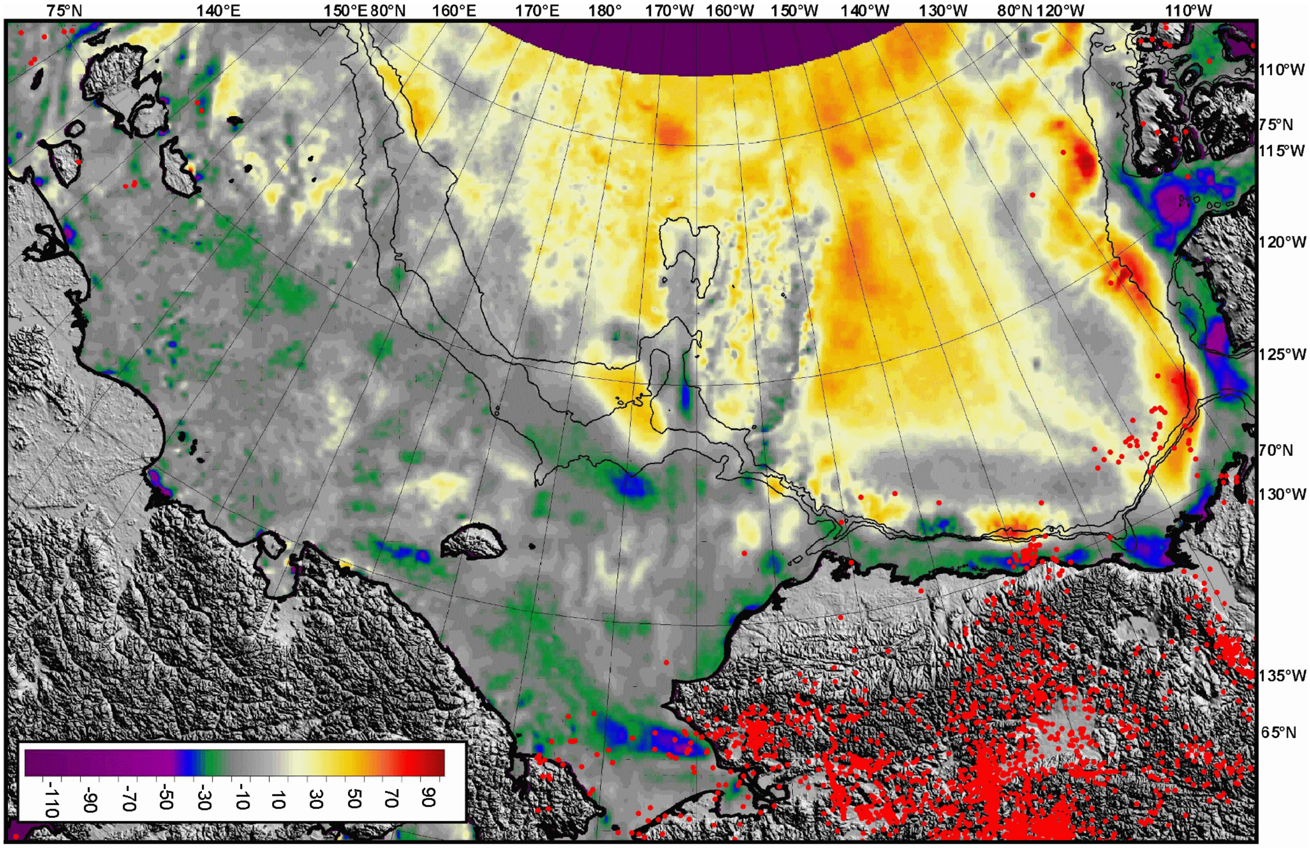


Figure 8. Isostatic anomaly (mGal) and seismicity from [*CNSS...,* 2002] data for M > 3.5 events. Shown are 100 m, 200 m, and 500 m depth contours.

The Chukchi borderland and Mendeleev Ridge are transitional between the shelf and oceanic domains in terms of the values of Bouguer anomaly. This might be due to a block with densities of 2.5–2.6 g/cm^3 having been superposed on basement with densities of 2.7–2.8 g/cm^3, which is evidenced by the general picture of the anomalous field.

The paleorift system of the Canada Basin is portrayed considerably less distinctly by Bouguer anomaly than by free air anomaly. This implies that this system is entirely restricted to within the crust, and there are virtually no mantle inhomogeneities to correspond to it. This rift system is inactive and lacks partially molten regions beneath it. A similar effect was recorded in the Atlantic while calculating Bouguer anomalies for certain transform faults [*Mazarovich and Sokolov,* 1999].

Collating Bouguer anomalies with the map of acoustic basement relief of the US sector of the Chukchi Sea [*National...,* 1995] shows that the anomalous field portrays precisely this density discontinuity. The strong correlation between Bouguer anomaly and acoustic basement relief is disturbed where local basement highs are overlain by thick successions of the Ellesemerian Sequence, as indicated by drilling data (Klondike Well,) [*National...,* 1995]. This suggests that, by and large, the Bouguer anomaly values are directly proportional to the depth to acoustic basement.

Isostatic anomaly. The final phase in analyzing the gravity field for the Chukchi and East Siberian seas was to calculate isostatic anomalies (Figure 8). It involved locating the excess (or shortage) of anomalous masses above the compensation surface. The optimum parameters to calculate isostasy for the oceanic and transitional zones are: a compensation depth of 33 km and a crust/mantle density contrast of 0.4 g/cm^3 [*Artemyev et al.,* 1987]. For the eastern sector of the Arctic, a density contrast of 0.6 g/cm^3 was chosen, because the transformation was intended to add contrast to the features of the shelf part of the region. Integration was conducted within a radius of 166 km by the algorithm using approximation of the field by prisms.

Analysis of isostatic anomalies shows the shelf area to be isostatically compensated. The oceanic part of the region is compensated either, although, as noted by the students of this phenomenon in the oceans [*Artemyev et al.,* 1987], in this domain the level of anomaly that corresponds to compensation is +20 to +30 mGal. Excess of masses above the compensation surface (positive isostatic anomalies) means that currently, either a process that adds masses (e.g., overthrusting) is taking place or, provided this process has ceased, excess masses are sinking to equilibrium. Shortage of masses above the compensation surface (negative isostatic anomalies) implies either an ongoing process that leads to strong basement subsidence (e.g., sedimentation) or, in case this process has terminated, compensatory uplifting of the basement surface to equilibrium. Considering the above, it can be inferred that overthrusting along the Wrangel–Herald rise is going on in the shelf area. Strong subsidence is occurring on the west of the South Chukchi Basin, in the Hope and North Chukchi basins, and in the Vilkitsky Trough and its branches.

Along the entire perimeter of the oceanic basin, present are shelf-edge maxima, which may be due to shelf aggradation through sedimentation. Southwest of the Mendeleev Ridge, the anomalous field has a compensated character pointing to the existence of additional mechanisms for subsidence and, possibly, to reduced depositional rates. Isostatic pattern of the oceanic domain is upset perceptibly near the eastern edge of the Chukchi borderland. Here, the strong contrast in anomalies is most likely to imply vigorous isostatic equilibration of masses after the cessation of tectonic processes that are responsible for the modern structural grain.

Principal Tectonic Features of NE Russia

Very generally, the nearshore portion of northeastern Russia and the Chukchi and East Siberian seas make part of the Late Cimmerian Verkhoyansk–Chukchi province, which is subdivided into two fold systems: Verkhoyansk–Kolyma and Novosibirsk–Chukchi [*Khain,* 2001]. The former has a highly complex fold-and-thrust structure. Its portions nearest the coast are composed of black-shale successions of Late Permian–Jurassic age folded into folds of various orders and cut through by granites of Cretaceous age.

The Chukchi fold area [*Morozov,* 2001] has ancient metamorphic basement that occurs at rather shallow depths and is overlain by a Permian–Triassic terrigenous and carbonate assemblage. The latter is composed of sandstones, siltstones, and mudstones with an appreciable proportion of carbonate matter in the cement, sulfide concretions, and, in places, elevated contents of carbonaceous matter in the clay rocks. The rocks are heavily deformed, occasionally to the extent of isoclinal folding. These rocks are unconformably overlain by Triassic strata represented by mudstones, siltstones, and sandstones, evidently deposited by turbidity currents. Toward the north these deposits give way to shelf facies. The top of the succession is composed of Upper Jurassic–Lower Cretaceous rocks subdivided into tuff/terrigenous and volcanic/terrigenous sequences. The volcanics belong to the calc-alkaline suite.

The Chukchi massif, which includs the rocks of the Seward Peninsula [*Calvert,* 1999; *Chekhov,* 2000; *Natal'in,* 1999], makes a basement high. Metamorphic basement incorporates rocks of Precambrian (Late Proterozoic?) age, Paleozoic shelf deposits, and fragments of a Devonian island arc. These rocks stretch from Kolyuchinsky Inlet to eastern Seward Peninsula, where a thrust contact has been recorded. Here, ancient rocks make up granite–gneiss domes (Neshkan, Koolen, Senyavin Rise, Kigluaik Mountains, Bendeleben, Darby, etc.) of Cretaceous age. These domes are composed of amphibolite facies metamorphics and numerous intrusions of intermediate to felsic compositions dated from 117 to 82 Ma (Aptian–Campanian). The rocks surrounding the domes are shales, sandstones, and limestones of Ordovician and Late Paleozoic age.

The Okhotsk–Chukchi volcanic belt overlaps unconformably on all the provinces described and on the more southerly collisional system of the Koryak–Kamchatka region, and it extends into Alaska. The belt is composed of a variety of volcanics of intermediate to felsic composition of Albian–Cenomanian age.

In the western East Siberian Sea, situated are New Siberian Islands, which are heterogeneous in structure [*Dorofeyev et al.,* 1999]. The basement of Bennett Island is composed of siltstone/mudstones successions of Middle Cambrian–Middle Ordovician age making a shallow anticline of NNW–SSE strike. This basement is overlain by flatly lying rocks of the Lower Cretaceous terrigenous/volvcanic association. The islands of Zhokhov and Vilkitsky are composed of Neogene–Quaternary olivine basalts and alkaline ultramafic rocks. These basalts contain limestone xenoliths of Carboniferous age. In the islands of Jeannette and Henrietta, established are deformed Carboniferous (?) terrigenous and volcanic rocks. Here, numerous sills, dikes, and flow units of basalt and dolerite are developed. Within the De Longa Rise, the thickness of sedimentary cover does not exceed 500–800 m [*Sekretov,* 2002]. It is generally assumed that De Longa Islands are fragments of the Hyperborean craton.

The islands of Faddeyevsky and Novaya Sibir are composed of Upper Cretaceous–Cenozoic deposits. In the central part of the latter, drilling intersected terrigenous successions folded into folds of WNW strike. In Kotelny Island exposed are Paleozoic–Mesozoic rocks folded into folds of northwestern strike. These rocks are represented by a calcareous/dolomite assemblage of Ordovician–Devonian age and by terrigenous successions of Late Devonian–Early Carboniferous age. The top of the stratigraphy is composed of Permian–Jurassic terrigenous strata.

Basement of Lyakhovsky Islands is composed of Proterozoic amphibolites and crystalline schists, a Permian–Triassic flysch-like association, and an Upper Jurassic–Cretaceous flysch. Here, ophiolites are recorded, which provided the basis for establishing an oceanic structure of Late Paleozoic age [*Khain,* 2001]. All the islands are known to display magmatic bodies of mafic and felsic compositions spanning a broad age interval, including the Cretaceous.

Wrangel Island is composed of a series of tectonic slices [*Kos'ko et al.,* 1992], in which fragments of the sedimentary/metamorphic succession of various ages are telescoped onto one another. The thrusts trend roughly E–W with their planes dipping gently (ca. 20°) southward. The magnitude of horizontal displacement is estimated at 12.5–15 km. Assumedly, overthrusts are also developed in the region of Academy Tundra [*Byalobzhesky and Ivanov,* 1971]. The structure is modified by numerous strike-slip faults trending NW–SE.

Tentative Tectonic Subdivision of the East Siberian and Chukchi Seas

Issues of the Tectonic Structure and Subdivision of the East Siberian and Chukchi seas and Adjacent Areas were Addressed repeatedly and in various degrees of detail by Soviet/Russian workers [*Burlin and Sheshukov,* 1999; *Drachev et al.,* 2001; *Ivanov,* 2001; *Khain,* 2001; *Kim,* 2002; *Kogan,* 1981; *Kos'ko,* 1992; *Kos'ko et al.,* 1993; *Leonov and Khain,* 1988; *Sevastyanov,* 1971; *Shipilov,* 1989; *Shipilov et al.,* 1989; *Sekretov,* 2001; *Tectonic...,* 1988; et al.].

We propose our own version of tectonic subdivision for the East Siberian and Chukchi seas (Figure 9) based on interpretation of new geophysical data and a wealth of geological materials. Certain introductory remarks of terminological nature are required, because the existing names of basins within the Chukchi Sea do not reflect their true geographic position. Thus, the South Chukchi Basin is located north of Chukchi Peninsula, and it is more relevant to call it "South Chukchi Sea Basin." Accordingly, the more northerly basin should be called "North Chukchi Sea Basin." As was shown above, the Vilkitsky Basin is integral to the North Chukchi Sea Basin and the Colville Basin. In this connection we propose a new name, "Novosibirsk–Alaska Basin," for the entire structure that extends from New Siberian Islands to western Alaska, while leaving intact the old names for second-order structures (with due regard for the terminological corrections). In what follows, we will re-address this issue.

In the structural setup of Alaska, recognized are three roughly E–W trending zones [see, e.g., *Kumar et al.,* 2002) with distinctive deformation styles and somewhat different age intervals of formation. The best understood area is the Brooks Range fold-and-thrust belt in northeastern Alaska [*Atkinson,* 2000]. This is an imbricate thrust package folded into folds of numerous orders. These structures were formed through crustal shortening by 400–500 km across the Brooks Range in Late Jurassic–Late Cretaceous times [*Howell et al.,* 1992]. Further north a zone of moderate deformations occurs; it is reflected in folds and imbricate thrusts or reverse faults. The northernmost zone, currently concealed beneath the thick cover of Upper Mesozoic–Cenozoic deposits, is almost undeformed as compared to the more southerly regions.

To the east of the North Slope of Alaska, deformation took place [*O'Sullivan,* 1991, 1992] episodically during the Tertiary and consisted in that the thrusting front migrated northward to cause uplifting and erosion of the Brooks Range. South of the front, K-Ar biotite ages from the Okpilak Batholith equal 59–61 Ma, values corresponding to cooling in the wake of thrusting-related metamorphism. Near the front, the Upper Cretaceous and Lower Tertiary rocks are involved in folding along with the older assemblages. Further north, within the plain, seismic data show that the most significant deformations occurred in pre-Eocene time. However, the surface of this unconformity is also gently folded, which suggests that deformation continued, albeit less heavily, in later times. In the northeastern Brooks Range uplifting and erosion events are recorded in the Paleocene (ca. 60±4 Ma), Eocene (50 and 43±3 Ma), and Early and Late Oligocene (34±3 and 25±3 Ma, respectively). Similar phases (100, 60, 40, and 25 Ma) [*Murphy et al.,* 1992] were recorded in the central parts of the range. Evidently, the pulses of terrigenous supply into the Colville Basin and the Beaufort and Chukchi seas were induced by these phases.

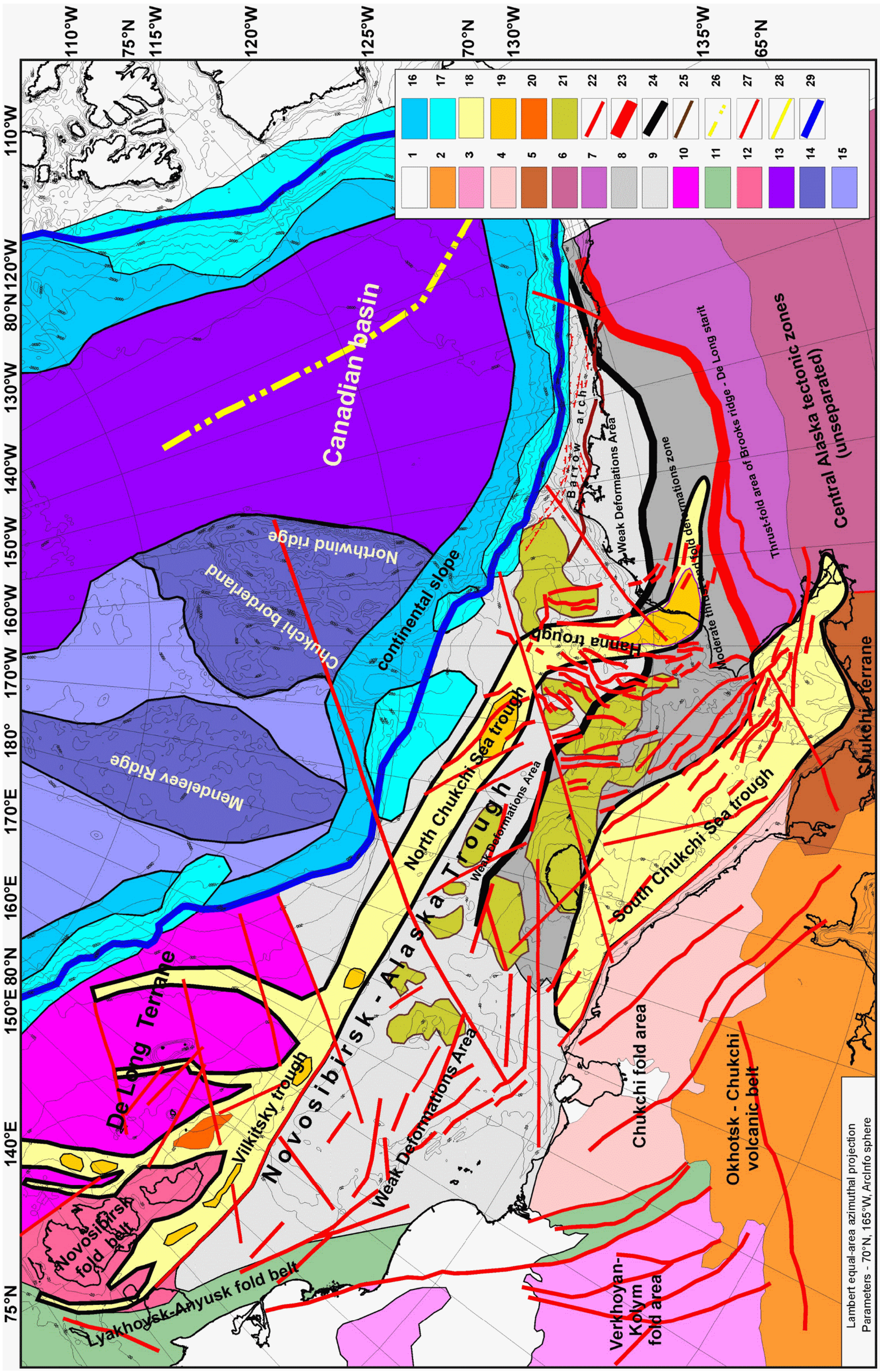
The style of deformations described in the first zone persists as far westward as the Chukchi Sea coast. Further west still, the main thrusting front of the Brooks Range plunges beneath the Chukchi Sea to merge with the thrust of the eastern part of Cape Lisburne and then stretches on to Wrangel Island; this is supported in all the works known to us [*Grantz et al.,* 1998; *Herman and Zerwick,* 1992; *Khain,* 2001; *Natal'in,* 1999; etc.].

However, a number of circumstances suggest that this model may require some corrections. Firstly, it is evident that Jurassic–Early Cenozoic movements gave rise to a fold-and-thrust edifice that has since been eroded away. This implies that the southward- dipping thrust planes were bound to migrate in the same direction. Secondly, the imbricate thrusts of Wrangel Island and Lisburne Peninsula [*Natal'in,* 1999] are incomparable in their displacement magnitudes with the Brooks Range overthrusts, being instead similar to deformations developed in the fore-thrust zone or in the foreland [*Wallace et al.,* 2001]. Thirdly, as was shown above, satellite altimetry data indicate (Figure 7) that, on trend with the fold-and-thrust area, there occurs a strong negative anomaly of sigmoid character stretching from Alaska to Longa Strait. Apparently, it is into this locality that the main deformation front extends. Subsequently, the South Chukchi Sea Basin took shape here. Under this interpretation, the foreland zone stretches to Wrangel Island, and north of the foreland there exists a slightly deformed zone corresponding to northern Alaska.

The South Chukchi Sea Basin stretches for almost 1300 km from Kotzebue Bay in Alaska to the latitude of Cape Shelagsky. Its structure was repeatedly discussed in publications [e.g., *Hope...,* 1986; *Kim,* 2002; *Tectonic...,* 2002] with various degrees of detail. The basin is heterogeneous in structure and can be subdivided [*Kim,* 2002] into a number of basins, which are (from west to east): Hope, North Schmidt, and Longa. Maximum thicknesses of sedimentary cover in these basins are 8200, 2700, and 4000 m, respectively. Judging by seismic data, principal deposition in the Hope Basin took place in Aptian–Albian and Paleogene times. The numerous faults virtually do not affect the Neogene–Quaternary interval of the stratigraphy.

Satellite altimetry imaging shows that offshore, on trend with the two northern tectonic zones of Alaska, there occurs a strip of positive anomalies stretching into the East Siberian Sea as far as 165°E longitude. In all likelihood, this strip corresponds to the uplifts of the Ellesemerian Sequence, one of which was penetrated by five wells within the US territory. Zones of heavy and moderate deformations die out some distance short of where they would pass by Ayon Island.

South of the shelf break, the North Chukchi Sea Basin is located [*Lothamer,* 1992]. Satellite altimetry data show that it extends toward the Vilkitsky Basin, but is separated from it by a rise possibly related to fault zones. The basin is a large structure with branches that stretch deep into the Longa massif. This rift-like structure is modified by basement highs and incorporates several sediment-starved


110°W
75°N
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65°N
80°N 120°W
130°W
140°W
150°W
160°W
170°W
180°
170°E
160°E
150°E 80°N
140°E
75°N
Canadian basin
Northwind ridge
Chukchi borderland
Mendeleev Ridge
continental slope
North Chukchi Sea trough
Novosibirsk - Alaska Trough
Hanna trough
South Chukchi Sea trough
Weak Deformations Area
Weak Deformations Area
Weak Deformations Area
Weak Deformations Area
Weak Deformations zone
Moderate thrust and fold deformations zone
Barrow arch
Thrust-fold area of Brooks ridge - De Long starit
Central Alaska tectonic zones (unseparated)
Chukchi terrane
De Long Terrane
Vilkitsky trough
Novosibirsk fold belt
Lyakhovsk-Anyusk fold belt
Verkhoyan-Kolym fold area
Chukchi fold area
Okhotsk - Chukchi volcanic belt
Lambert equal-area azimuthal projection
Parameters - 70°N, 165°W, ArcInfo sphere

Figure 9. Sketch map showing tectonic subdivision of the East Siberian and Chukchi seas. 1 – continental areas with thick sedimentary cover of Neogene–Quaternary age; 2 – Okhotsk–Chukchi volcanic belt (Albian–Senonian). Mesozoides of northeastern Asia (3–4): 3 – Verkhoyansk–Kolyma fold-and-thrust area, 4 – Chukchi fold area; 5 – Chukchi massif (Precambrian crystalline basement highs), 6 – tectonic zones, central Alaskan and undivided; 7 – fold-and-thrust area of Brooks Range–Longa Strait (repeated deformations in Late Jurassic–Paleogene times); 8 – area of moderate deformations of thrust, reverse fault, and fold nature (repeated deformations in Late Jurassic–Paleogene times); 9 – area of zero or slight deformation in Jurassic–Cenozoic deposits; 10 – area with shallow occurrence and outcrops of Precambrian crystalline basement; in Anjou Islands, development of Paleozoic cover (De Longa massif); 11 – Lyakhovsky fold-and-thrust zone; 12 – Novosibirsk fold zone. Morphostructures of the Amerasia Basin (13–17): 13 – Canada Basin (oceanic crust overlain by sedimentary cover), 14 – rises with continental crust, 15 – basins with continental crust, 16 – continental slope, 17 – areas of uncompensated subsidence (sedimentary lenses). 18 – major basins; 19 – areas of strongest subsidence; 20 – rise within basin; 21 – uplifts of Ellesmerian basement (positive gravity anomalies); 22 – faults; 23 – frontal thrust of the Brooks Range; 24 – inferred boundary of deformed and undeformed domains; 25 – Barrow Arch; 26 – fossil spreading zone (from satellite altimetry data); 27 – shelf break; 28–30 – trends of ridges and basins on the Chukchi outer shelf.

depressions. Isostatic anomalies and several seismic events [*CNSS...,* 2002] (Figure 8) that occurred between 1973 and 1986 indicate that its western part is still subsiding. Judging by seismic data [*Grantz et al.,* 1990] and gradient zones, the basin is bounded on the south by a flexure modified by high-angle faults of the same trend.

To the east of the Chukchi Sea, the tectonic setup is more complex. Here, the so-called Hanna Trough with sediment thicknesses in excess of 15 km is situated [*National...,* 1995; *Sherwood et al.,* 2002]. This trough is interpreted as a rift of Devonian–Permian age; it is an asymmetrical feature with a gentle western slope and a steeper eastern one. The Hanna Trough is located on trend with the Chukchi borderland, and the area of impact from the structures trending roughly N–S extends as far as the south boundary of the South Chukchi Sea Basin (Kotzebue Sill, which is a locus of vigorous modern seismicity; [*CNSS...,* 2002]) (Figure 8). Within the US sector [*Lothamer,* 1992) seismic surveys have resolved a system of dextral strike-slip faults (the Hanna shear zone) trending roughly N–S, which developed from Paleocene to Middle Eocene. In some localities, vertical displacements are as large as 3000 m. Within the strike-slip zone, recognized are three principal (root) zones, but the impact of strike-slip deformation reaches far outside their confines. The origin of this zone is associated with episodic extension processes of regional character. The curvature of the Novosibirsk–Alaska Basin matches the Hanna Trough structures, which are most likely inherited by this basin. The existence of this basin is evidenced not only by geophysical data alone, but also by the isopach pattern [*Sherwood et al.,* 2002].

Seismologic, geophysical, and geological data for the shelf area of the eastern Arctic make it possible to locate fault systems of various ages, scales, and kinematic types. Satellite altimetry imaging pinpoints or further constrains the location of the main fault systems in the East Siberian and Chukchi seas with a high degree of confidence. These systems have two principal directions: NE–SW and NW–SE. The former modifies the Novosibirsk–Alaska Basin and Chukchi borderland. Evidently, this system also incorporates those faults [*Grantz et al.,* 1990; *Sherwood,* 1992] with which the Barrow Valley is associated spatially. Dextral strike slips of northeastern orientation have been established in Chukchi Peninsula; these are traceable toward Lisburne Peninsula [*Natal'in,* 1999]. Therefore, a number of faults of this system have a dextral strike-slip component.

The other system is oriented NW–SE. The numerous faults that provide southern boundaries to the Vilkitsky, South Chukchi, and North Chukchi basins can be attributed to this system. Within Chukchi Peninsula [*Natal'in,* 1999], faults of a similar trend and northeasterly dip have been reported. As mentioned above, the faults in Wrangel Island have a closely similar trend as well.

Conclusions

The above facts have suggested us the idea that tectonic mapping of the East Siberian and Chukchi seas can be based on the degree of rock deformation. Currently, such mapping is feasible only in a tentative form. However, there are obvious distinctions between the fold-and-thrust belt, zones of imbricate thrust piles, and slightly deformed rock assemblages that are folded into gentle folds and cut by high-angle faults. The tectonic zones have individual "signatures" in potential fields, which can be used to trace these zones offshore.

The Chukchi Sea shelf is composed of correlatives of the Alaskan tectonic zones. The main Alaskan thrust does not stretch into Wrangel Island but is instead located in the region of the South Chukchi Sea Basin. The Brooks Range fold-and-thrust area and the fore thrust pass somewhat west of Wrangel Island, to die out within the eastern East Siberian Sea. Most part of the shelf is occupied by a zone of zero or slight deformation. This part displays positive gravity anomalies that can be compared to uplifts of the Ellesmerian Sequence. Tectonically, this is the most promising zone for petroleum prospecting. The North Chukchi Sea Basin along with the Vilkitsky Trough and the region of maximum subsidence in the Colville Trough make a single entity, the Novosibirsk–Alaska Basin. Its curvature is due to the fact that it is superposed on the structures of the Hanna Trough. The closely parallel sigmoid bends of these basins render them comparable to pull-apart structures. Under such an interpretation, a major dextral shear stretching from Chukchi borderland almost as far as Bering Strait is likely to exist here.

The proposed tectonic subdivision of the study area may be instrumental in refining the history of the entire eastern Arctic region, an exercise that deserves special consideration.

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