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Geology and Assessment of Undiscovered Oil and Gas Resources of the Laptev Sea Shelf Province, 2008

Chapter W of
The 2008 Circum-Arctic Resource Appraisal

Professional Paper 1824

U.S. Department of the Interior
U.S. Geological Survey

COVER

Eocene strata along the north side of Van Keulenfjorden, Svalbard, include basin-floor fan, marine slope, and deltaic to fluvial depositional facies. The age and facies of these strata are similar to Tertiary strata beneath the continental shelves of Arctic Eurasia, thus providing an analog for evaluating elements of those petroleum systems. Relief from sea level to top of upper bluff is approximately 1,500 feet. Photograph by David Houseknecht.

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Chapter W

Geology and Assessment of Undiscovered Oil and Gas Resources of the Laptev Sea Shelf Province, 2008

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Abstract

The U.S. Geological Survey (USGS) recently assessed the potential for undiscovered oil and gas resources of the Laptev Sea Shelf Province as part of the 2008 Circum-Arctic Resource Appraisal (CARA) program. The province is situated in the Russian Federation and is located between the Taimyr Peninsula and the Novosibirsk (New Siberian) Islands. Three assessment units (AUs) were defined for this study: the West Laptev Grabens AU, the East Laptev Horsts AU, and the Anisin-Novosibirsk AU, two of which were assessed for undiscovered, technically recoverable resources. The East Laptev Horsts AU was not quantitatively assessed. The estimated mean volumes of undiscovered oil and gas for the Laptev Sea Shelf Province are approximately 3 billion barrels of crude oil, 32 trillion cubic feet of natural gas, and <1 billion barrels of natural gas liquids, all north of the Arctic Circle.

Laptev Sea Shelf Province

Province Boundary Definition

The Laptev Sea Shelf Province is located primarily in the Russian part of the Arctic Ocean, north of eastern Siberia, with a small area onshore (fig. 1). The geologic province lies between the Taimyr Fold-and-Thrust Belt to the west and the New Siberian Islands to the east. The northern, onshore part of the Verkhoyansk Fold-and-Thrust Belt and Olenek Fold Zone form the southern boundary of the province, and the inferred southwest-trending Severnyi Transform Fault along the Laptev Sea Shelf edge forms the north boundary.

The Laptev Sea Shelf Province is divided into three assessment units (AUs) on the basis of their location and predominant structural style (graben or horst). The West Laptev Grabens AU comprises the graben system in the western part of the province. The East Laptev Horsts AU represents the horst system in the eastern part of the province. Shallow half-grabens, presumably containing Cenozoic strata, are present in the East Laptev Horsts AU. The Anisin-Novosibirsk Basins AU comprises the deep grabens in the northeastern part of the province, in an area of structural extension. A map of major structural features and approximate depth to economic basement is shown in figure 2.

Petroleum Occurrence

No petroleum accumulations have been discovered in the Laptev Sea Shelf as of 2008, thus source, reservoir, and seal rocks, as well as trap configurations can only be inferred.

Tectonostratigraphic Evolution

The Laptev Sea Shelf is an area of episodic extensional tectonics, initially formed sometime in Late Cretaceous and Paleocene time, presumably coeval with formation of the Eurasia Basin; extension is still occurring, as indicated by earthquake data (Franke and others, 2001; Franke and Hinz, 2005). The geologic province consists of a rift system (Ust' Lena Rift) in the west and horsts partitioned by faults and half grabens (Laptev Horst) in the east. Both the rift system and the horsts and half grabens are aligned with the Gakkel Ridge midoceanic spreading center directly north of the Laptev Sea Shelf boundary. The Lazarev Fault, which separates the West Laptev Grabens from the East Laptev Horsts, is a west-dipping listric fault that flattens in the prerift section and might act as a detachment surface beneath the eastern part of the Ust' Lena Rift (Franke and others, 2001). Recent movements on this fault are interpreted to have occurred in Pliocene time or later (Franke and others, 2001).

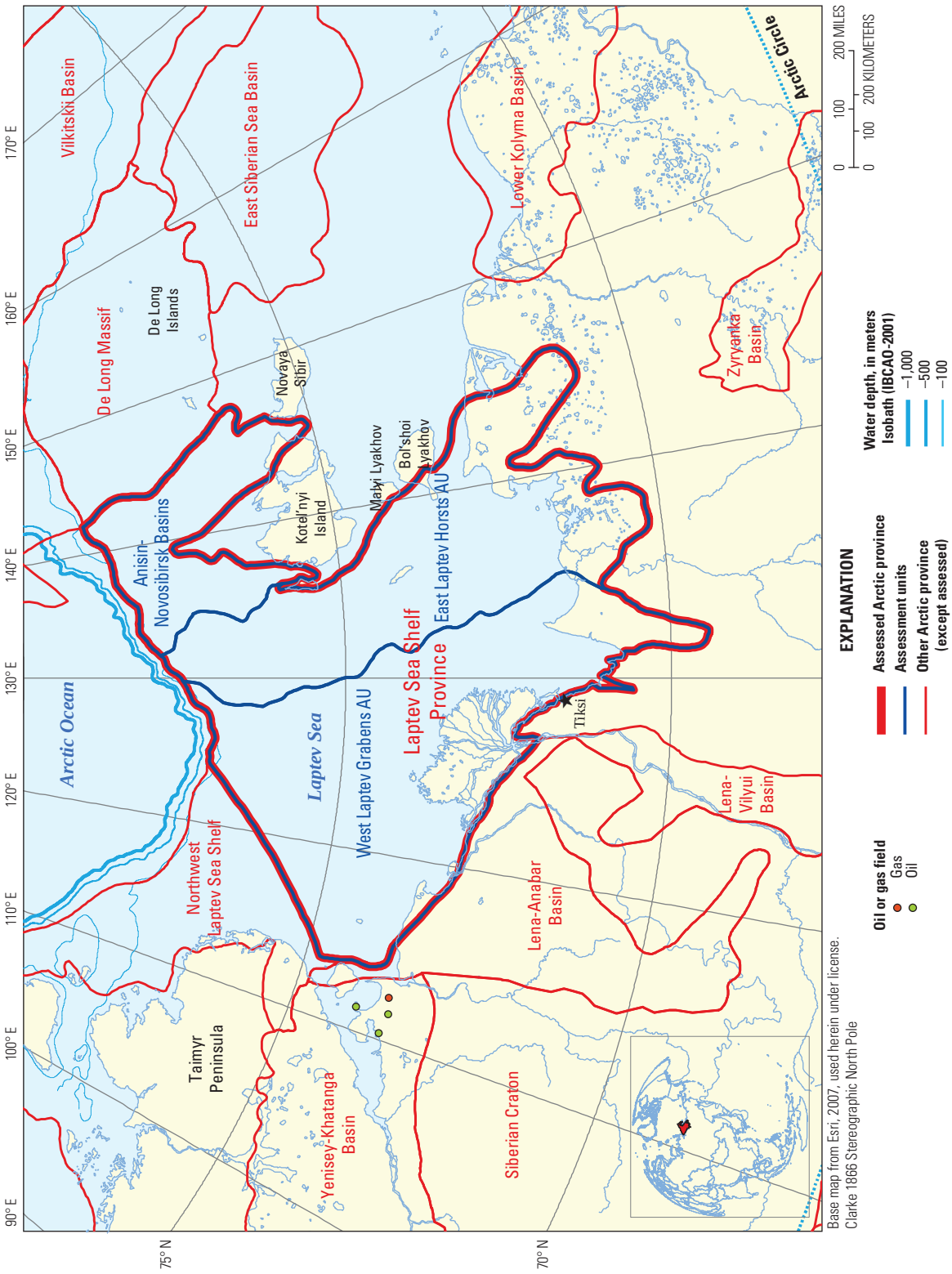

Figure 1. Map showing location of the Laptev Sea Shelf Province and assessment units (AUs). Oil and gas field data from data from IHS Energy (2007).

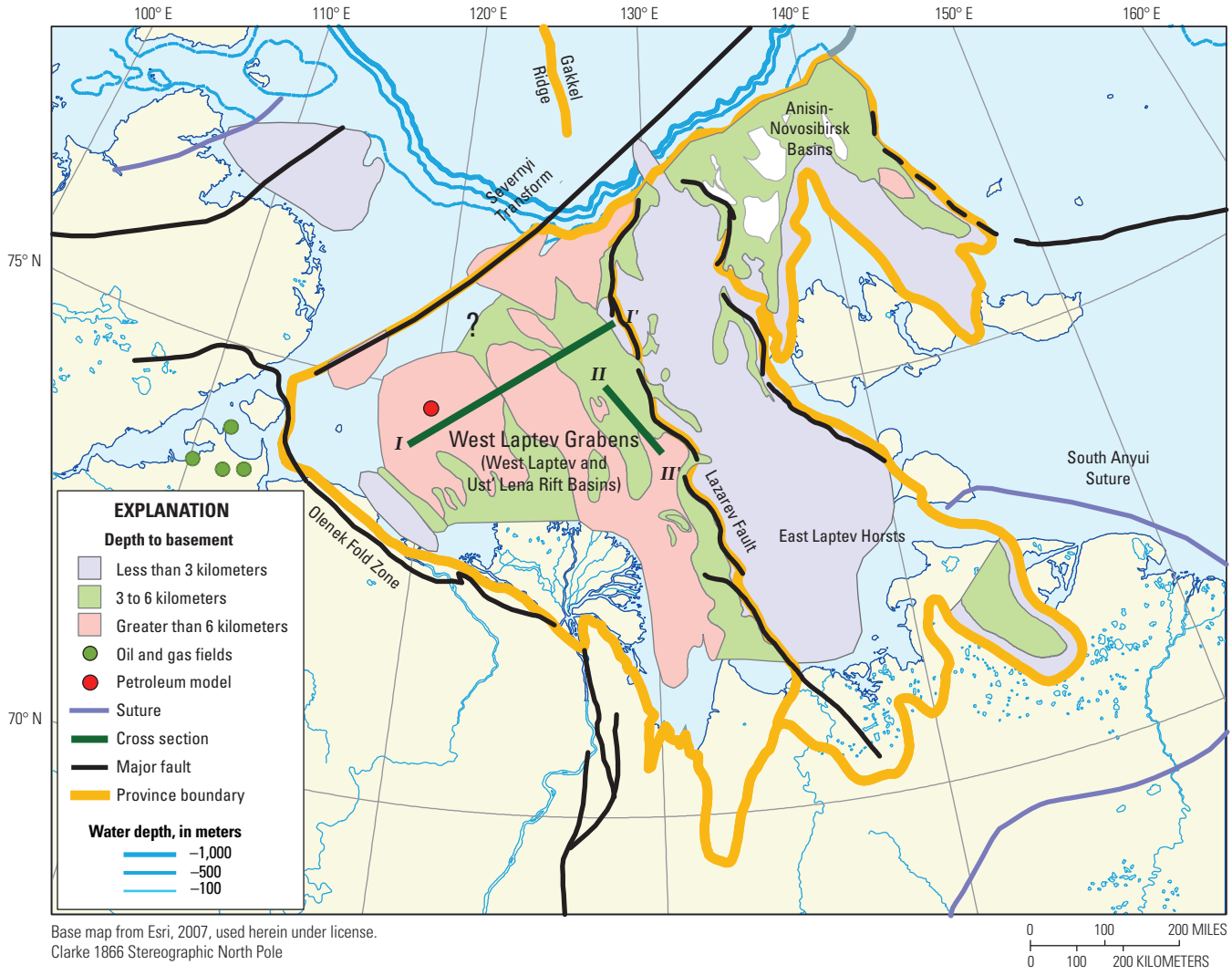

Figure 2. Structural map showing major structural features and approximate depth to economic basement in the Laptev Sea Shelf Province. Data from IHS Energy (2007) and Persits and Ulmishek (2003).

The prerift sedimentary section in the Laptev Sea Shelf Province is poorly known but is thought to consist mainly of Proterozoic to Devonian carbonate and Carboniferous to lowest Cretaceous clastic rocks that were deformed during Early Cretaceous compression (Drachev, 2002). A prerift Mesozoic sedimentary section of the platform crops out south of the shelf and on the Taimyr Peninsula. Although the intensity of deformation is unknown, the relatively fine-grained texture and moderate thickness of Lower Cretaceous (Aptian to Albian) continental clastic rocks indicate that deformation did not result in the formation of an orogen.

Rocks of the Siberian cratonic basement might underlie part of the sedimentary section in the West Laptev Grabens AU (Sekretov, 2000; Franke and others, 2001) and the East Laptev Horsts AU. The prerift sedimentary section underlying the Anisin-Novosibirsk Basins AU and perhaps at least part of the East Laptev Horsts AU is presumed to be similar to rocks exposed on Kotel'nyi Island and might be part of the Alaska-Chukotka block. A transform fault, extending from the South Anyui suture northward, is presumed to exist between the Siberian craton and Alaska-Chukotka. Although its exact location is unknown, the transform fault might extend along the western margin of the Novosibirsk Islands (Drachev, 2002).

Synrift rocks of the Laptev Sea Shelf are interpreted to consist of uppermost Cretaceous and Paleogene clastic rocks. Three major seismic-marker horizons punctuate the synrift section. The top of acoustic basement appears to be an erosional unconformity that developed during Late Cretaceous to early Paleocene time; it can be traced to depths of 13 km. Geologic cross sections are shown in figure 3.

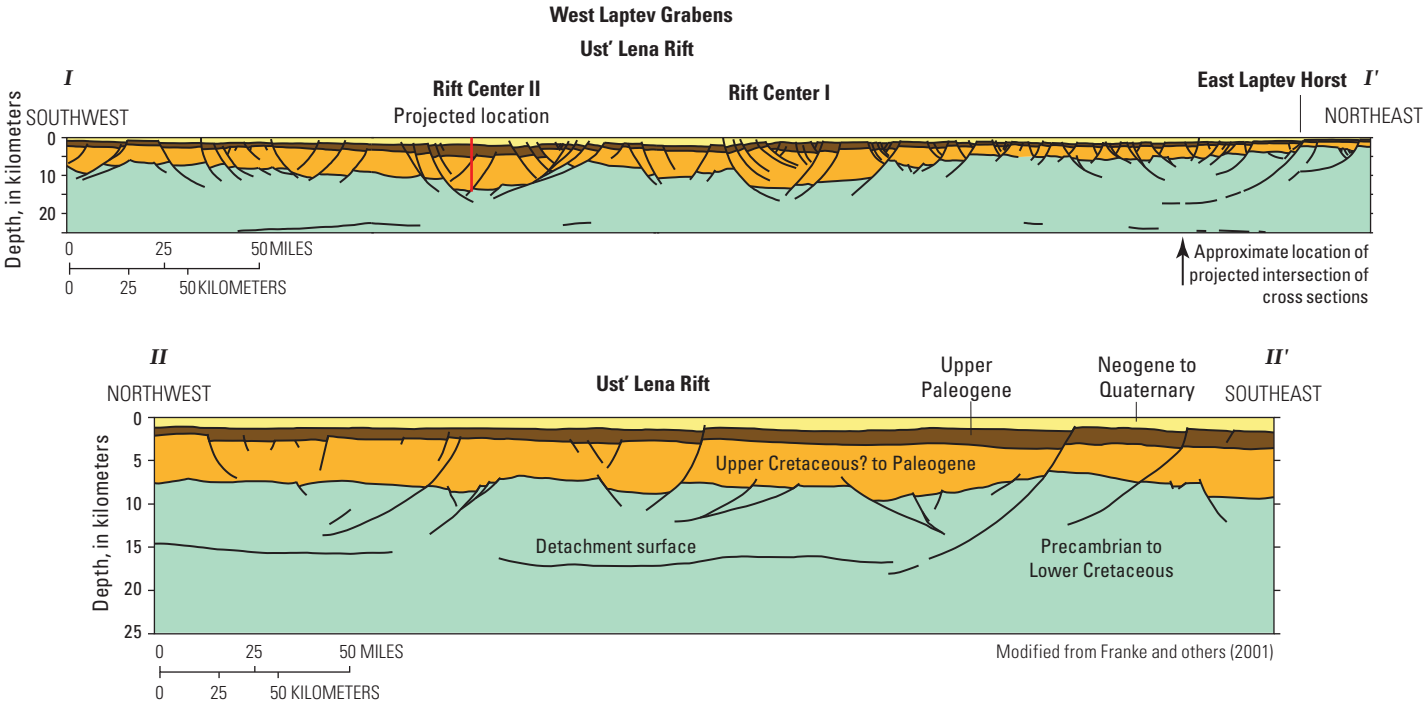

Figure 3. Regional geologic cross sections. Locations shown on figure 2. Vertical red line is location of pseudowell used for petroleum-generation model. Modified from Franke and others (2001).

Petroleum System Elements

Two total petroleum systems (TPSs) were identified in the study area: a Jurassic-Cretaceous-Paleogene composite TPS in the West Laptev Grabens AU and in the East Laptev Horst AU, and a Paleogene TPS in the Anisin-Novosibirsk Basins AU. A lithostratigraphic column and TPS events chart for the individual petroleum system elements are shown in figure 4.

Source Rocks

Numerous natural gas seeps have been observed and analyzed throughout the Laptev Sea Shelf Province. Most seeps that have high methane contents occur within the East Laptev Horst AU, but no source rocks have yet been identified. Analyses of natural gas collected from bottom sediment and near-bottom waters from western and northern parts of the Laptev Sea Shelf indicate the presence of mature marine source rocks, presumably of Paleogene age and oil-prone (Cramer and others, 2001; Cramer and Franke, 2005). Postulated source rocks include oil-prone Upper Jurassic marine mudstone and Paleozoic, Lower Cretaceous, and uppermost Cretaceous to Paleogene gas-prone coaly and carbonaceous source rocks. Upper Jurassic (Kimmeridgian to Tithonian) organic-rich mudstone crops out on the Pakhsa Peninsula, adjacent to the West Laptev Grabens AU. The mudstone, which is interpreted to represent a transition between presumed basinal facies to the north and nearshore facies exposed to the south, probably represents the southernmost extent of an important petroleum source rock in at least the southwestern part of the AU. The geochemical composition of organic matter in samples of Cenozoic rocks recovered from steep slopes of the Northwind and Lomonosov Ridges indicates that restricted marine and anoxic conditions could have existed in the Arctic Ocean during Paleogene time (Grantz and others, 2001). Organic-rich mudstone could have been deposited on the Laptev Sea Shelf and might have generated petroleum if sufficiently buried.

Petroleum-generation modeling indicates that Jurassic source rocks would have begun to thermally mature prior to Cretaceous erosion and again during the Paleogene (fig. 5). Upper Cretaceous and Paleogene source rocks, deposited in synrift grabens, would have started to generate petroleum during the Paleogene and are presently in the petroleum-generation stage of maturity (fig. 5). Petroleum migrated vertically along faults, as evidenced by natural gas chimneys observed on seismic profiles, with short lateral migration from source rocks juxtaposed to reservoir rocks by fault displacements.

Reservoir and Seal Rocks

Major synrift reservoir rocks are likely to be shelf and slope clastic sediment derived from the ancestral and present-day Lena River. Reservoir rocks could include coarse-grained, clastic topset beds, clinoforms, submarine channels, fans, and

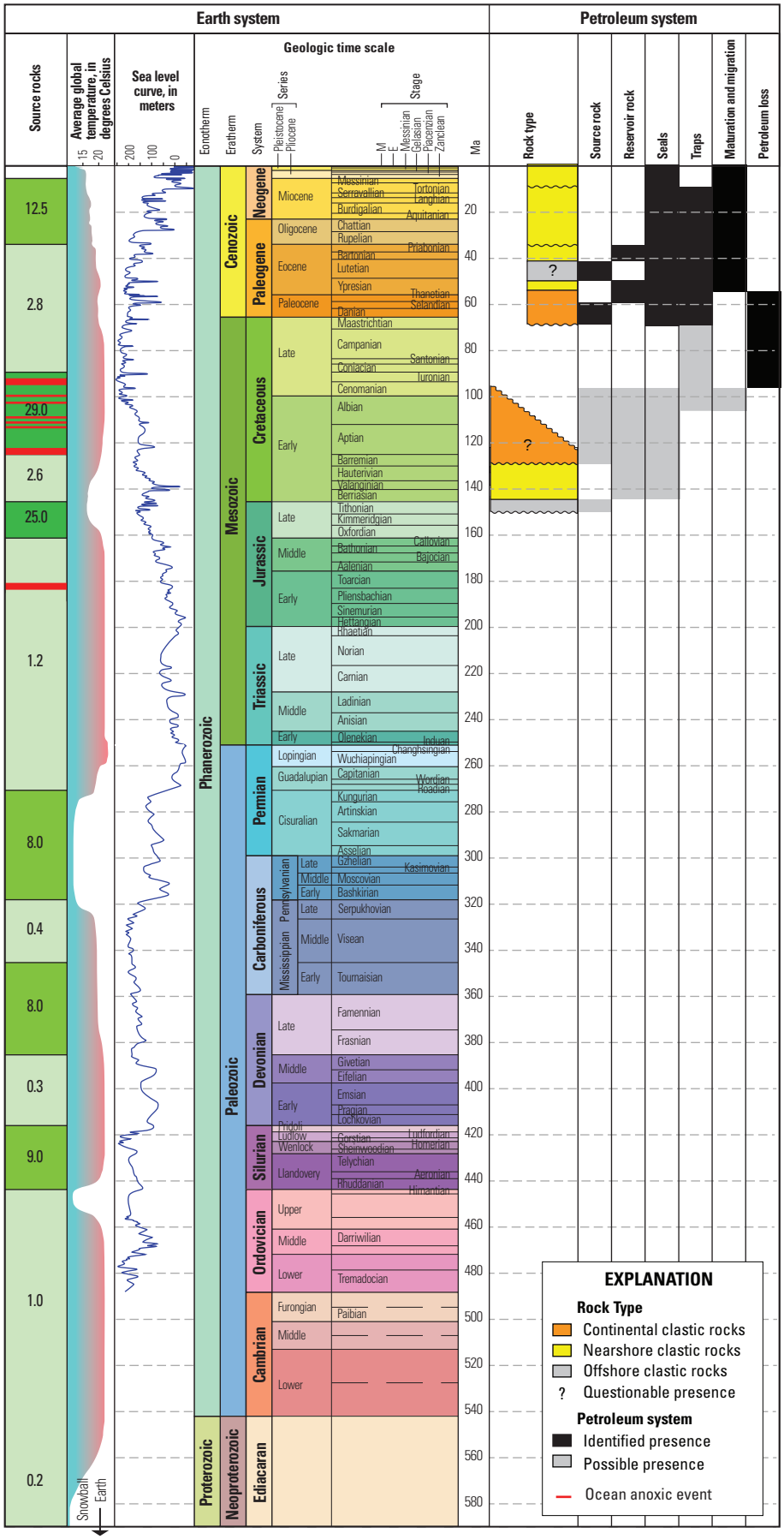

Figure 4. Lithostratigraphic column and total petroleum system events chart for the Laptev Sea Shelf Province. Source rocks column shows the percent of the world's total petroleum reserves generated by source (modified from Ulmishek and Klemme, 1990). Average global temperature data is from Frakes and others (1992) and Barrett (2003). Sea level curve is from Golonka and Kiessling (2002) and Hardenbol and others (1998). Geologic time scale is that of Gradstein and others (2004). Data from Cramer and others (2001), Cramer and Franke (2005), Franke and others (2001, 2004), Grantz and others (2001), Kaplan and others (1973), Kim and others (1999), Kos'ko and Trufanov (2002), Matykhin and Sokolov (1998), Sekretov (1999), Surkova (1987), Yakovlev and Koporulin (1996), and Zakharov and others (1983).

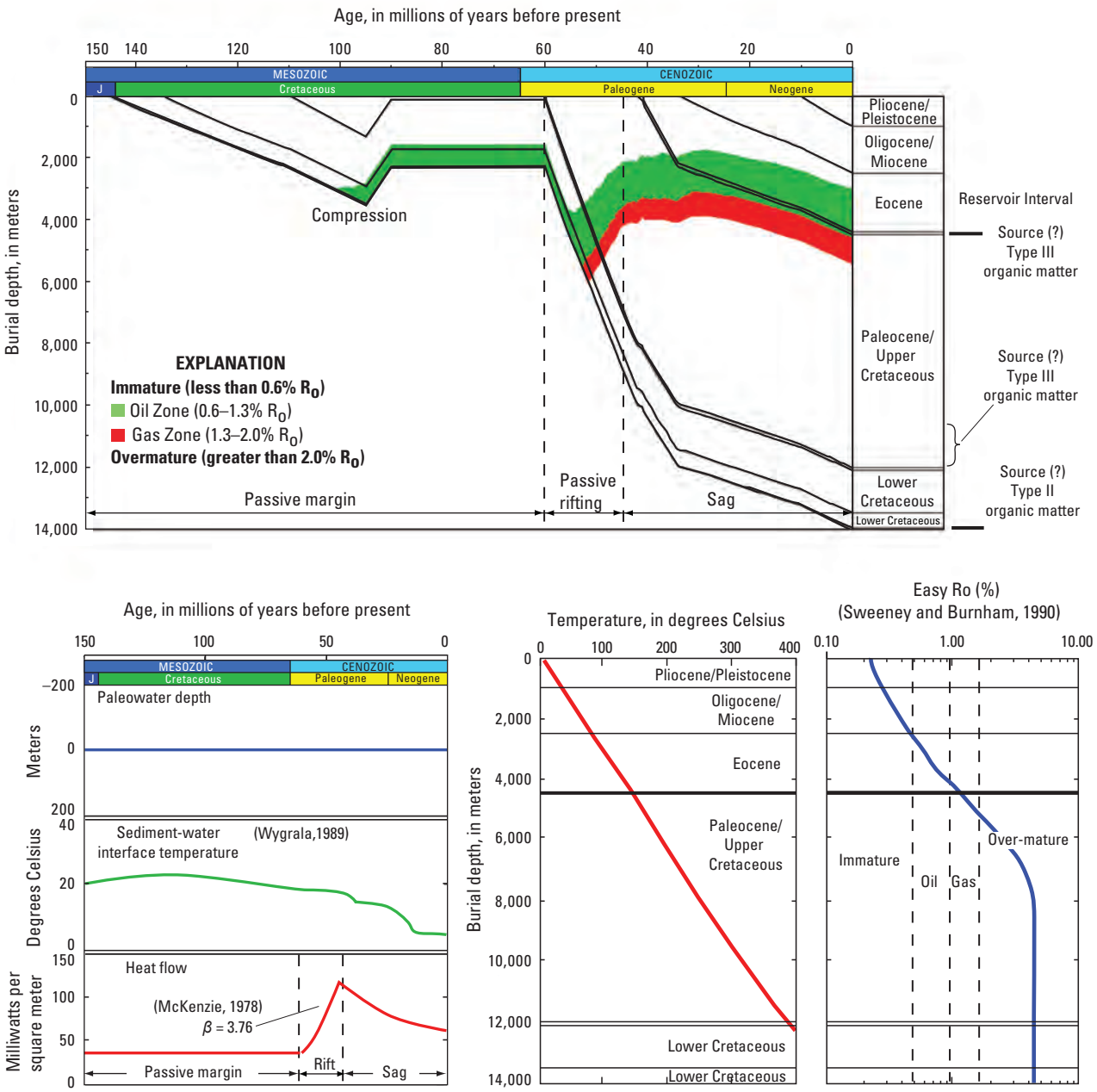

Figure 5. Burial history model for pseudowells in the West Laptev Grabens Assessment Unit depicting thermal maturity. Location of wells shown in figure 2. Ro, vitrinite reflectance, in percent (%); J, Jurassic. Data from Duchkov and others (1982) and Franke and others (2001). PetroMod references are Integrated Exploration Systems (2008), McKenzie (1978), Sweeney and Burnham (1990), and Wygrala (1989).

turbidites. The presence of prerift reservoir rocks is uncertain, but might include compressionally deformed upper Paleozoic to Mesozoic paralic and marine clastic rocks and Paleozoic carbonates. The presence of effective seals remains in question but is likely, considering the thick clastic section. Permafrost averaging 300 to 400 meters thick, which covers the southern and central areas of the shelf, together with associated gas hydrates, may also act as an effective seal.

Traps and Timing

Traps for petroleum accumulation include rotated fault blocks, horsts, and pinchouts of clastic rocks within grabens of the synrift sedimentary section. In addition, structures associated with Early Cretaceous compression including anticlines, faulted anticlines, and thrust faults, might trap petroleum in the prerift section.

Assessment Units

West Laptev Grabens Assessment Unit

The Laptev Sea Shelf Province is an area of Cenozoic structural extension. Paleozoic and Mesozoic sediment presumably was deposited in the area prior to extension and was deformed by compression during Early Cretaceous time. A rift/sag system formed over the area during Paleogene and Neogene time. The West Laptev Grabens AU, which is located in the western part of the province, consists of the synrift and prerift sedimentary sections. One or more TPSs may exist in the study area, corresponding to prerift and synrift sedimentary sections. Because of lack of data and possible mixing of petroleum, however, one composite TPS was defined. Stratigraphically, the AU includes the Jurassic to Cretaceous and Cenozoic sedimentary sections. One well was drilled on the Lena Delta, but the offshore area experienced only seismic exploration.

Assessment of the West Laptev Grabens AU used two scenarios that differed in the existence and maturation of source rocks, because charge probability alone is insufficient to characterize combinations of source rocks. The first scenario, a best-case configuration, includes existence of both prerift and synrift source rocks under geologic conditions favorable for petroleum occurrence, and the second scenario, a base-case configuration, includes existence of only synrift source rocks and favorable conditions for petroleum occurrence. The probability of scenario 1 was estimated at 0.1 (10 percent) and the probability of scenario 2 was estimated at 0.9 (90 percent; see appendix 1)

Geological Analysis of Assessment Unit Probability

No petroleum accumulations have been discovered in the Laptev Sea Shelf as of this 2008 study, so source, reservoir, and seal rocks, as well as trap configurations, can only be inferred. The overall probability for the existence of at least one accumulation greater than 50 million barrels of oil equivalent (MMBOE) is 0.49 for the base-case scenario (scenario 2) and 1.00 for the best-case scenario (scenario 1). The assessment input data are summarized in appendix 1.

Charge Probability.—Natural gas chimneys have been observed on seismic profiles throughout the study area (Cramer and Franke, 2005), but source rocks in the Laptev Sea Shelf Province have not been identified. Possible source rocks might include (1) Lower Cretaceous gas-prone coaly and carbonaceous strata, (2) synrift, uppermost Cretaceous and Paleogene coaly and carbonaceous continental rocks, and (3) Paleogene (Eocene) organic-rich mudstones deposited during major marine flooding events. In the West Laptev Grabens AU, an oil-prone Upper Jurassic basinal organic-rich mudstone might be present in the prerift sedimentary section, where it overlies the Siberian craton. A charge probability of 1.00 was estimated for scenario 1, but a probability of 0.60 was estimated for scenario 2 because potential Cretaceous and Paleogene source rocks might be less likely to generate enough petroleum to form accumulations that exceed 50 MMBOE.

Rock Probability.—Rock probabilities of 1.00 and 0.90 were estimated for scenarios 1 and 2, respectively, because the depositional setting in the synrift section is amenable for adequate reservoir and seal rocks and traps. Major synrift reservoir rocks are likely to be shelf and slope clastic strata deposited by the ancestral and present-day Lena River. Prerift reservoir rocks might include upper Paleozoic (?) and Mesozoic paralic and marine clastic rocks. Traps for petroleum accumulation could include rotated fault blocks, horsts, and pinchouts of clastic rocks within grabens, as well as anticlinal traps in the prerift section. Petroleum could have migrated vertically along faults, as evidenced by natural gas chimneys, and laterally into juxtaposed reservoirs along faults. The presence of seal rocks and their effectiveness remain uncertain, but they are probably adequate, considering the presence of a thick mixed clastic section. Permafrost averaging 300 to 400 m thick (Franke and others, 2001) that covers the southern and central parts of the shelf, together with associated gas hydrates, may also act as a seal.

Timing and Preservation Probability.—Timing and preservations probabilities of 1.00 and 0.90 were estimated for scenarios 1 and 2, respectively, because most traps were probably formed prior to petroleum generation and expulsion. Petroleum could have migrated vertically along faults, as evidenced by natural gas chimneys observed on seismic profiles, and laterally into reservoirs juxtaposed to source rocks by fault displacements.

Geologic Analogs for Assessment

The area of the West Laptev Grabens AU is approximately 242,000 km^2; 82 percent of the AU area and 90 percent of its potential petroleum resources occur offshore in the Laptev Sea (fig. 1).

Two analog datasets from within the USGS World Analog Database (Charpentier and others, 2008) were selected, one to represent the prerift section and another to represent the synrift section. The analog set selected for the prerift sedimentary section includes compressional trap systems without salt-related traps in craton interior architectures that have clastic depositional systems and discovered fields of 50 MMBOE or greater. In addition, analog AUs in foreland basins, which are numerous and distributed worldwide, were used to constrain the estimates. The analog set selected for the synrift sedimentary section includes settings that have rift/sag architecture, clastic depositional systems without salt-related traps, and analongs that have discovered fields of 50 MMBOE or greater.

Number of Undiscovered Accumulations.—The number of undiscovered oil and gas accumulations was estimated by comparing the field densities (estimated number of undiscovered accumulations plus number of discovered accumulations that exceed a size of 50 MMBOE per 1,000 km^2) of the analog

dataset. The density of discovered oil and gas accumulations, which is usually smaller than the number of undiscovered accumulations, was used to calibrate the actual field densities of the West Laptev Grabens AU. Minimum, median, and maximum field densities of 0, 0.3, and 1.4, respectively, were used for scenario 1; those used for scenario 2 were slightly smaller: 0, 0.25, and 0.9, respectively, representing the distribution of field densities of the rift/sag analog set. The estimated median and maximum field densities are smaller than those in the two analog datasets. An oil-to-gas mixture of 50 percent (±20 percent), similar to global statistics, was assumed for scenario 1; an oil-to-gas mixture of 30 percent (± 20 percent) was assumed for scenario 2 because potential gas-prone source rocks in the synrift section would contribute most of the petroleum.

Sizes of Undiscovered Accumulations.—The estimated minimum, median, and maximum sizes of undiscovered oil and gas fields in the West Laptev Grabens AU are reported in appendix 1. The minimum sizes of undiscovered fields defined for this AU are 50 million barrels (MMB) of crude oil and 300 billion cubic feet (BCF) of natural gas (6 BCF equals 1 MMBOE). The median size of crude oil and natural gas accumulations, 100 MMBOE, was estimated to approximate the mean and median sizes of the analog datasets. The low-probability maximum size of the crude oil and natural gas accumulations under scenario 1, 20,000 MMBOE, approximates the largest discovered field size in the two analog datasets. The low-probability maximum size of the crude oil and natural gas accumulations under scenario 2, 1,000 MMBOE, approximates the median of the largest discovered field size in the rift/sag analog dataset.

Expected Maximum Undiscovered Accumulation Size.—The largest expected maximum crude oil and natural gas accumulation size in scenario 1, 4,200 MMBOE, allows for the possibility of an accumulation of similar size as the largest discovered in the Viking Graben, which is included in the analog datasets. The expected maximum crude oil and natural gas accumulation sizes in scenario 2, 300 to 400 MMBOE, reflects the smaller sizes of oil and gas accumulations in the rift/sag analog set.

Petroleum Composition and Properties of Undiscovered Accumulations.—Coproducts and petroleum-quality properties were estimated based on global statistics.

East Laptev Horsts Assessment Unit

The East Laptev Horsts AU comprises the horst system in the eastern part of the Laptev Sea Shelf Province. The prerift sedimentary section is presumed to be that of the Siberian craton, but it could also be part of the Alaska-Chukotka block. Sediment in the prerift section was most likely deformed by compression during the Early Cretaceous. A few shallow half-grabens containing Cenozoic sediment are present. Stratigraphically, this AU includes the Mesozoic and Cenozoic sedimentary section.

Geologic Analysis of Assessment Unit Probability

No petroleum accumulations have been discovered in the Laptev Sea Shelf Province as of this study (begun in 2007), and source, reservoir, and seal rocks, as well as trap configurations, can only be inferred. The overall probability of at least one accumulation greater than 50 million barrels of oil equivalent (MMBOE) is 0.030 percent, so the East Laptev Horst AU was not quantitatively assessed. The assessment input data are summarized in appendix 2.

Charge Probability.—A charge probability of 0.3 was estimated for this AU. If the prerift sedimentary section is part of the Siberian craton, then Upper Jurassic source rocks might be present, but the degree of deformation and erosion caused by Cretaceous compression is unknown. If the prerift sedimentary section is part of the Alaska-Chukotka block, prerift (Jurassic and Lower Cretaceous?) source rocks are most likely absent. The synrift sedimentary section is thin and too shallow for petroleum generation. Most of the natural gas seeps that have high methane contents occur on the East Laptev Horst, but no source has yet been identified. These natural gas occurrences might be biogenic rather than thermogenic.

Rock Probability.—A rock probability of 0.5 was estimated for this AU. If prerift rocks of reservoir quality are present, they might include Mesozoic paralic and marine clastics. Traps for petroleum accumulation could include rotated fault blocks, horsts, and pinchouts of siliciclastic rocks within grabens, and anticlinal traps in the prerift section. The presence of seal rocks and their effectiveness are unknown. Permafrost averaging 300 to 400 m thick (Franke and others, 2001) and covering the southern and central parts of the shelf, together with associated gas hydrates, may also act as a seal.

Timing and Preservation Probability.—The timing and preservation of petroleum accumulation is not favorable for the East Laptev Horsts AU because generation would have had to occur prior to Cretaceous deformation, which most likely destroyed any previously trapped petroleum accumulations. A timing probability of 0.2 was estimated for this AU.

Geologic Analogs for Assessment

The area of the East Laptev Horsts AU is approximately 184,000 km^2, of which 73 percent is offshore. No analog datasets were selected because this AU was not quantitatively assessed.

Anisin-Novosibirsk Basins Assessment Unit

The Anisin-Novosibirsk Basins AU, which is located in the northeastern part of the Laptev Sea Shelf Province, represents a structural extension of the Laptev Sea rift system that consists of two grabens that form the Anisin and Novosibirsk Basins. Rocks that comprise the prerift sedimentary section are probably part of the Alaska-Chukotka block and they are presumed to be similar to those exposed on Kotel'nyi Island.

Synrift reservoir rocks are likely to consist of shelf and slope siliciclastic sedimentary deposits. Stratigraphically, the AU includes only the Cenozoic sedimentary section.

Geological Analysis of Assessment Unit Probability

No petroleum accumulations have been discovered in the Laptev Sea Shelf as of this study (begun in 2007), so source, reservoir, and seal rocks, as well as trap configurations, can only be inferred. The overall probability for the existence of at least one accumulation greater than 50 MMBOE is 0.432 percent. The assessment input data are summarized in appendix 3.

Charge Probability.—Although natural gas chimneys have been observed on seismic profiles throughout the AU (Cramer and Franke, 2005), and source rocks in the Laptev Sea Shelf Province have not been identified, they might include synrift, uppermost Cretaceous and Paleogene coaly and carbonaceous continental rocks, and Paleogene organic-rich mudstones. In the Anisin-Novosibirsk Basins AU, the prerift sedimentary section is presumed to be different than that in the West Laptev Grabens AU and prerift source rocks are most likely absent. A charge probability of 0.6 was estimated for this AU.

Rock Probability.—A rock probability of 0.8 was estimated for this AU. Major synrift reservoir rocks are likely to consist of shelf and slope siliciclastic strata deposited by the ancestral Lena River. If prerift reservoir rocks are present, they might include Cenozoic marine clastic rocks. Traps for petroleum accumulation could include rotated fault blocks, horsts, and pinchouts of siliciclastic rocks within grabens, as well as anticlinal traps in the prerift sedimentary section. Most traps were probably formed prior to petroleum generation and expulsion. Petroleum could have migrated vertically along faults, as evidenced by natural gas chimneys, and laterally into juxtaposed reservoirs along fault displacements. The presence of seal rocks and their effectiveness remain uncertain, but they are probably adequate, considering the thickness of the clastic section.

Timing and Preservation Probability.—A timing and preservation probability of 0.9 was estimated for this AU. Most potential traps probably formed prior to any petroleum generation and expulsion, resulting in good timing. Petroleum could have migrated vertically along faults and laterally into reservoirs juxtaposed to source rocks by fault displacements.

Geologic Analogs for Assessment

The area of the Anisin-Novosibirsk Basins AU is approximately 73,000 km^2, of which 98 percent of the area and 100 percent of the potential petroleum resources are offshore.

The analog set from within the USGS World Analog Database (Charpentier and others, 2008) that was selected to represent the synrift section includes AUs having rift/sag architecture, clastic depositional systems without salt-related traps, and AUs having discovered fields of 50 MMBOE or greater. In addition, the Vienna Basin Province was used for comparison.

Number of Undiscovered Accumulations.—The number of undiscovered oil and gas accumulations was estimated by comparing the field densities (number of accumulations larger than 50 MMBOE per 1,000 km^2) of the analog data set. Minimum, median, and maximum field densities of 0, 0.3, and 0.9, respectively, were used, representing the distribution of field densities of the rift/sag analog set. The maximum field density is less than those in the two analog datasets. An oil/gas ratio of 50 percent (±30 percent) was assumed because the contribution from potential source rocks is unknown.

Sizes of Undiscovered Accumulations.—The estimated minimum, median, and maximum sizes of undiscovered oil and gas fields in the Anisin and Novosibirsk Basins AU are reported in appendix 3. The minimum size of undiscovered fields, as defined for the CARA program, is 50 MMBOE. The median size of crude oil and natural gas accumulations (75 MMBOE) and the low-probability maximum crude oil and natural gas accumulation size (800 MMBOE) were adjusted slightly downward from those of the rift/sag analog dataset (a median of 100 MMBOE and a maximum of 1,000 MMBOE) because the petroleum source rocks in the Anisin and Novosibirsk Basins AU might not be sufficient to charge large accumulations.

Expected Size of Maximum Undiscovered Accumulation.—The expected maximum crude oil and natural gas accumulation sizes (100 to 300 MMBOE) reflects the smaller sizes of oil/gas accumulations in the rift/sag analog datasets.

Petroleum Composition and Properties of Undiscovered Accumulations.—Coproducts and petroleum-quality properties were estimated based on global statistics.

Assessment Results

The assessment results for the three AUs in the Laptev Sea Shelf Province are summarized in table 1, which includes the assessment of the full geographic extent of each AU (fig. 1). Estimates represent undiscovered, technically recoverable, conventional petroleum resources.

The probability of discovering a field of 50 MMBOE or larger in the West Laptev Grabens AU from the two scenarios is 0.542 (table 1). The estimated mean undiscovered crude oil resource in the West Laptev Grabens AU is 2,646 MMB and the mean volume of undiscovered nonassociated natural gas resource is 25,194 BCF. The largest expected undiscovered oil field size is estimated to be approximately 749 MMB, and the largest expected undiscovered gas field size is estimated to be approximately 5,082 BCF.

The East Laptev Horsts AU was not quantitatively assessed and therefore no estimates of undiscovered petroleum resources are given.

Table 1. Assessment results (conventional undiscovered resources) for the Laptev Sea Shelf Province.

[Discovered reserves not inlcuded. AU, assessment unit; BCF; billion cubic feet; MMB, million barrels. Results shown are fully risked estimates. For gas accumulations, all liquids are included under the natural gas liquids (NGL) category. F95, 95-percent probability of at least the amount tabulated, and so on for F50 and F5. Fractiles are additive under the assumption of perfect positive ocrrelation. Aggregate means for the West Laptev Grabens AU calculated by multiplying the mean by the scenario probability. %, percent; N/A, not applicable. Numbers do not exactly add to totals because totals were added by statistical aggregation]

Total Petroleum Systems and Assessment Units	AU probability	Field type	Oil (MMB)				Gas (BCF)				NGL (MMB)			
			F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
Assessment results—Laptev Sea Shelf Province; Jurassic-Cretaceous-Paleogene composite total petroleum system														
West Laptev Grabens AU Scenario 1, 0.1% probability	1	Oil	3,344	12,790	38,691	15,861	4,221	17,699	62,602	23,545	111	470	1,694	633
		Gas	N/A	N/A	N/A	N/A	18,947	76,933	245,801	97,337	493	2,028	6,624	2,593
West Laptev Grabens AU Scenario 2, 0.9% probability	0.49	Oil	0	0	2,611	526	0	0	6,587	1,660	0	0	177	45
		Gas	N/A	N/A	N/A	N/A	0	0	59,147	16,886	0	0	1,583	450
West Laptev Grabens AU aggregate	0.504	Oil			7,207	1,913				3,849				104
		Gas	N/A	N/A	N/A	N/A				24,931				664
East Laptev Horsts AU	0.03	Not quantitatively assessed												
Total						**2,600**				**28,780**				**768**
Assessment results—Laptev Sea Shelf Province, Paleogene total petroleum system														
Anisin-Novosibirsk Basins AU	0.43	Oil	0	0	1,837	469	0	0	2,901	693	0	0	79	19
		Gas	N/A	N/A	N/A	N/A	0	0	10,694	2,779	0	0	286	74
Total			0	0	**1,837**	**469**	0	0	**13,595**	**3,472**	0	0	**365**	**93**
Total undiscovered petroleum resources, Laptev Sea Shelf						**3,069**				**32,252**				**861**

The probability of discovering a field of 50 MMBOE or larger in the Anisin-Novosibirsk Basins AU is 0.432 (table 1). The mean undiscovered crude oil resource in the AU is estimated to be 469 MMB and the mean volume of undiscovered nonassociated natural gas resource is 2,779 BCF. The largest expected undiscovered oil field size is estimated to be approximately 217 MMB, and the largest expected undiscovered gas field size is approximately 1,294 BCF (not reported in table 1 or appendix 1).

The total estimated mean undiscovered petroleum resources in the Laptev Sea Shelf Province are approximately 3,069 MMB of crude oil, 32,252 BCF of associated and nonassociated natural gas, and 861 MMB of NGL (table 1). Additional statistics are provided in table 1.

The geologic probabilities of the AUs in this study were determined based on a consideration of the geology of this province, but also on the geologic probabilities assigned to AUs during the assessment of all Arctic basins. In this manner the probabilities were consistently determined throughout the 2008 Circum-Arctic Resource Appraisal project.

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References

Barrett, P., 2003, Paleoclimatology: Cooling a continent: Nature, v. 421, p. 221–223.

Charpentier, R.R., Klett, T.R., and Attanasi, E.D., 2008, Database for assessment unit-scale analogs, exclusive of the United States: U.S. Geological Survey Open-File Report 2007–1404, 61 p.

Cramer, B., and Franke, D., 2005, Indications for an active petroleum system in the Laptev Sea, northeast Siberia: Journal of Petroleum Geology, v. 28, no. 4, p. 369–384.

Cramer, B., Faber, E., Franke, D., Gerling, P., and Hinz, K., 2001, Petroleum generation in the Laptev Sea [abs.]: Proceedings of the VNIGRI/AAPG Regional International Conference, Saint Petersburg, Russia, P3-18, 1 p.

Drachev, S.S., 2002, On the basement tectonics of the Laptev Sea Shelf: Geotectonics, v. 36, no. 6, p. 483–497.

Duchkov, A.D., Balobaev, V.T., Lysak, S.V., Sokolova, L.S., Devyatkin, V.N., Volod'ko, B.V., and Levchenko, A.N., 1982, The heat flow of Siberia: Geologiya i Geofizika, v. 23, no. 1, p. 42–51 [in English; p. 42–51 in Russian].

Frakes, L.A., Francis, J.E., and Syktus, J.I., 1992, Climate modes of the Phanerozoic—The history of the Earth's climate over the past 600 million years: Cambridge, U.K., Cambridge University Press, 274 p.

Franke, D., and Hinz, K., 2005, The structural style of sedimentary basins on the shelves of the Laptev Sea and western East Siberian Basin, Siberian Arctic: Journal of Petroleum Geology, v. 28, no. 3, p. 269–286.

Franke, D., Hinz, K., and Oncken, O., 2001, The Laptev Sea rift: Marine and Petroleum Geology, v. 18, p. 1083–1127.

Franke, D., Hinz, K., and Reichert, C., 2004, Geology of the East Siberian Sea, Russian Arctic, from seismic images—Structures, evolution, and implications for the evolution of the Arctic Ocean Basin: Journal of Geophysical Research, v. 109, B07106, 19 p.

Golonka, J., and Kiessling, W., 2002, Phanerozoic time scale and definition of time slices, *in* Kiessling, W., Flügel, E., and Golonka, J., eds., Phanerozoic reef patterns: Society of Economic Paleontologists and Mineralogists Special Publication 72, p. 11–20.

Gradstein, F.M., Ogg, J.G., Smith, A.G., Agterberg, F.P., Bleeker, W., Cooper, R.A., Davydov, V., Gibbard, P., Hinnov, L.A., House, M.R., Lourens, L., Luterbacher, H.P., McArthur, J., Melchin, M.J., Robb, L.J., Shergold, J., Villeneuve, M., Wardlaw, B.R., Ali, J., Brinkhuis, H., Hilgen, F.J., Hooker, J., Howarth, R.J., Knoll, A.H., Laskar, J., Monechi, S., Plumb, K.A., Powell, J., Raffi, I., Röhl, U., Sadler, P., Sanfilippo, A., Schmitz, B., Shackleton, N.J., Shields, G.A., Strauss, H., Van Dam, J., van Kolfschoten, T., Veizer, J., and Wilson, D., 2004, A geologic time scale: Cambridge, U.K., Cambridge University Press, 589 p.

Grantz, A., Pease, V.L., Willard, D.A., Phillips, R.L., and Clark, D.L., 2001, Bedrock cores from 89° North—Implications for the geologic framework and Neogene paleoceanography of Lomonsov Ridge and a tie to the Barents shelf: Geological Society of America Bulletin, v. 113, no. 10, p. 1272–1281.

Hardenbol, J., Thierry, J., Farley, M.B., Jacquin, T., de Graciansky, P.-C., and Vail, P.R., 1998, Mesozoic and Cenozoic sequence chronostratigraphic framework for European basins, *in* de Graciansky, P.-C., Hardenbol, J., Jacquin, T., and Vail, P.R., eds., Mesozoic and Cenozoic sequence stratigraphy of European basins: Society of Economic Paleontologists and Mineralogists Special Publication 60, p. 3–13.

IHS Energy Group, 2007 [includes data current through October 2007], International exploration and production database: Englewood, Colo., IHS Energy Group [database available from IHS Energy Group, 15 Inverness Way East, D205, Englewood, CO 80112, U.S.A].

Integrated Exploration Systems, 2008, PetroMod 1D, version 10: Aachen, Germany, Integrated Exploration Systems [purchased by Schlumberger in 2008].

Kaplan. M.Ye., Yudovnyy, Ye.G., Zakharov, V.A., Basov, V.A., and Voytsekhovskaya, A.G., 1973, Conditions of accumulations of transitional Jurassic-Cretaceous sediments of the Pakhsa Peninsula, Anabar Bay: Doklady Akademii Nauk SSSR, v. 209, no. 3, p. 691–694.

Kim, B., Grikurov, G., and Soloviev, V., 1999, High resolution seismic studies in the Laptev Sea Shelf—First results and future needs, *in* Kassens, H., Bauch, H.A., Dmitrenko, I.A., Eicken, H., Hubberten, H.-W., Melles, M., Thiede, J., and Timokhov, L.A., eds., Land-ocean systems in the Siberian Arctic—Dynamics and history: Berlin, Springer-Verlag, p. 683–692.

Kos'ko, M.K., and Trufanov, G.V., 2002, Middle Cretaceous to Eopleistocene sequences on the New Siberian Islands—An approach to interpret offshore seismic: Marine and Petroleum Geology, v. 19, p. 901–919.

Matykhin, R.G., and Sokolov, P.N., 1998, New data on Middle Paleozoic salt of Siberian craton: Petroleum Geology, v. 32, no. 1 [translated from Problemy morskogo i kontinental'nogo galogeneza, 1991, Novosibirsk, Nauka, in Russian].

McKenzie, D.P., 1978, Some remarks on the development of sedimentary basins: Earth and Planetary Science Letters, v. 40, p. 25–32.

Persits, F.M., and Ulmishek, G.F., 2003, Maps showing geology, oil and gas fields, and geologic provinces of the Arctic: U.S. Geological Survey Open-File Report 97–470-J, CD-ROM.

Sekretov, S.B., 2000, Petroleum potential of Laptev Sea basins—Geological, tectonic and geodynamic factors: Polarforschung, v. 68, p. 179–186.

Sekretov, S.B., 1999, Southeastern Eurasian Basin termination—Structure and key episodes of tectonic history: Polarforschung, v. 69, p. 251–257.

Surkova, V.S., 1987, Megakompleksy i glubinnoya struktura zemnoiy kory neftegazonosnykh provintsii Sibirskoyi Platformi: Moscow, "Nedra", Sibirskiy Nauchno-Issledovatelskiy Institut Geologii, Geofiziki i Mineralnogo Syrya, SNIIGIMS, 203 p. (in Russian).

Sweeney, J.J., and Burnham, A.K., 1990, Evaluation of a simple model of vitrinite reflectance based on chemical kinetics: American Association of Petroleum Geologists Bulletin, v. 74, p. 1559–1570.

Ulmishek, G.F., and Klemme, H.D., 1990, Depositional controls, distribution, and effectiveness of world's petroleum source rocks: U.S. Geological Survey Bulletin B-1931, 59 p.

Yakovlev, G.E., and Koporulin, B.I., 1996, Usloviya nakopleniya i perspektivi neftegasonosnosti melovikh otlozheniy Laptevomorskogo neftegasonosnogo basseina, *in* Sokolov, B.A., ed., Neftegasonosniye i uglenosniye basseini Rossii: Moscow, Moscow State University (in Russian).

Zakharov, V.A., Hal'nyaeva T.I., and Shul'gina, N.I., 1983, New data on biostratigraphy of the Upper Jurassic and Lower Cretaceous sediments of the Pakhsa Peninsula, Anabar Bay, north Middle Siberia: Paleobiogeografiya i biostratigrafiya yuri i mela Sibiri, Institut Geologii i Geofiziki Akademiya Nauk SSSR, Trudi, v. 528, p. 56–101 (in Russian).

Appendixes

Appendixes are available online only, and may be accessed at https://doi.org/10.3133/pp1824W

Appendix 1*A*. Input Data for the West Laptev Grabens Assessment Unit—Best Case Sceanrio
Appendix 1*B*. Input Data for the West Laptev Grabens Assessment Unit—Base Case Scenario
Appendix 2. Input Data for the East Laptev Horsts Assessment Unit
Appendix 3. Input Data for Anisin-Novosibirsk Basins AU

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