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Geology and Assessment of Undiscovered Oil and Gas Resources of the Yenisey-Khatanga Basin Province, 2008

Chapter R 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 basinfloor 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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Edited by T.E. Moore and D.L. Gautier

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DAVID BERNHARDT, Secretary

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The 2008 Circum-Arctic Resource Appraisal

Chapters

North Atlantic Ocean

Eurasia

Arctic Ocean

Contents

Appendixes

[Available for download at https://doi.org/10.3133/pp1824R]

Figures

Tables

Chapter R

Geology and Assessment of Undiscovered Oil and Gas Resources of the Yenisey-Khatanga Basin Province, 2008

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Abstract

The U.S. Geological Survey (USGS) assessed the potential for undiscovered oil and gas resources of the Yenisey-Khatanga Basin Province as part of the USGS Circum-Arctic Resource Appraisal. The province is situated between the Taimyr-Kara high (Kara block, Central Taimyr fold belt, and South Taimyr fold belt) and the Siberian craton. The two assessment units (AUs) defined for this study—the Khatanga Saddle AU and the Yenisey-Khatanga Basin AU were assessed for undiscovered, technically recoverable, conventional resources. The estimated mean volumes of undiscovered resources for the Yenisey-Khatanga Basin Province are ~5.6 billion barrels of crude oil, ~100 trillion cubic feet of natural gas, and ~2.7 billion barrels of natural-gas liquids, all north of the Arctic Circle.

Yenisey-Khatanga Basin Province

Province Boundary Definition

The Yenisey-Khatanga Basin Province is situated between the Siberian craton to the south and the south slope of the Taimyr-Kara high to the north (figs. 1, 2). A north-northwest-trending contractional-deformation zone called the Pakhsino-Begichev Arch, which is the westward extent of the Verkhoyansk-Olenek fold and thrust zone, forms the province's east boundary (Mikulenko, 1983; Grebenyuk and others, 1988). The fold and thrust zone extends from the neighboring Lena-Anabar Basin to the south, northward through Bol'shoi Begichev Island in Khatanga Bay, to Cape Tsvetkov on the Taimyr Peninsula. The front of this fold and thrust zone extends westward to the Tigyano-Anabar horst (fig. 3), which might involve thrust faulting as part of its structural configuration (Drachev, 2002; G.F. Ulmishek, written commun., 2008).

The Yenisey-Khatanga Basin is a northeastern structural arm of the West Siberian Basin (Baldin, 2004). Although the Mesozoic and Tertiary stratigraphic successions in the two basins have much in common, the basins are structurally separated by Mesozoic uplifts (Ulmishek, 2003). The Taimyr-Kara high, which bounds the northern margin of the Yenisey-Khatanga Basin, consists of the South and Central Taimyr fold belts in the south and the Kara block to the north (Ulmishek, 2003). The Yenisey-Khatanga Basin is a Mesozoic sag that formed above a late Permian and Early Triassic extensional-rift basin (Kontorovich and others, 1994). The Yenisey-Khatanga Basin is filled with 7 to 12 km of Mesozoic clastic rocks (Baldin and others, 1997).

The Khatanga Saddle is a positive feature along the eastern margin of the Yenisey-Khatanga Basin. There, the Mesozoic section is thinnest (Grebenyuk and others, 1988), with a sedimentary thickness of no more than 1 to 2 km. Salt domes are present, in which the salt is presumed to be Devonian. A 2-km-thick sequence of Devonian and Carboniferous rocks is present in the northeastern part of the basin (Stepanenko, 1988).

Petroleum Occurrence

Petroleum was discovered in the Yenisey-Khatanga Basin Province in the early 1940s (1943–1945) in mainly Permian marine clastic rocks on the Khatanga Saddle. Because of poor reservoir quality (G.F. Ulmishek, written commun., 2006) and possibly extensive faulting (Danilkin, 1985), Mesozoic strata were considered noncommercial for petroleum, and exploration stopped in 1953. Exploration resumed in the western part of the Yenisey-Khatanga Basin Province in 1967, leading to the discovery of the Messoyakhskoye gas field and the North Soleninskoye gas-condensate field. Most of the discoveries were in Jurassic and Cretaceous rocks within anticlines. In 1979, the Deryabinskoye gas field was discovered in a nonanticlinal pinchout trap of Upper Jurassic and Berriasian sandstone. A total of 16 gas and gas-condensate fields and 4 oil fields had been discovered by 2008, most in the western part of the province. The gas fields in the western part of the province have been developed to supply natural gas to local industry in Noril'sk (fig. 2).

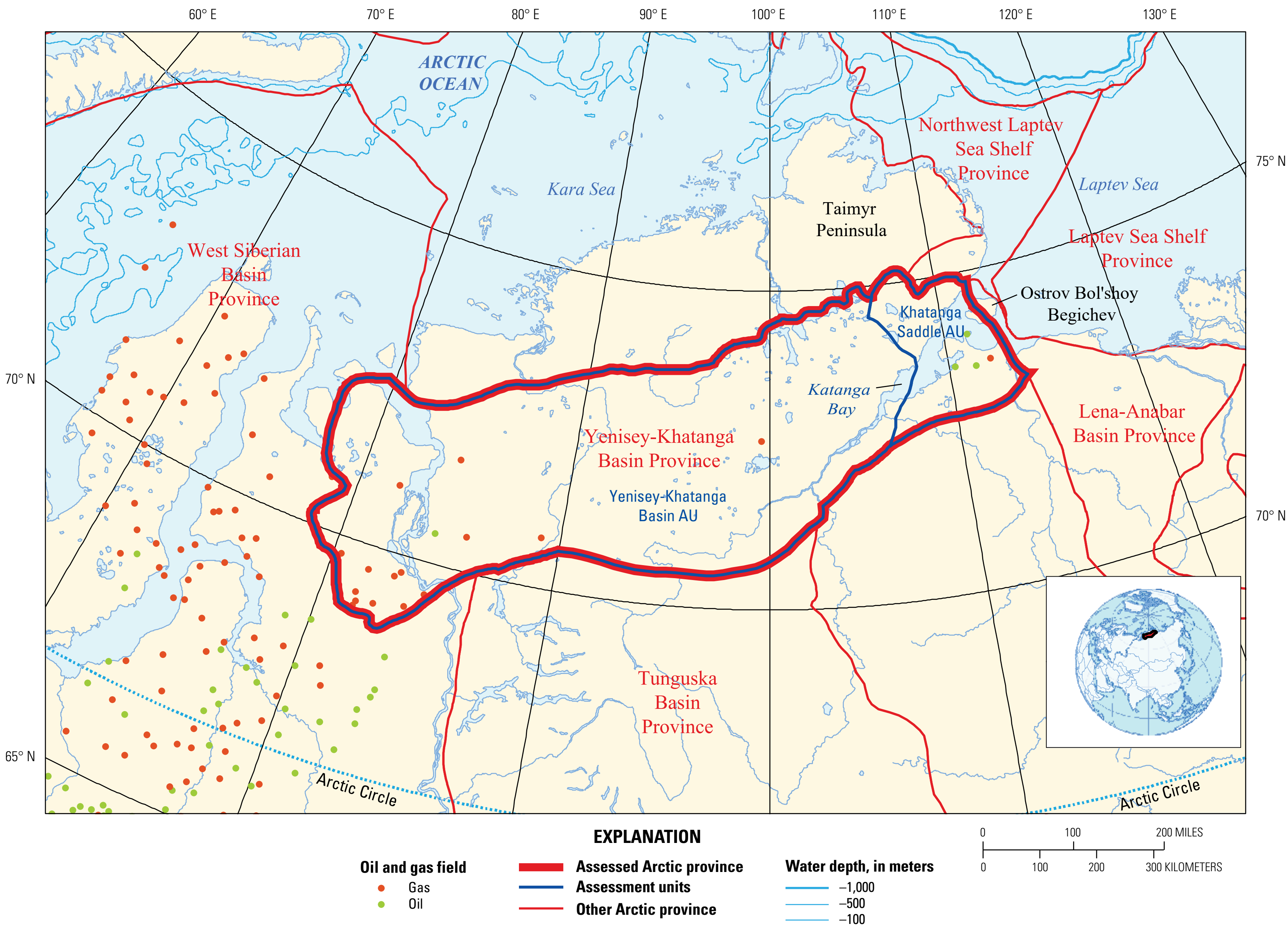


Figure 1. Map of Yenisey-Khatanga Basin Province, showing location of province and assessment units. Oil and gas field data from IHS Energy Group (2007). AU, assessment unit.

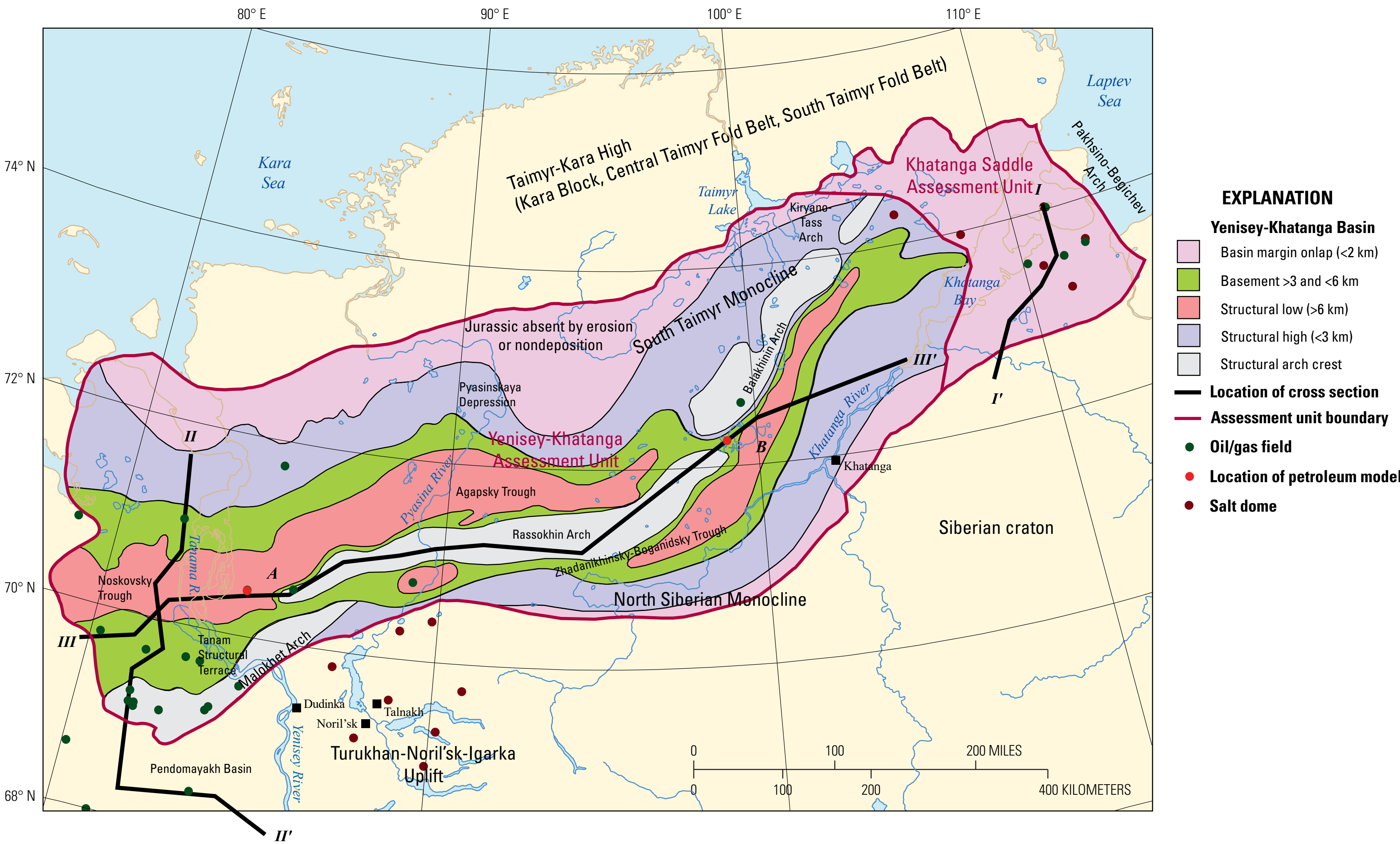


Figure 2. Map of Yenisey-Khatanga Basin Province, showing major structural features, approximate depth to economic basement, and locations of geologic cross sections and petroleum-system models used in assessment. Data from Persits and Ulmishek (2003) and IHS Energy Group (2007).

Tectonostratigraphic Evolution

The Yenisey-Khatanga Basin contains a regional system of arches and troughs that extend diagonally across the length of the basin for ~1,000 km from the Yenisey River to the Kiryano-Tass arch (fig. 2). The arches formed in a pre-Jurassic intercontinental extensional basin (Kontorovich and others, 1994). The geologic cross sections in figure 3 show the characteristics of the basin fill.

Proterozoic and Early Paleozoic

The Yenisey-Khatanga Basin formed along the present-day northern margin of the Siberian craton as a northwest-oriented Neoproterozoic (Riphean) rift filled with 2 to 3 km of clastic sediment (Kontorovich and others, 1994). During the Paleozoic, the area became a passive margin in which as much as 4 km of Neoroterozoic (Vendian) through middle Paleozoic shelf carbonates and mudstone were deposited (Kontorovich and others, 1994). The area was a northward-dipping (present-day orientation) monocline until the end of the late Paleozoic (Stepanenko, 1988).

Middle and Late Paleozoic

The Siberian craton drifted northward from the Devonian through Triassic, moving from a warm dry climate at low to middle latitudes into a cooler humid climate at higher latitudes (Zonenshain and others, 1990). During the Devonian, the craton passed over a mantle plume (hot spot), causing magmatism and forming rift grabens under the present-day Khatanga Saddle and the Yenisey-Khatanga Basin. In addition to carbonates, evaporites were deposited in the rift grabens and later deformed to form diapirs and other halokinetic structures on the Khatanga Saddle (Surkova, 1987; Matykhin and Sokolov, 1998). Organic-rich mudstone might also have been deposited within these rift grabens before evaporite deposition (G.F. Ulmishek, oral commun., 2006). In the middle Carboniferous, carbonate deposition was replaced by the deposition of terrigenous clastic sediment (Stepanenko, 1988; Kontorovich and others, 1994; Girshgorn, 1996).

On the basis of isotope-geochronologic data, the Central Taimyr fold belt is presumed to have formed by collision of island arcs with continental blocks during Neoproterozoic time (Vernikovsky, 1995). Whether Central Taimyr comprises an accretionary prism that collided with the North Taimyr terrane during the late Paleozoic to form the North Kara block (Zonenshain and others, 1990; Uflyand and others, 1991) or collided with the Siberian craton during the Neoproterozoic (late Riphean, 600–570 Ma; Bogdanov and others, 1998; Vernikovsky, 1998; Torsvik and Andersen, 2002) is unclear. Although early and middle Paleozoic ophiolites and subduction complexes have not been observed between the Central and South Taimyr terranes, such a collision might have been oblique or strike-slip (Vernikovsky, 1998). If the Central Taimyr terrane collided with the Siberian craton during the Neoproterozoic, the terrane would have become part of the Siberian passive margin (stable platform and shallow and open sea shelf) until the late Carboniferous (Zonenshain and others, 1990; Vernikovsky, 1998).

During the late Permian and Early Triassic, extension, magmatism, and volcanism occurred in the Yenisey-Khatanga Basin (Kontorovich and others, 1994; Girshgorn, 1996). The present-day basin might be a failed rift superimposed on a rifted passive margin. During the late Permian and Early Triassic, a triple junction was situated along the present-day northwestern margin of the Siberian craton (Allen and others, 2006). Rifting resulted in the emplacement of flood basalts across the Tunguska Basin and deposition of as much as 2 km of volcanic and volcaniclastic rocks in the western part of the Yenisey-Khatanga Basin. A central basin developed along the north edge of the Siberian craton, and a Triassic sea probably extended into the basin from the northeast, but conditions became lagoonal to continental southwestward (Kontorovich and others, 1994; Vernikovsky, 1995; Girshgorn, 1996). In the northeastern part of the basin (along the east coast of the Taimyr Peninsula), as much as 1.5 km of late Permian and Early Triassic rocks was deposited. These rocks contain marine and continental (freshwater) clastic rocks, with volcaniclastic rocks in the lower part of the section (Kazakov and others, 1982).

Jurassic and Cretaceous

Another major tectonic event associated with dextral transpression is assumed to have occurred during the Late Triassic and, possibly, the Early Jurassic (Inger and others, 1999; Torsvik and Andersen, 2002). The event resulted in deformation of the Taimyr fold and thrust belt (Torsvik and Andersen, 2002). Middle Triassic and older rocks were eroded from the edges of the Yenisey-Khatanga Basin and redeposited in the basin center (Grebenyuk and others, 1988; Kontorovich and others, 1994).

Throughout the Jurassic, clastic deposition continued along the rifted passive margins of the Siberian craton. In the Yenisey-Khatanga Basin, a sag basin formed in which 3 to 4 km of sediment was deposited (Gramberg and others, 1988; Kontorovich and others, 1994) with as much as 2 km on the Khatanga Saddle (Lebchuk, 1990).

Contractional deformation of the Yenisey-Khatanga Basin during the Late Jurassic and Early Cretaceous has been suggested in many studies (for example, Baldin and others, 1997). A system of diagonally orientated, faulted arches formed, upon which ~1 km of Middle Jurassic through Lower Cretaceous, pre-Valanginian rocks was subsequently eroded (Danilkin, 1984; Polyakova and others, 1986; Afanasenkov, 1988; Grebenyuk and others, 1988; Botneva and Frolov, 1996). Sediment eroded from the arches and the Siberian craton was deposited within the depressions as prograding clinoforms, grading upward into shallow-marine and deltaic strata (Lebchuk, 1990; Grebenyuk and others, 2003; Baldin, 2004). The Upper Jurassic and Lower Cretaceous progradational succession contains three packages

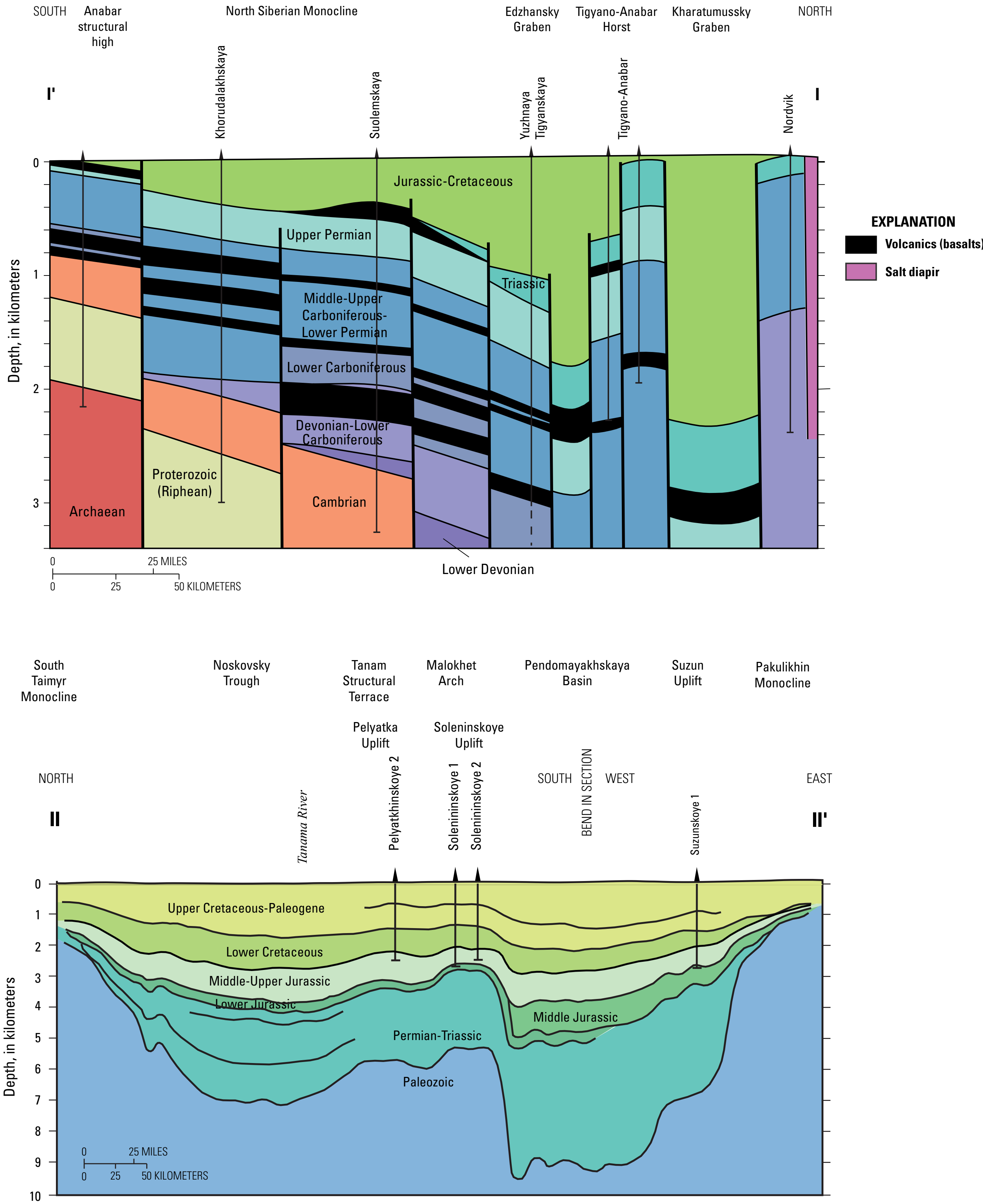


Figure 3. Regional geologic cross sections of the Yenisey-Khatanga Basin Province. Locations shown on figure 2. Vertical red lines are locations of wells or pseudowells used for petroleum-generation models. Fm., Formation. Modified from Kazais (1976), Danilkin (1985), and Filipiov and others (1999).

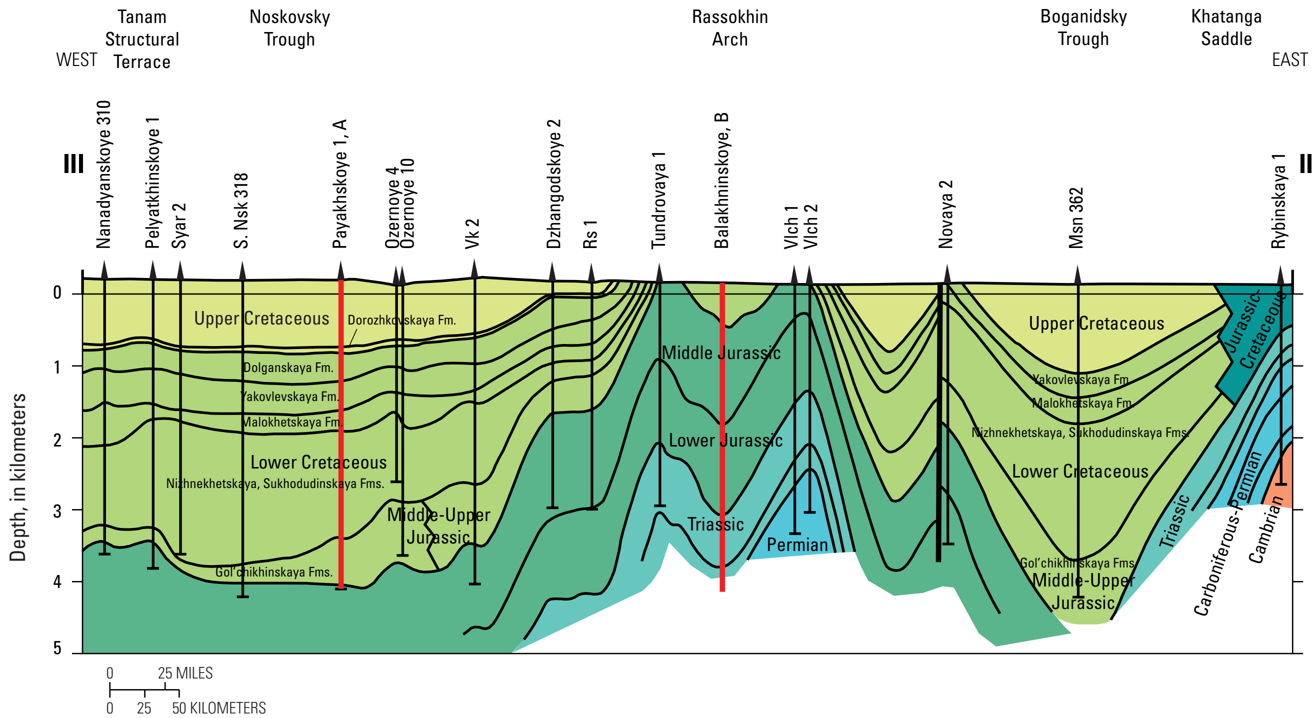


Figure 3.—Continued

of clinoforms of (1) Callovian through Kimmeridgian (only on the northwest slopes of the Rassokhin and Malokhet arches), (2) Volgian and Berriasian, and (3) Neocomian age (Lebchuk, 1990; Grebenyuk and others, 2003; Baldin, 2004). The arches within the Yenisey-Khatanga Basin separated the marine connection of the West Siberian Basin with the open sea to the northeast (Baldin and others, 1997).

The timing of formation of structures across the Yenisey-Khatanga Basin is, however, uncertain, possibly late Cenozoic. Upper Cretaceous rocks are absent on the arches but thick in the depressions (fig. 3). Kontorovich and others (1994) stated that 20–40 percent of local structural growth in the basin is attributable to neotectonic movements. Additionally, arches in the neighboring West Siberian Basin to the west primarily formed during the Oligocene and Neogene (G.F. Ulmishek, written commun., 2008). Other studies (for example, Kontorovich and others, 1994) suggest that the arches are structures that reflect earlier tectonic activity.

Cenozoic

Minor uplift (maximum 100 m) of the Yenisey-Khatanga Basin occurred during the Eocene (Stepanenko, 1988). Tectonic movements resumed in the Neogene. The amount of uplift increases from ~200 m in the east to 1,500 m in the west (Polyakova and others, 1986; Afanasenkov, 1984; Danilkin, 1984; Kontorovich and others, 1991; Botneva and Frolov, 1996). The Malokhet arch in the southwestern part of the basin was uplifted 900 m during this time (Kulakov and Makhotina, 1988).

Petroleum-System Elements

A single Proterozoic through Mesozoic composite total petroleum system (TPS) was identified for the Yenisey-Khatanga Basin province. A lithostratigraphic column and TPS events chart of petroleum-system elements are shown in figure 4.

Source Rocks

Middle and Upper Jurassic and Neocomian mudstones, containing 1.2–1.6 weight percent and as much as 6 weight percent total organic carbon (TOC), are the major petroleum-source rocks in the Yenisey-Khatanga Basin (Polyakova and others, 1986; Lebchuk, 1990; Kontorovich and others, 1991). These mudstones contain both type II and type III kerogen, with type III dominating (Fomin and Romakhina, 1989; Kontorovich and others, 1994).

Potential source rocks include Devonian, Permian, and Triassic mudstones (Botneva and Frolov, 1996), although no reliable information on Proterozoic and Paleozoic source rocks exists for the Yenisey-Khatanga Basin (Kontorovich and others, 1994). Organic-rich Proterozoic mudstone could exist in Riphean rift/sag basins but probably became overmature with respect to petroleum generation and generated dispersed petroleum before the Yenisey-Khatanga Basin formed during the Paleozoic (Stepanenko, 1988; Kontorovich and others, 1994; Botneva and Frolov, 1996). Presumed Devonian oil was collected from fractured Devonian limestone 470 m deep in the Komsomol'sky Mine on the Khatanga Saddle. Lower Permian marine mudstone on the Khatanga Saddle contains as much as 2 weight percent TOC (Grebenyuk and others, 1988; Stepanenko, 1988). Natural gas generated from Permian coal-bearing strata (containing coal beds maximally 1.5 m thick) might also contribute to petroleum accumulations along the Khatanga Saddle (Polyakova and others, 1984). Middle and Upper Triassic mudstone in the eastern part of the Yenisey-Khatanga Basin is TOC rich (Filipiov and others, 1999).

Heat flow has varied over time, and amounts of uplift and erosion vary and depend on position within the basin. Areas of tectonic uplift have higher geothermal gradients than deeper parts of the basin (Danilkin, 1984; Grebenyuk and others, 1988). Devonian through Permian extension was associated with higher heat flow (Botneva and Frolov, 1996). Maximum heat flow occurred at the beginning of the Triassic and decreased during the Jurassic and Cretaceous (Stepanenko, 1988; Botneva and Frolov, 1996). Although upper Paleozoic sediment entered the oil window during the early Mesozoic (Grebenyuk and others, 1988; Stepanenko, 1988), oil migration into Mesozoic rocks was limited because of the presence of Triassic volcanic rocks (Kontorovich and others, 1994).

Petroleum-generation modeling indicates that Jurassic and Lower Cretaceous strata were buried in the oil-generation window before the Cenozoic (fig. 5). Some of this section is presently in the gas window. The data of Afanasenkov (1988), Grebenyuk and others (1988), and Kontorovich and others (1994) support these interpretations. The models also indicate that oil generation begins at ~2 km depth with the main part of the window between 3 and 4 km. The top of the gas window is at ~6 km depth for both the Yenisey-Khatanga Basin and the Khatanga Saddle (fig. 5). This interpretation is supported by the models of Polyakova and others (1986), Stepanenko (1988), and Lebchuk (1990).

Reservoir and Seal Rocks

Jurassic and Lower Cretaceous clastic rocks are the primary reservoirs in the Yenisey-Khatanga Basin (Kontorovich and others, 1994). Fields are multipooled, with local reservoirs and traps (Kontorovich and others, 1994). Accumulations are structurally controlled, but reservoirs commonly pinch out (Kontorovich and others, 1994). Eight reservoir and seal pairs have been identified: five in the Jurassic, two in the Lower Cretaceous, and one in the Upper Cretaceous section.

Potential reservoirs include Proterozoic and Paleozoic carbonate and clastic rocks, as well as Permian and Triassic clastic rocks. Permian clastic rocks along the basin margin and on the Khatanga Saddle contain numerous shows of bitumen, crude oil, and natural gas (Gramberg and others, 1988). Proterozoic and Paleozoic mudstone, Paleozoic evaporites, Permian and Triassic mudstone, and Triassic volcanic rocks could serve as effective seals (Gramberg and others, 1988; Grebenyuk and others, 1988).

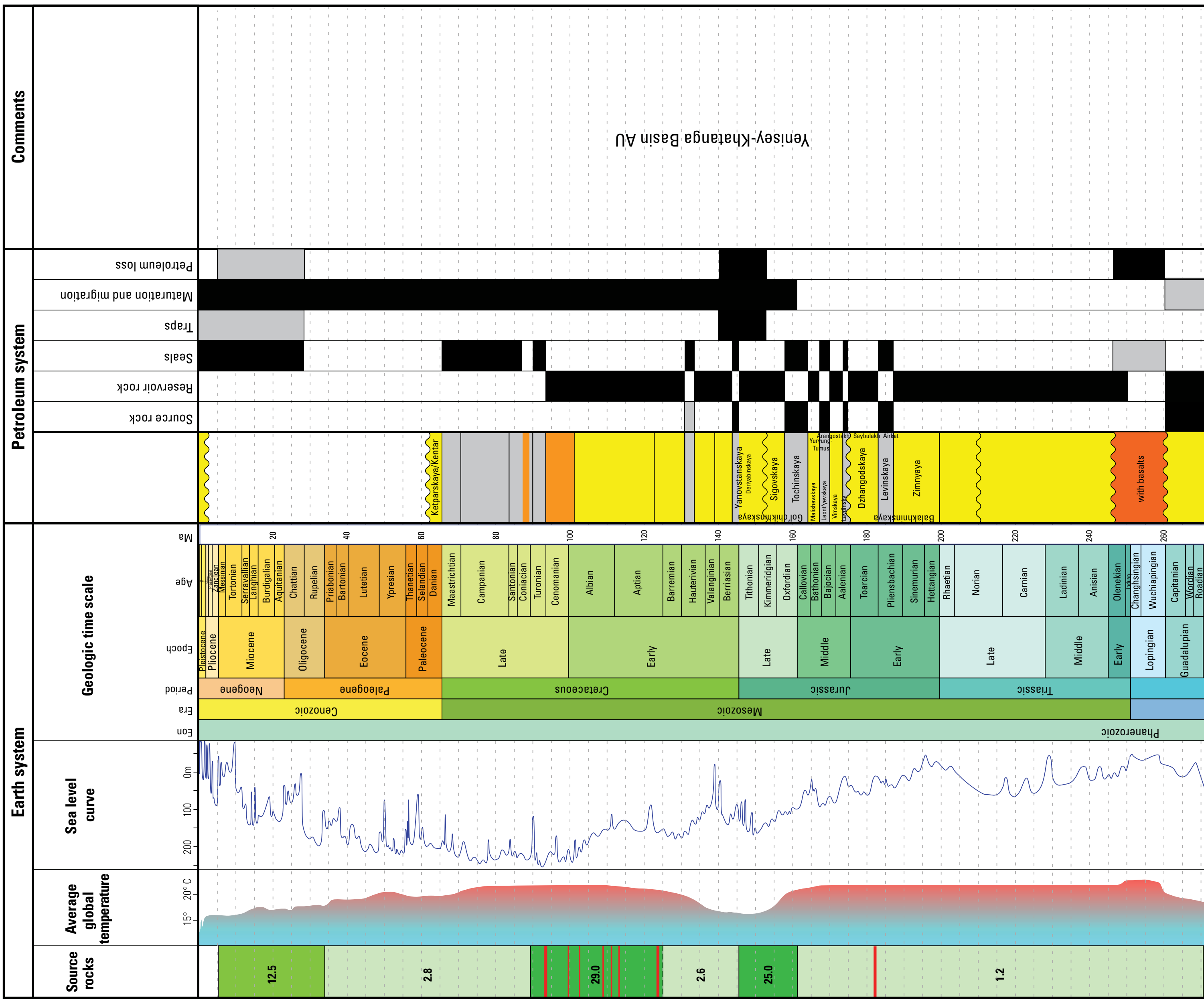
Surface temperature dropped by 20–25 °C at the end of the Oligocene (Kontorovich and others, 1994). Permafrost and gas hydrates could act as seals for shallow reservoirs (Kontorovich and others, 1994). On the basis of permafrost thickness and temperatures and pressures, the base of hydrate stability is at ~1-km depth (Kontorovich and others, 1994).

Traps and Timing

Traps for petroleum accumulation in the Yenisey-Khatanga Basin Province include arches, anticlines, and other structural highs; pinchouts along the basin margins and arches; traps associated with prograding sequences (clinoforms, topsets, submarine channels, gravity flows, and fans; Khmelevskii and others, 1990); salt-related structures on the Khatanga Saddle; and reservoirs associated with faulted basement rocks (Kontorovich and others, 1994). Structural traps formed as a result of Mesozoic or Cenozoic compression.

According to petroleum-generation models, Lower Jurassic rocks started generating petroleum by Middle Jurassic time in deeper parts of the basin, and Middle and Upper Jurassic and Neocomian source rocks generated petroleum by Paleogene time, before and during deformation and trap formation (fig. 5). Petroleum migrated vertically (Stepanenko, 1988), but thick Upper Jurassic, Berriasian, and Valanginian mudstone could have complicated migration patterns (Kontorovich and others, 1994).

Recent tectonic movements have modified older structures and caused remigration, formation of new traps and new migration pathways, and destruction and dispersal of older accumulations (Grebenyuk and others, 1988; Kulakov and Makhotina, 1988). Gas expansion might have displaced crude oil from traps, escaping or forming oil legs. Some crude oil could have been cracked to natural gas (Polyakova and others, 1984; Grebenyuk and others, 1988). Destruction of previously trapped petroleum might account for degraded petroleum (bitumen) in Proterozoic and lower Paleozoic rocks along the Anabar structural high of the Siberian craton and locally within the Yenisey-Khatanga Basin (Stepanenko, 1988).


Comments
Yenisey-Khatanga Basin AU
Petroleum system
Petroleum loss
Maturation and migration
Traps
Seals
Reservoir rock
Source rock
Earth system
Geologic time scale
Sea level curve
Average global temperature
Source rocks
Phanerozoic
Cenozoic
Mesozoic
Neogene
Paleogene
Cretaceous
Jurassic
Triassic

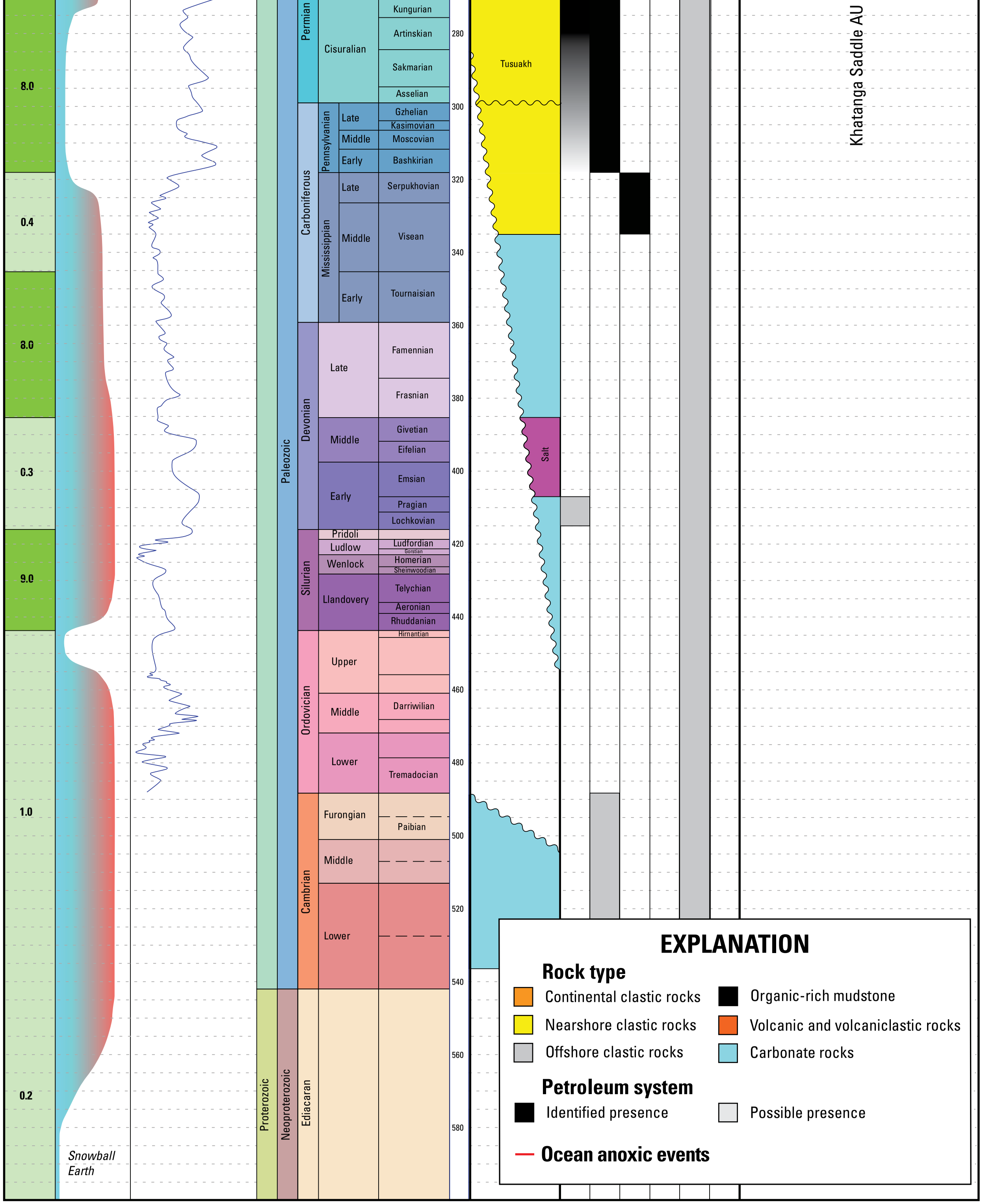
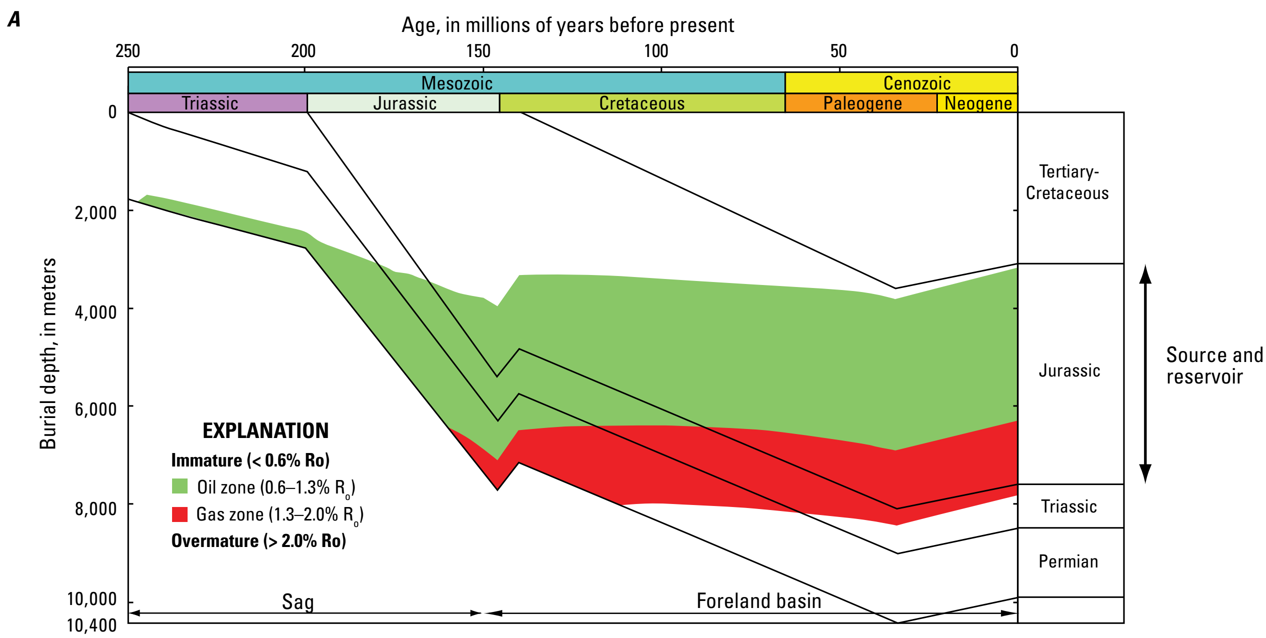


Figure 4. Lithostratigraphic column and total petroleum system events chart for the Yenisey-Khatanga Basin Province. Data from Bobiliev (1985), Surkova (1987), Kulikov (1989), Lebchuk (1990), Krason and Finley (1993), Kontorovich and others (1994), and Filipiov and others (1999). Source rocks column 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).



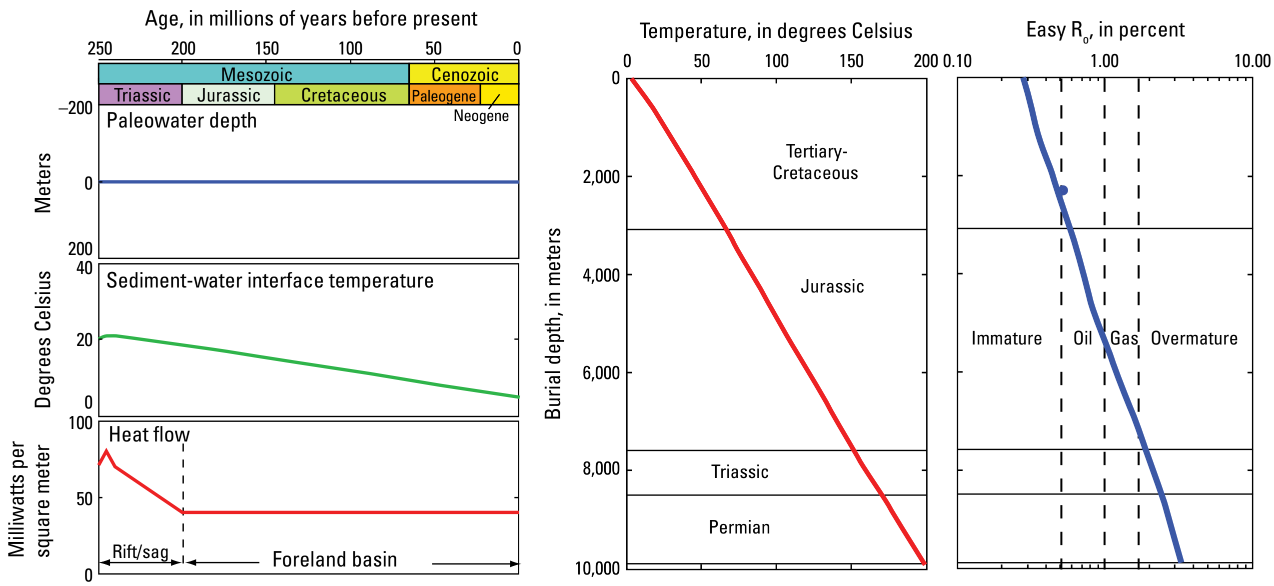


Figure 5. Burial-history models for pseudowells, Payakhskoye, *A*; and Balakhninskoye, *B*, in the Yenisey-Khatanga Basin, showing thermal maturity. See figure 3 for locations of wells. R_o, vitrinite reflectance, in percent (%). Data from Afanasenkov (1988), Levchuk and Fomin (1988), Fomin and Romakhina (1989), Krason and Finley (1993), and Botneva and Frolov (1996). Petromod references are Wygrala (1989), Sweeney and Burnham (1990), and Integrated Exploration Systems (2008).

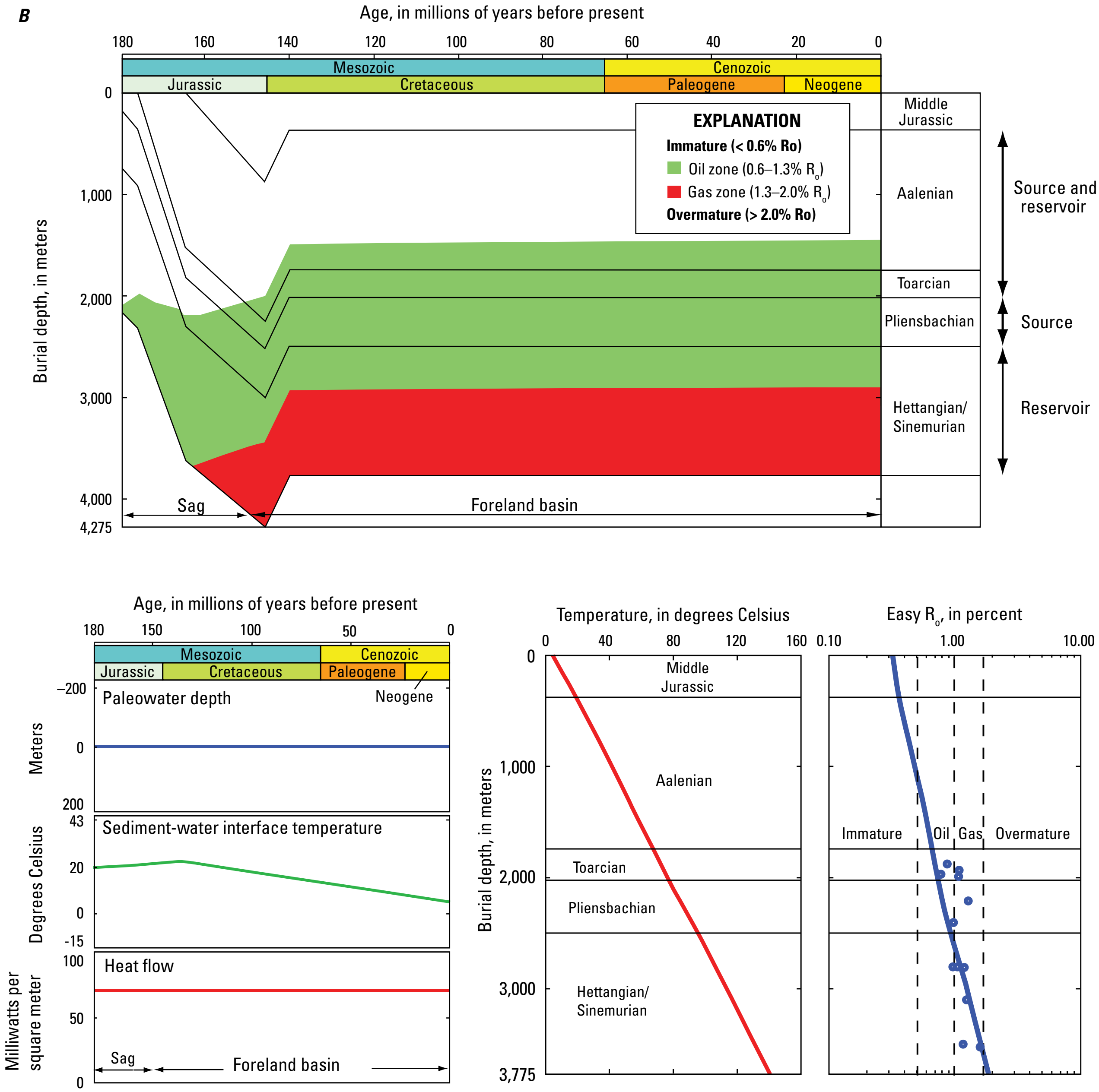


Figure 5.—Continued

Assessment Units

Two assessment units (AUs), the Khatanga Saddle AU and the Yenisey-Khatanga Basin AU, have been defined for the Yenisey-Khatanga Basin Province. For this study, an AU is defined as a volume of rock within the TPS that has similar geologic characteristics. The estimated numbers and sizes of undiscovered oil and gas fields in each AU are reported in appendixes 1 and 2, and the geologic analog data used to evaluate the AUs are summarized in tables 1 and 2.

Khatanga Saddle Assessment Unit

The Khatanga Saddle AU, which comprises the eastern updip margin of the Yenisey-Khatanga Basin, is most likely the northward-plunging extension of the Anabar structural high of the Siberian craton (figs. 1, 2). The break in slope between the Khatanga Saddle and the Yenisey-Khatanga Basin is the west boundary of the AU. The AU is bounded on the east by the west edge of a north-south-trending fold and thrust front called the Pakhsino-Begichev arch, which might be a westward extent of the Verkhoyansk-Olenek contractional-deformation front. The Taimyr-Kara high (including the Kara block, the Central Taimyr fold belt, and the South Taimyr fold belt) and the frontal fault of the Kiryano-Tass arch are the northern boundary of the AU (figs. 1, 2), and the Siberian craton bounds the southern margin. The area of the AU is ~45,000 km^2, 23 percent of which is offshore within Khatanga Bay.

The saddle is structurally complex, consisting of many inverted horsts and grabens intruded by Permian and Triassic basaltic sills. Stratigraphically, the AU includes the entire sedimentary section from Proterozoic through Mesozoic (Cretaceous). The section of Proterozoic (Riphean) through Silurian rocks is >3 km thick locally. A 2-km-thick section of Devonian and Carboniferous rocks is present in the northeastern part of the AU. Within the Yenisey-Khatanga Basin Province, the Mesozoic section is thinnest on the Khatanga saddle, with sedimentary thickness of no more than 1 to 2 km. Potential petroleum reservoirs include Paleozoic carbonate rocks and Proterozoic clastic and carbonate rocks. Traps are associated with salt domes and faulted anticlines.

Four petroleum discoveries—three oil fields and one gas field—were made in the AU, all of which are now abandoned (IHS Energy Group, 2007). All of these fields were smaller than the minimum size defined for this assessment. Accumulations in these fields are in Permian sandstone, and hydrocarbon shows were observed in Triassic and Jurassic sandstones. Crude oil is too heavy (API (American Petroleum Institute) gravity of 20–25°) and viscous (240–270 centistokes) to be produced from primary production operations; drilling and testing technologies at the time of discovery and production were inadequate to increase flow rates. Exploration ended by 1954 and has not resumed.

Geological Analysis of Assessment-Unit Probabilities

The probability that the Khatanga Saddle AU contains at least one field equal to or greater than the minimum field size of 50 million barrels of oil equivalent (MMBOE) defined for this assessment is estimated at 50 percent (0.50). The assessment input data are summarized below and reported in appendix 1.

Charge Probability.—A charge probability of 1.00 was estimated because the AU area has a petroleum system sufficient to charge one field equal to or greater than the minimum field size (50 MMBOE), as indicated by reported shows in exploration wells and large amounts of bitumen along the flanks of the AU.

Rock Probability.—A rock probability of 1.00 was estimated because the AU area has a petroleum system sufficient to charge one field equal to or greater than the minimum field size (50 MMBOE).

Timing and Preservation Probability.—A timing-and-preservation probability of 0.50 was estimated because the timing of petroleum generation relative to trap formation and preservation may not be conducive for fields of ≥50 MMBOE. Mesozoic tectonic events most likely destroyed many previously trapped petroleum accumulations.

Geologic Analogs for Assessment

Two analog datasets from the USGS Analog Database (Charpentier and others, 2007)—(1) foreland basins (24 analogs) and (2) rifted passive margins and foreland basins with mixed clastic and carbonate depositional systems (15 analogs)—were used to estimate the numbers and sizes of undiscovered fields in the Khatanga Saddle AU (table 1). The analog datasets have discovered fields larger than the minimum field size (50 MMBOE) defined for this assessment. Analog categories include both extensional and contractional structural settings and traps containing carbonate and clastic depositional systems (table 1). Four AUs are common to both analog datasets.

Number of Undiscovered Fields.—The number of undiscovered fields was estimated by comparing the field densities (estimated numbers of undiscovered fields plus numbers of discovered fields containing >50 MMBOE per 1,000 km^2) of the two combined analog datasets (table 1). The median and maximum densities of discovered fields are 0.2 and 1.1 fields per 1,000 km^2, respectively, whereas the median and maximum densities of discovered plus undiscovered fields are 0.3 and 1.6 fields per 1,000 km^2, respectively. Minimum, median, and maximum densities of 0.02, 0.22, and 1.1, respectively, were used in this assessment. The total minimum, median, and maximum numbers of undiscovered fields are 1, 10, and 50, respectively (see appendix 1). A slightly gas rich oil/gas mixture of 0.4 (0.1–0.8) was assumed because Proterozoic and Paleozoic source rocks might be overmature with respect to crude-oil generation. The estimated numbers of undiscovered oil fields are 0 (minimum),

Table 1. Basins used as geologic analogs in assessment of the Khatanga Saddle Assessment Unit.

[Analog data from Charpentier and others (2008). Asterisk (*), not reported in analog database; gas volumes are nonassociated; MMBOE, million barrels of oil equivalent; MMB, millions of barrels]

Province name (assessment unit number)	Structural setting	Trap system	Depositional system	Field density (fields >50 MMBOE per 1,000 km²)		Field size distribution	Exploration maturity	Maximum field size (MMBOE)
				*Number of discovered fields	Number of discovered and undiscovered fields	Median oil field size (>50 MMB)	Percent oil by volume in fields >50 MMB	
			Foreland basins					
Middle Caspian Basin (11090101)	Compressional	Compressional anticlines, folds, thrusts	Carbonate shelf; Paralic clastics	0.38	1.15	116	61	
Amu-Darya Basin (11540101)	Compressional	Compressional anticlines, folds, thrusts; Basement-involved block structures	Paralic clastics; Carbonate shelf	0.12	0.13	111	94	
Amu-Darya Basin (11540102)	Passive	Compressional anticlines, folds, thrusts; Stratigraphic undeformed	Paralic clastics; Carbonate shelf	0.17	0.29	110	97	
Amu-Darya Basin (11540103)	Compressional	Compressional anticlines, folds, thrusts	Paralic clastics	0.08	0.09	149	96	
Rub Al Khali Basin (20190101)	Compressional; Extensional	Compressional anticlines, folds, thrusts	Carbonate shelf	0.09	0.18	204	90	
Rub Al Khali Basin (20190102)	Compressional	Compressional anticlines, folds, thrusts; Salt-induced structures	Carbonate shelf	0.54	0.80	175	95	
Rub Al Khali Basin (20190103)	Compressional	Compressional anticlines, folds, thrusts	Carbonate shelf	0.27	0.55	109	54	
Zagros Fold Belt (20300101)	Compressional	Compressional anticlines, folds, thrusts	Continental clastics; Carbonate shelf	0.20	0.57	162	79	
Zagros Fold Belt (20300102)	Compressional	Compressional anticlines, folds, thrusts	Carbonate shelf; Continental clastics	0.19	0.59	126	83	
Zagros Fold Belt (20300201)	Compressional	Compressional anticlines, folds, thrusts	Carbonate shelf	0.30	1.55	213	57	
Junggar Basin (31150101)	Compressional	Compressional anticlines, folds, thrusts; Basement-involved block structures	Continental clastics	0.11	0.17	121	98	
Sichuan Basin (31420101)	Compressional	Compressional anticlines, folds, thrusts	Carbonate shelf	0.07	0.12	98	89	
Tarim Basin (31540101)	Compressional	Compressional anticlines, folds, thrusts; Basement-involved block structures	Carbonate shelf; Paralic clastics	0.02	0.13	112	14	
North Carpathian Basin (40470101)	Passive	Compressional anticlines, folds, thrusts	Paralic clastics; Slope, clinoforms, turbidites	0.22	0.27	119	99	
North Carpathian Basin (40470201)	Compressional	Compressional anticlines, folds, thrusts	Paralic clastics; Slope, clinoforms, turbidites	0.09	0.10	77	98	
San Jorge Basin (60580102)	Compressional	Compressional anticlines, folds, thrusts	Paralic clastics	0.07	0.29	124	99	

Table 1. Basins used as geologic analogs in assessment of the Khatanga Saddle Assessment Unit. —Continued

Province name (assessment unit number)	Structural setting	Trap system	Depositional system	Field density (fields >50 MMBOE per 1,000 km²)		Field size distribution	Exploration maturity	Maximum field size (MMBOE)
				*Number of discovered fields	Number of discovered and undiscovered fields	Median oil field size (>50 MMB)	Percent oil by volume in fields >50 MMB	
Middle Magdalena (60900101)	Compressional	Compressional anticlines, folds, thrusts	Paralic clastics	1.13	1.25	177	99	
Middle Magdalena (60900102)	Compressional	Compressional anticlines, folds, thrusts	Paralic clastics	0.73	0.92	115	91	
Llanos Basin (60960101)	Compressional; Extensional	Compressional anticlines, folds, thrusts		0.24	0.44	123	58	
Llanos Basin (60960102)	Compressional; Extensional	Compressional anticlines, folds, thrusts		0.09	0.22	147	66	
East Venezuela Basin (60980101)	Compressional	Compressional anticlines, folds, thrusts	Paralic clastics	0.64	1.38	187	73	
East Venezuela Basin (60980102)	Compressional	Compressional anticlines, folds, thrusts	Paralic clastics	0.07	0.46	90	16	
Maracaibo Basin (60990102)	Compressional	Compressional anticlines, folds, thrusts	Paralic clastics	0.44	0.60	112	90	
Greater Antilles Deformed Belt (61170101)	Compressional	Compressional anticlines, folds, thrusts	Carbonate shelf	0.02	0.03	102	67	
Median				0.18	0.37	120	89	874
Mean				0.26	0.51	132	78	6,926
Rifted passive margins and foreland basins with mixed carbonate and clastic depositional systems								
Timan-Pechora Basin (10080102)	Compressional	Basement-involved block structures; Paleogeomorphic	Paralic clastics; Carbonate shelf	0.26	0.44	115	74	
Timan-Pechora Basin (10080103)	Compressional	Compressional anticlines, folds, thrusts	Paralic clastics; Carbonate shelf	0.01	0.23	103	53	
Volga-Ural Region (10150101)	Passive	Basement-involved block structures; Paleogeomorphic	Paralic clastics; Carbonate shelf	0.25	0.29	114	100	
Volga-Ural Region (10150102)	Compressional	Basement-involved block structures	Paralic clastics; Carbonate shelf	0.14	0.14	116	100	
Middle Caspian Basin (11090101)	Compressional	Compressional anticlines, folds, thrusts	Carbonate shelf; Paralic clastics	0.38	1.15	116	61	
Amu-Darya Basin (11540101)	Compressional	Compressional anticlines, folds, thrusts; Basement-involved block structures	Paralic clastics; Carbonate shelf	0.12	0.13	111	94	
Nepa-Botuoba Arch (12100101)	Compressional	Basement-involved block structures; Stratigraphic undeformed	Paralic clastics; Carbonate shelf	0.02	0.07	117	76	
Ma’Rib-Al Jawf/Masila Basin (20040101)	Extensional	Extensional grabens and other structures related to normal faulting	Paralic clastics; Carbonate shelf	0.20	0.41	100	66	

Table 1. Basins used as geologic analogs in assessment of the Khatanga Saddle Assessment Unit. —Continued

Province name (assessment unit number)	Structural setting	Trap system	Depositional system	Field density (fields >50 MMBOE per 1,000 km²)		Field size distribution	Exploration maturity	Maximum field size (MMBOE)
				*Number of discovered fields	Number of discovered and undiscovered fields	Median oil field size (>50 MMB)	Percent oil by volume in fields >50 MMB	
Fahud Salt Basin (20160201)	Compressional; Extensional	Compressional anticlines, folds, thrusts	Paralic clastics; Carbonate shelf margin, reefs	0.23	0.28	223	92	
Zagros Fold Belt (20300101)	Compressional	Compressional anticlines, folds, thrusts	Carbonate shelf margin, reefs, Slope, clinoforms, turbidites	0.20	0.57	162	79	
Zagros Fold Belt (20300102)	Compressional	Compressional anticlines, folds, thrusts	Continental clastics; Carbonate shelf	0.19	0.59	126	83	
Pelagian Basin (20480101)	Compressional; Extensional	Extensional grabens and other structures related to normal faulting; Transtensional and transpressional	Carbonate shelf; Continental clastics	0.12	0.19	157	94	
Pelagian Basin (20480201)	Compressional; Extensional	Extensional grabens and other structures related to normal faulting; Transtensional and transpressional	Carbonate shelf; Paralic clastics	0.01	0.02	63	66	
Tarim Basin (31540101)	Compressional	Compressional anticlines, folds, thrusts; Basement-involved block structures	Paralic clastics; Carbonate shelf	0.02	0.13	112	14	
Bombay (80430101)	Extensional	Basement-involved block structures; Stratigraphic undeformed	Paralic clastics; Carbonate shelf	0.06	0.11	106	82	
Median				0.14	0.23	115	79	1,666
Mean				0.15	0.32	123	76	8,007
Summary of all geologic analogs used for Khatanga Saddle assessment								
Median				0.15	0.29	116	86	1,025
Mean				0.22	0.43	129	78	5,810
Maximum				1.13	1.55	223	100	

4 (median), and 40 (maximum); and the estimated numbers of undiscovered gas fields are 1 (minimum), 6 (median), and 45 (maximum) (see appendix 1).

Sizes of Undiscovered Fields.—The estimated minimum, median, and maximum sizes of undiscovered oil and gas fields in the Khatanga Saddle AU are reported in appendix 1. The minimum sizes of undiscovered fields defined for the AU are 50 million barrels (MMB) of crude oil and 300 billion cubic feet (BCF) of natural gas (6 BCF=1 MMBOE). The median sizes of undiscovered fields in the AU are 100 MMB of crude oil and 400 BCF of natural gas. The median undiscovered oil-field size (100 MMBOE) is slightly smaller than the median field size in the analog dataset (116 MMBOE). The low-probability maximum field size of 1,000 MMBOE approximates the median size of the maximum values of the combined analog datasets, 1,000 MMBOE (see appendix 1). On an oil-equivalent basis, the median (400 BCF) and maximum (4,000 BCF) sizes of undiscovered gas fields are smaller than those of undiscovered oil fields because of a greater risk for preservation (see appendix 1).

Expected Maximum Size of Undiscovered Fields.—The expected maximum sizes of undiscovered fields are based on the analog dataset: 200 million barrels (MMB) for undiscovered oil fields and 900 BCF (150 MMBOE) for undiscovered gas fields. The expected maximum size of gas fields is slightly smaller than that of oil fields because of a greater risk for preservation. These sizes are reduced in this AU from the median of the largest discovered size of analog fields because of the complex tectonic history and uplift since petroleum generation.

Petroleum Composition and Properties of Undiscovered Fields.—Oil/gas mixture, coproducts, and petroleum-quality properties used in assessing this AU are based on the fields discovered in this AU and those from global statistics (table 3).

Yenisey-Khatanga Basin Assessment Unit

The Yenisey-Khatanga Basin AU coincides with the main part of the Yenisey-Khatanga Basin. The AU is bounded on the east by the Khatanga Saddle, on the north by the Taimyr fold and thrust belt, and on the south by the Siberian craton. On the west, the Yenisey-Khatanga Basin borders the West Siberian Basin (figs. 1, 2). The west boundary of the AU is somewhat arbitrary but is approximately delineated by the extent of the Tanam structural terrace, the Noskovsky Trough, and the southwest slope of the Taimyr fold and thrust belt (figs. 1, 2). Stratigraphically, the AU includes the sedimentary section from Upper Permian through Cretaceous. The area of the AU is ~345,000 km^2, 4 percent of which is offshore within Yenisey Bay (Ust' Yenisey).

Three producing gas fields and nine discoveries, four of which are awaiting development approval, are present in this AU (IHS Energy Group, 2007). Only one oil field was discovered as of 2007, although some oil legs are present in the gas fields. The sizes of the three producing gas fields exceed the specified minimum field size of 50 MMBOE. Discovered fields in the Yenisey-Khatanga Basin AU have reservoirs primarily in Jurassic and Lower Cretaceous sandstones. Potential reservoirs include Permian and Triassic sandstones. Traps in discovered fields are associated with simple and faulted anticlines but could include combination and stratigraphic traps associated with deltaic and progradational (slope, clinoform, and turbidite) sandstone reservoirs. Most of the anticlines in this AU have been tested; exploration is now focused on pinchouts along structures and within clinoforms (Grebenyuk and others, 2003).

Geological Analysis of Assessment-Unit Probabilities

The probability that the Yenisey-Khatanga Basin AU contains at least one field equal to or greater than the minimum field size is 100 percent (1.00). The assessment input data are summarized below and reported in appendix 2.

Charge Probability.—A charge probability of 1.00 was estimated because the AU area has a petroleum system sufficient to charge one field equal to or greater than the minimum field size (50 MMBOE).

Rock Probability.—A rock probability of 1.00 was estimated because the AU area has a petroleum system sufficient to charge one field equal to or greater than the minimum field size (50 MMBOE).

Timing and Preservation Probability.—A timing-and-preservation probability of 1.00 was estimated because the AU area has a petroleum system sufficient to charge one field equal to or greater than the minimum field size (50 MMBOE) and because oil and gas fields are known to be present in the AU.

Geologic Analogs for Assessment

Two different analog datasets were used to estimate the number of undiscovered fields for the Yenisey-Khatanga Basin AU: (1) rift/sag basins that were subsequently compressed (7 analogs); and (2) basins with slope, clinoform, and turbidite depositional systems (20 analogs) (table 2). The analog datasets contain primarily clastic reservoir rocks and have discovered fields of sizes equal to or greater than the minimum field size (50 MMBOE).

Number of Undiscovered Fields.—The number of undiscovered fields was estimated from the two combined analog datasets (table 2). The median and maximum densities of discovered fields in the combined analog datasets are 0.1 and 0.7 fields per 1,000 km^2, respectively, whereas the median and maximum densities of discovered plus undiscovered fields are 0.3 and 1.7 fields per 1,000 km^2, respectively. Minimum, median, and maximum, respectively densities of <0.01, 0.2, and 0.3, respectively, were used in this assessment. The median density of 0.2 falls between the median densities of the analog datasets and the maximum density of 0.3 approximates the density of the neighboring West Siberian Basin AUs (0.35, included in the analog dataset, table 2). The total minimum, median, and maximum numbers of undiscovered fields are 1,

Table 2. Basins used as geologic analogs in assessment of the Yenisey-Khatanga Basin Assessment Unit.

[Analog data from Charpentier and others (2008). Asterisk (*), not reported in analog database; gas volumes are nonassociated; MMBOE, million barrels of oil equivalent; MMB, millions of barrels]

Province name (assessment unit number)	Structural setting	Trap system	Depositional system	Field density (fields >50 MMBOE per 1,000 km^2)		Field size distribution	Exploration maturity	Maximum field size (MMBOE)
				*Number of discovered fields	Number of discovered and undiscovered fields	Median oil field size (>50 MMB)	Percent oil by volume in fields >50 MMB	
			Compressed rift/sag basins					
Middle Caspian Basin (11090201)	Compressional	Compressional anticlines, folds, thrusts; Basement-involved block structures	Paralic clastics	0.09	0.15	142	95	
North Ustyurt Basin (11500101)	Compressional	Compressional anticlines, folds, thrusts	Paralic clastics	0.16	0.29	251	82	
North Ustyurt Basin (11500201)	Compressional	Local uplifts of uncertain origin	Paralic clastics	0.01	0.04	105	84	
West Siberian Basin (11740101)	Compressional	Basement-involved block structures; Stratigraphic undeformed	Paralic clastics; Slope, clinoforms, turbidites	0.15	0.32	132	79	
West Siberian Basin (11740301)	Compressional	Compressional anticlines, folds, thrusts	Continental clastics; Paralic clastics	0.15	0.35	224	92	
Malay Basin (37030101)	Compressional	Basement-involved block structures	Paralic clastics; Continental clastics	0.39	0.64	108	69	
Malay Basin (37030201)	Compressional	Basement-involved block structures	Paralic clastics; Continental clastics	0.36	0.51	186	94	
Median				0.15	0.32	142	84	1,268
Mean				0.19	0.33	164	85	13,749
			Basins with slope, clinoforms, turbidites					
Baram Delta/Brunei-Sabah Basin (37010102)	Compressional	Extensional grabens and other structures related to normal faulting	Slope, clinoforms, turbidites	0.09	0.28	100	39	
Bonaparte Gulf Basin (39100201)	Compressional	Extensional grabens and other structures related to normal faulting	Slope, clinoforms, turbidites	0.03	0.14	95	8	
Bonaparte Gulf Basin (39100301)	Compressional	Extensional grabens and other structures related to normal faulting	Paralic clastics; slope, clinoforms, turbidites	0.03	0.14	112	68	
Browse Basin (39130101)	Extensional	Extensional grabens and other structures related to normal faulting	Paralic clastics; slope, clinoforms, turbidites	0.02	0.14	125	48	
Northwest Shelf (39480101)	Extensional	Extensional grabens and other structures related to normal faulting	Paralic clastics; slope, clinoforms, turbidites	0.40	1.53	108	56	
Northwest Shelf (39480201)	Extensional	Extensional grabens and other structures related to normal faulting	Paralic clastics; slope, clinoforms, turbidites	0.00	0.02	111	41	
Pannonian Basin (40480101)	Extensional	Stratigraphic undeformed; Gravity-induced growth faults; basement-involved block structures	Paralic clastics; slope, clinoforms, turbidites	0.11	0.09	102	98	
Pannonian Basin (40480201)	Extensional	Stratigraphic undeformed; gravity-induced growth faults; basement-involved block structures	Paralic clastics; slope, clinoforms, turbidites	0.15	0.13	95	99	

Table 2. Basins used as geologic analogs in assessment of the Yenisey-Khatanga Basin Assessment Unit.—Continued

Province name (assessment unit number)	Structural setting	Trap system	Depositional system	Field density (fields >50 MMBOE per 1,000 km²)		Field size distribution	Exploration maturity	Maximum field size (MMBOE)
				*Number of discovered fields	Number of discovered and undiscovered fields	Median oil field size (>50 MMB)	Percent oil by volume in fields >50 MMB	
Po Basin (40600101)	Compressional	Stratigraphic undeformed; compressional anticlines, folds, thrusts	Slope, clinoforms, turbidites	0.21	0.35	110	76	
Sergipe-Alagoas Basin (60290102)	Extensional	Gravity-induced growth faults	Slope, clinoforms, turbidites	0.09	0.51	105	5	
Campos Basin (60350101)	Extensional	Salt-induced structures	Slope, clinoforms, turbidites	0.74	1.74	178	55	
Santa Cruz-Tarija Basin (60450101)	Compressional	Compressional anticlines, folds, thrusts	Paralic clastics; slope, clinoforms, turbidites	0.19	0.38	115	68	
Neuquen Basin (60550103)	Compressional; extensional	Extensional grabens and other structures related to normal faulting	Slope, clinoforms, turbidites	0.65	0.76	130	98	
Tobago Trough (61030101)	Compressional; extensional	Extensional grabens and other structures related to normal faulting	Paralic clastics; slope, clinoforms, turbidites	0.38	0.94	128	42	
West-Central Coastal (72030201)	Passive	Salt-induced structures	Slope, clinoforms, turbidites	0.05	0.14	114	24	
West-Central Coastal (72030302)	Passive	Stratigraphic undeformed	Slope, clinoforms, turbidites	0.01	0.49	140	23	
Orange River Coastal (73030101)	Extensional	Stratigraphic undeformed	Slope, clinoforms, turbidites	0.00	0.01	110	50	
Bombay (80430102)	Extensional	Extensional grabens and other structures related to normal faulting; stratigraphic undeformed	Continental clastics; slope, clinoforms, turbidites	0.20	0.24	114	88	
Ganges-Brahmaputra Delta (80470302)	Compressional	Compressional anticlines, folds, thrusts; gravity-induced growth faults	Continental clastics; paralic clastics; slope, clinoforms, turbidites	0.05	0.18	116	41	
Irrawaddy (80480102)	Compressional; extensional	Compressional anticlines, folds, thrusts; gravity-induced growth faults; Stratigraphic undeformed	Paralic clastics; slope, clinoforms, turbidites	0.01	0.04	107	37	
Median				0.09	0.21	112	49	575
Mean				0.17	0.41	116	53	1,075
Summary of all geologic analogs used for Yenisey-Khatanga Basin assessment								
Median				0.11	0.28	114	68	850
Mean				0.17	0.39	128	62	4,361
Maximum				0.74	1.74	251	99	

Table 3. World statistics for oil and gas coproduct ratios, ancillary data, and depths.

Variable	Minimum	Median	Maximum
Coproduct Ratios			
Natural Gas-to-Crude Oil Ratio in Oil Accumulations (cubic feet per barrel)	100	1,000	20,000
Natural Gas Liquids-to-Natural Gas Ratio in Oil Accumulations (barrels per thousand cubic feet)	5	25	85
Natural Gas Liquids-to-Natural Gas Ratio in Gas Accumulations (barrels per thousand cubic feet)	5	25	75
Ancillary Data for Oil Accumulations			
API gravity (degrees)	20	38	55
Viscosity (centipoise)	0.01	3	30
Sulfur content of oil (percent)	0	0.3	1.5
Ancillary Data for Gas Accumulations			
Inert gas content (percent)	0	2	10
Carbon dioxide content (percent)	0	1.5	10
Hydrogen sulfide content (percent)	0	0.5	3.5
Depths			
Depth (m) of water (if applicable)	0	50	2,700
Drilling Depth (m)	350	2,000	7,000

62, and 112, respectively (see appendix 2). Oil/gas mixtures of 0.1 (minimum), 0.3 (mode), and 0.5 (maximum) were assumed because of gas-prone kerogen type in Mesozoic source rocks. The estimated numbers of undiscovered oil fields are 0 (minimum), 20 (median), and 60 (maximum); and the estimated number of undiscovered gas fields are 1 (minimum), 45 (median), and 100 (maximum) (see appendix 2).

Sizes of Undiscovered Fields.—The estimated minimum, median, and maximum sizes of undiscovered oil and gas fields in the Yenisey-Khatanga Basin AU are reported in appendix 2. The minimum sizes of undiscovered fields defined for the AU are 50 MMB of crude oil and 300 BCF of natural gas (6 BCF=1 MMBOE). The median field size of 150 MMBOE approximates the median size of the rift/sag-basin analog dataset, 142 MMBOE, but exceeds the median field size of the combined analog dataset (114 MMBOE). This median field size is consistent with the average size of discovered fields in this AU and the neighboring Northern West Siberian Onshore Gas AU (median size 200–300 MMBOE, included in the analog dataset). The low-probability maximum field sizes of 4,000 MMB for undiscovered oil fields and of 24,000 BCF for undiscovered gas fields approximate the mean of the maximum field sizes in the combined analog datasets.

Expected Maximum Size of Undiscovered Fields.—The expected maximum sizes of undiscovered fields are based on the analog dataset, with a smaller oil-field than gas-field size, to be consistent with the sizes of discovered fields in this AU: ~1,000 MMB for undiscovered oil fields and 9,000 BCF (1,500 MMBOE) for undiscovered gas fields. These sizes are based on a distribution of sizes of the fields in this and neighboring AUs and are constrained by the discovery history.

Petroleum Composition and Properties of Undiscovered Fields.—Oil/gas mixture, coproducts, and petroleum-quality properties used in assessing this AU (table 3) are based on the fields discovered in this AU and in the neighboring Northern West Siberian Onshore Gas AU, which has a similar geologic setting, source rocks, reservoir rocks, and traps.

Assessment Results

The assessment results for the Khatanga Saddle and Yenisey-Khatanga Basin AUs in the Yenisey-Khatanga Basin Province are summarized in table 4. Estimates represent undiscovered, technically recoverable, conventional petroleum resources.

Given the probability of 0.5 for a field of minimum size (see appendix 1), there is a 50-percent chance (F50) that no crude-oil or natural-gas resources exist in the Khatanga Saddle AU (table 4). The risked mean undiscovered crude-oil resource is 327 MMB, with a 95-percent chance (F95) of 0 MMB and a five-percent chance (F5) of 1,376 MMB. The risked mean volume of undiscovered nonassociated natural gas resource is 1,797 BCF, with an F95 of 0 BCF, an F50 of 0 BCF, and an F5 of 6,764 BCF. The largest expected size of an undiscovered oil

Table 4. Assessment results (conventional undiscovered resources) for the Yenisey-Khatanga Basin Province.

[AU, assessment unit; BCF; billion cubic feet; MMB, million barrels; TPS, total petroleum system. Results shown are fully risked estimates. For gas fields, 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. 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—Proterozoic-Paleozoic composite total petroleum system														
Khatanga Saddle AU	0.5	Oil	0	0	1,376	327	0	0	932	206	0	0	25	6
		Gas	N/A	N/A	N/A	N/A	0	0	6,764	1,797	0	0	182	48
Yenisey-Khatanga Basin AU	1	Oil	2,201	4,847	9,716	5,257	11,604	26,571	55,375	29,078	305	710	1,529	786
		Gas	N/A	N/A	N/A	N/A	38,629	66,089	108,413	68,884	1,009	1,754	2,929	1,835
Total undiscovered petroleum resources			2,192	5,190	10,594	5,584	50,233	94,955	167,863	99,957	1,332	2,539	4,552	2,675

field is ~220 MMB (not reported in appendix 1), and the largest expected size of an undiscovered gas field is ~900 BCF (not reported in appendix 1).

The overall probability for oil and gas fields in the Yenisey-Khatanga Basin AU is 1.00 (see appendix 2). The mean undiscovered crude-oil resource is 5,257 MMB, with an F95 of 2,201 MMB, an F50 of 4,847 MMB, and an F5 of 9,716 MMB (table 4). The mean volume of undiscovered nonassociated natural-gas resource is 68,884 BCF, with an F95 of 38,629 BCF, an F50 of 66,089 BCF, and an F5 of 108,413 BCF. The maximum size of an expected undiscovered oil field is ~1,100 MMB (not reported in appendix 2), and the maximum size of an expected undiscovered gas field is ~9,100 BCF (not reported in appendix 2).

The total estimated mean undiscovered petroleum resource in the Yenisey-Khatanga Basin Province AU is 5,584 MMB of crude oil, 99,957 BCF of associated and nonassociated natural gas, and 2,675 MMB of natural-gas liquids (table 4). Additional statistics are listed in table 2.

The geologic probabilities of the AUs in this study were determined on the basis of a consideration of the geology of each province and the geologic probabilities assigned to the AUs in all Arctic basins. Using this approach, the probabilities were consistently applied throughout the Arctic region.

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Appendixes

Appendix files are available online only, and may be accessed at https://doi.org/10.3133/pp1824R.

1. Assessment Input Data for the Khatanga Saddle Assessment Unit.
2. Assessment Input Data for the Yenisey-Khatanga Basin Assessment Unit.

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