Map Showing the Sedimentary Successions of the Arctic Region (58°-64° to 90°N) that may be Prospective for Hydrocarbons

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Abstract

One hundred and forty three (143) sedimentary successions that may be prospective for oil and gas were identified in the Arctic Region north of 58°-64° N and mapped in four quadrants at a scale of 1:6,760,000. Eighteen of these successions (12.6 percent) occur in the Arctic Ocean Basin, twenty five (17.5 percent) in the passive and strike-slip continental margins of the Arctic Basin and one hundred (70.0 percent) on the circum-Arctic continents of which one (<1 percent) lies in an active margin on the Pacific Rim. Each succession was assigned to one of 13 tectono-stratigraphic and morphologic classes and colored accordingly on the map. The thickness of each succession and that of any underlying sedimentary section down to economic basement, where known, is shown on the map by isopachs.

Major structural or tectonic features associated with the creation of the successions, or with the enhancement or degradation of their hydrocarbon potential, are also shown. Forty four (30.8 percent) of the successions are known to contain hydrocarbon accumulations, sixty four (44.8 percent) are sufficiently thick to have generated hydrocarbons and 35 (24.5 percent) may be too thin to be prospective.

Introduction

Assessment of the petroleum potential of the Arctic Region is handicapped by incomplete knowledge of the location, character, age and geologic setting of the sedimentary successions that underlie this large, remote and incompletely mapped region. The accompanying map (Plate 1) attempts to fill this void by displaying all of the supra-continental and submarine sedimentary successions in the Arctic Region (variously 58°-64° N to 90°N) that are known or inferred to lie at or near the land surface or the seafloor on the basis of currently available data. The map consists of four quadrants--Alaska and Arctic Canada, East Siberia, Barents/Kara, and Greenland) at a uniform scale of 1:6,760,000. This scale was chosen because it is the largest that will allow the map to be printed on standard 42 inch wide printer paper. An Explanation and Time Scale for the map is presented on Plate 2. A total of 143 sedimentary successions known to contain hydrocarbons that were either generated internally or expelled from other successions, or which appear to be sufficiently thick to warrant at least consideration of their hydrocarbon potential based on their known or inferred thermal gradients, were identified in the Arctic Region in the present study. The successions range in age from Late Mesoproterozoic (mid-Riphean) to Cenozoic and, within the confines of the Arctic Region, range in size from less than 100 to more than 50,000 sq. km. Summaries of the tectonic/morphologic character, location and apparent hydrocarbon prospectivity of the sedimentary successions identified within the confines of each quadrant of the map are presented in tables located in the adjacent map margins.

Data on the subsurface geology of the Arctic Region, in particular seismic reflection and refraction data, are insufficient to assure that all of the sedimentary successions of the region of sufficient size and character to be of interest for commercial hydrocarbon exploration have been identified in the present study. Our review of the data suggests to us, however, that no more than a few potentially prospective sedimentary successions may remain unrecognized.

The hydrocarbon potential of the sedimentary successions of the Arctic Region ranges from many with little or no potential to several that contain world-class hydrocarbon deposits. Indeed, geochemical data for more than 1,000 crude oil samples from wells and seeps show that the circum-Arctic region contains at least 31 genetically distinct oil families (Peters et al., 2007). Sedimentary successions that were subjected to levels of heating, structural deformation or erosional breaching that appear to preclude the retention or preservation of economic deposits of oil or gas are excluded from the map (Plate 1). We have, however, chosen to include others that may not have been subjected to sufficiently high temperatures, as estimated from known sediment thickness, to have generated oil or gas. These successions were included, but specifically identified as unlikely to be prospective for hydrocarbons (see Explanation of "Synoptic Boxes" in Plate 2), because our knowledge of their thickness and thermal state is insufficient to preclude the possibility that some of them may, in places, contain types of kerogen and levels of sedimentary thickness and (or) heat flow that might have generated oil or gas.

Our understanding of the 143 sedimentary successions of the Arctic Region shown on the map ranges from adequate in some onshore and offshore areas that are under oil and gas exploration and development, such as the North Slope of Alaska and the Timan-Pechora and West Siberia Basins of northwestern

Russia, to limited in offshore regions with sparse geophysical data, such as most of the East Siberian shelf and the Amerasia Basin of the Arctic Ocean. In consideration of the scale and regional focus of this study we relied most heavily on recent syntheses and large-scale maps to delineate the sedimentary successions of the generally better-studied onshore areas. In the relatively little-studied Arctic Ocean basin we relied mainly on regional aeromagnetic maps (Roest et al., 1996; Cande et al., 1989; Brozena et al., 2003; and unpublished aeromagnetic maps of the Arctic Region provided by J.M. Brozena of the U.S. Naval Research Laboratory), airborne and satellite gravity data (Forsberg and Skourup, 2005, <http://earth-info.nga.mil/GandG/wgs84/agp/index.html> Laxon and McAdoo, 1997; McAdoo et al., 2008), unevenly distributed (and commonly sparse) seismic reflection and refraction data, piston cores and shallow drill holes (Grantz et al., 1998 and 2001; Moran and Backman, 2004) and bathymetry (Jakobsson et al., 2003 and <http://www.ngdc.noaa.gov.mgg/bathymetry/arctic/arctic.html>). The principal data sources used for each of the four quadrants of Plate 1 are listed separately in Appendices A to D.

In addition to the areal extent of the sedimentary successions, the map (Plate 1) shows the location, character and age of many of the major geologic structural features of the Arctic Region thought to have enhanced or degraded the petroleum potential of the 143 successions that were mapped. Conversely, all or part of sedimentary successions that contain structures, such as imbricate thrust fault zones or isoclinal fold belts, that may have destroyed petroleum prospectivity are not shown (have been left uncolored) on the map. In places fold-and-thrust belts may have been emplaced above strata with petroleum potential about which we have inadequate information. No attempt was made to depict such strata on the map. The locations of evaporite or shale diapirs (both are known to occur) and impact structures (astroblemes) that may locally affect petroleum prospectivity are also shown. The thicknesses of many of the sedimentary successions on the map are shown by isopachs of either the entire sedimentary section or of selected parts of the section, by interpreted depths along geophysical profiles or by spot seismic soundings (see Explanation, Plate 2). The stratigraphic interval represented by the isopachs is encircled by an ellipse of the same color as the isopachs in the Synoptic Box (see Plate 2) that accompanies each mapped sedimentary succession on the map.

This report is a collaborative effort of all of the authors. Primary compilation of the individual map quadrants, however, was as follows: Alaska and Arctic Canada quadrant--Grantz and Moore; East Siberia quadrant--Drachev and Grantz; Barents-Kara quadrant--Scott, James P. Howard (CASP), Drachev, Grantz and Stewart Sinclair (CASP); Greenland quadrant--Moore and Grantz.

Plate-tectonic context of sedimentary successions in the Arctic Region

We employed an empirical tectonic and morphologic classification for the sedimentary successions of the Arctic Region (see Explanation, Plate 2) based on our analysis of the available geological, geophysical and bathymetric data. (The sources of these data are listed in References Cited and Appendices A to D.) The sedimentary successions of the Arctic Region were deposited on continental and oceanic crust and across prograded passive and strike-slip continental margins, but the tectonic history of the Arctic Region imposed a strong bias for successions that formed in platform, stable shelf and extensional environments. The only successions of the Arctic Region (58°-64° to 90° N) that formed in convergent environments and retain petroleum prospectivity were deposited in foreland basins created by convergence within or between continental plates or microplates and in the Anadyr Fore-Arc Basin, which formed in the arc-trench gap at the Pacific rim along the south margin of the map (Plate 1) near 64 ° N, 180° W.

The continents and micro-continents of much of the present-day Arctic Region were originally part of Laurussia, which formed by the collision of Baltica and Siberia with North America and the closure of the intervening Neoproterozoic-Early Paleozoic Iapetus Ocean (Fig. 1A) during the Silurian and Devonian Caledonian orogeny (Lawver et al., 2002). The eastern part of Baltica, from the present-day southern Urals to Novaya Zemlya, the eastern Barents Shelf, and the Varanger Peninsula of northeastern Norway, is underlain by the Timanian orogen. The orogen consists of Vendian turbidites, ophiolites and molasse deposited in the Timanian Ocean, which were thrust against the eastern margin of Baltica prior to peneplanation and deposition of a cover of marine shelf deposits beginning in the Late Early Cambrian to Ordovician (Gee, 2005). The Timanides underlie the Timan-Pechora, West Siberia and other productive petroleum basins in northwestern Russia and contain Vendian foreland deposits with at least theoretical petroleum potential in the Mezen' Basin.

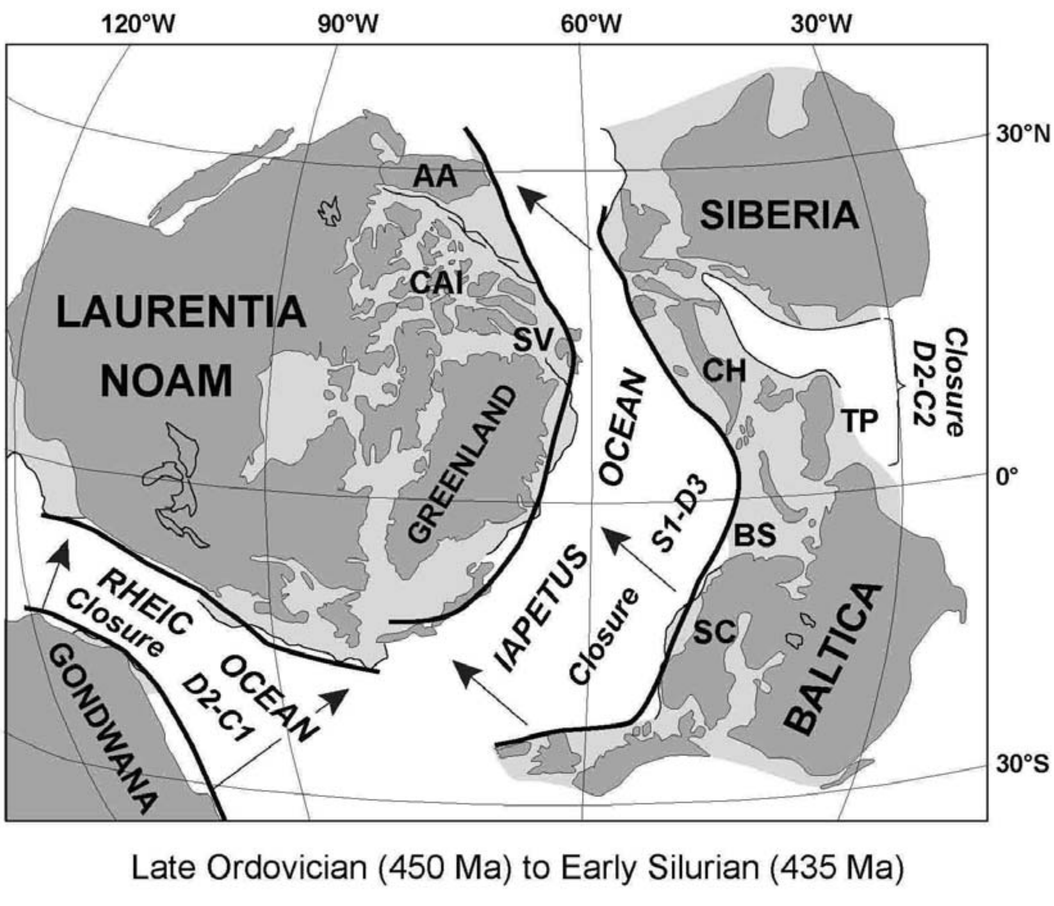


Figure 1A. Palaeogeography of the present Arctic Region during the Late Ordovician (450 Ma) to Early Silurian (435 Ma) showing 1.) the position of the Iapetus Ocean between Laurentia

and Siberia-Baltica prior to the amalgamation of Laurussia by the closure of Iapetus during the Caledonian orogeny and 2.) the position of the Rheic Ocean between Laurentia and Gondwana prior to the amalgamation of Pangea by closure of the Rheic Ocean during the Late Devonian and Early Carboniferous. The convergence that closed Iapetus produced the Caledonides in Scandinavia, northeastern Greenland and Svalbard during the late Early Silurian to Late Devonian and the Ellesmerides in the Canadian Arctic Islands and North Greenland during the Late Devonian and early Early Carboniferous.

The Caledonian orogeny and its Late Devonian and Early Carboniferous terminal phase in Arctic North America, the Ellesmerian orogeny, compressed the oceanic and marginal marine deposits of the Iapetus Ocean (Fig. 1A). This compression created the extensive tracts of strongly deformed Early Paleozoic strata, the Caledonides, that constitute economic basement [1] over much of the Arctic Region. Northwest Europe, the western Barents Shelf, Svalbard, northeast Greenland and possibly part of the East Siberian shelf are underlain by the Caledonides and northern Greenland and the northwestern part of the Canadian Arctic Islands are underlain by the only slightly younger Ellesmerides. The continental platforms that were marginal to the Iapetus Ocean, including the Franklinian Province and Arctic Platform of northeastern and northern Greenland and northwestern Canada, received carbonate-dominated shelf deposits from the Cambrian to Early Devonian and foreland clastic deposits during the Middle and Late Devonian. All of these supra-platform deposits escaped intense Caledonian deformation and in places retain their prospectivity for hydrocarbons. Closure of the Late Cambrian to Early Carboniferous Rheic Ocean by the collision of Gondwana with Laurussia (Laurentia plus Baltica and Siberia) during the Middle Devonian to Early Carboniferous and of the PaleoAsian and Uralian Oceans by the collision of the Kazakhstan block with Baltica and Siberia during the Late Carboniferous created first Eurasia and then

[1] Economic basement is the upper surface of igneous, metamorphic or strongly deformed sedimentary rocks that do not, as a rule, contain hydrocarbon accumulations. It commonly corresponds to acoustic basement on seismic reflection profiles.

the super-continent of Pangea (Fig. 1B). Closure of the Rheic Ocean was

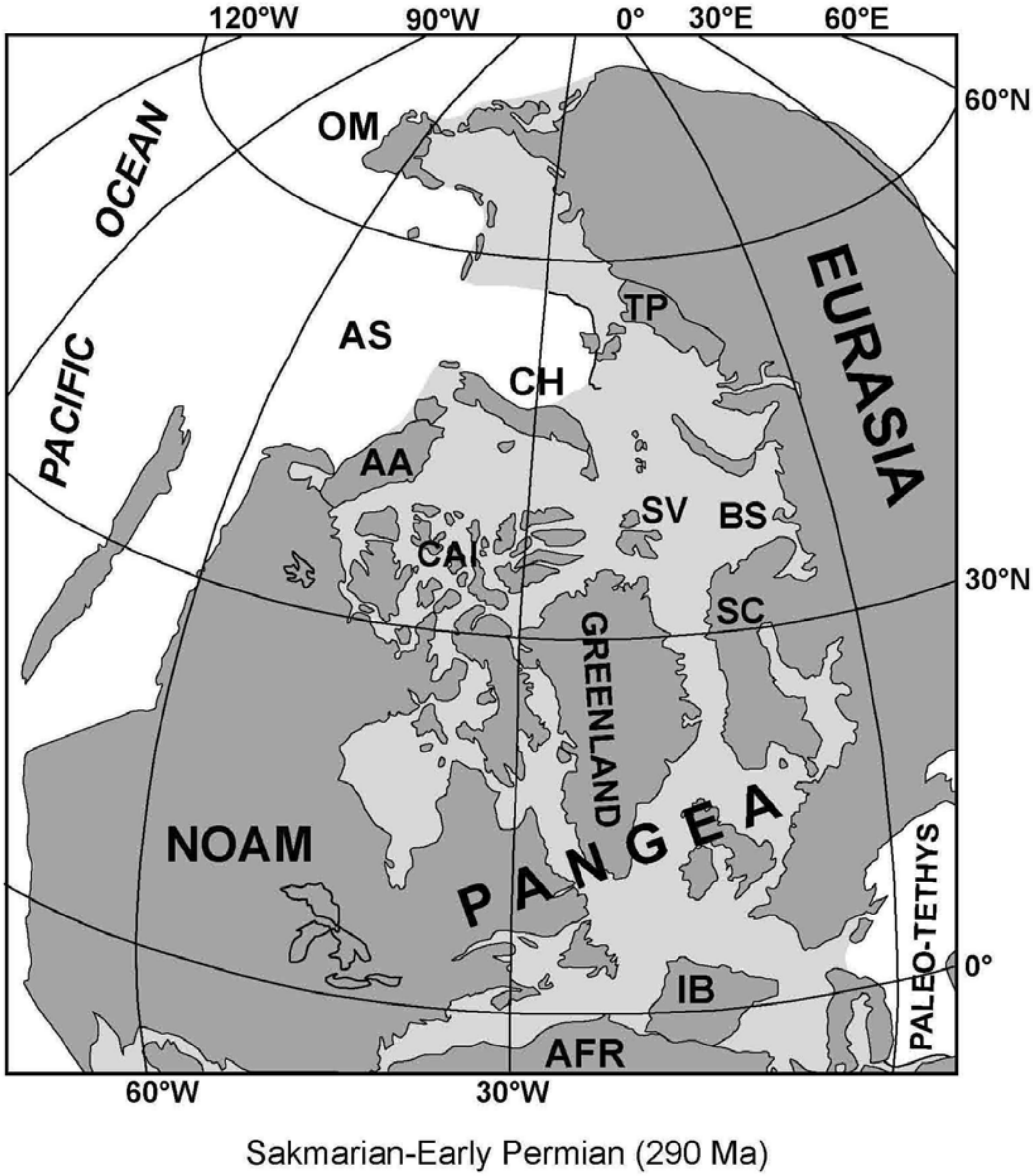


Figure 1B. Palaeogeography of the present Arctic Region after closure of the Rheic Ocean created the super-continent of Pangea by the amalgamation of Gondwana and Laurussia during the Kasimovian (Late Pennsylvanian), about 305 Ma. All of the present-day continents and micro-continents of the Arctic Region (58°-64° to 90°N) were once part of Pangea.

generally correlative with the Late Devonian Ellesmerian phase of the Caledonian orogeny in northwestern North America. Pangea included almost all parts of the modern Arctic Region that existed prior to its breakup beginning in the earliest Jurassic. As a result, all pre-Jurassic sedimentary successions of the present-day Arctic Region that retain hydrocarbon prospectivity rest on continental crust, which protected them from strong convergence-related deformation during closure of the Iapetus and Rheic Oceans and the assembly of Pangea.

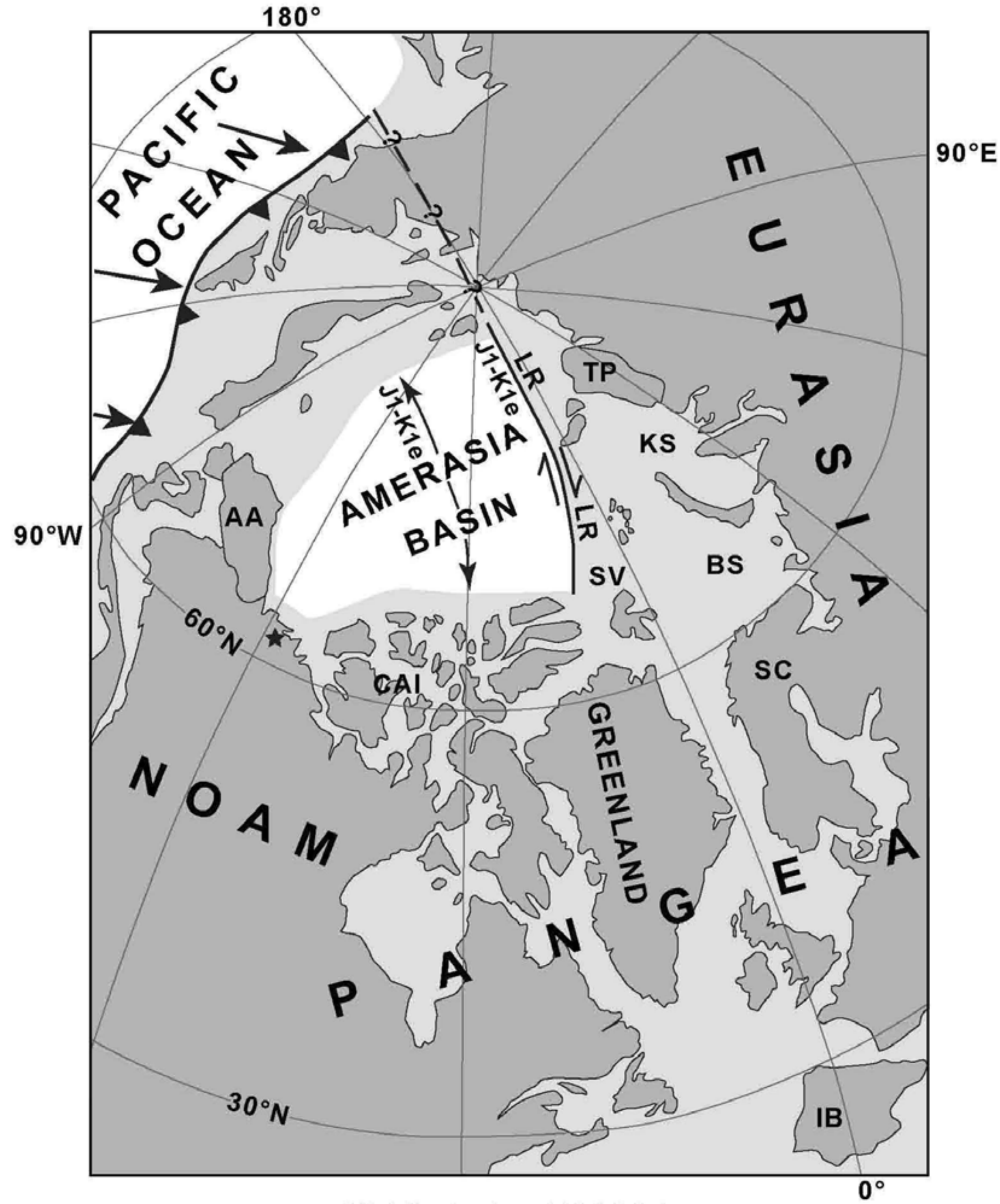


Figure 1C. Paleogeography of the present Arctic Region after the final amalgamation of Pangea at the end of the Triassic and opening of the Amerasia Basin by two stages of rotational rifting within Pangea during the Jurassic and early Early Cretaceous. Rifing was

accomplished by crustal thinning and extension and the creation of ocean-continent transitional crust during the Jurassic and possibly the early Early Cretaceous and by sea-floor spreading and the creation of MORB during the mid-Early Cretaceous. Rotation was about a pole in the lower Mackenzie Valley (indicated by a star) and along the right-lateral Amerasia Basin Transform Fault along the Amerasian margin of the Late Paleocene and younger Lomonosov Ridge (LR). The projection of the Amerasia Basin Transform Fault to the fault to the Pacific Rim has been tectonically overridden and its path is conjectural.

The Jurassic and younger basins of the Arctic Region, on the other hand, are more varied in origin. Most lie between the fragments dispersed by the breakup of Pangea beginning in the Early Jurassic and rest on ocean-continent transitional or oceanic crust, or across the Jurassic and younger passive or strike-slip margins of the fragmented Pangea super-continent (Figs. 1C and 1D). Less extensive, and generally thinner Jurassic and(or) younger sedimentary successions rest on the margins of the circum-Arctic continents and shelves including the North Slope of Alaska, the Sverdrup Basin of northwest Canada, the Barents and Kara shelves, and northeastern Russia.

Stages in the creation of the Arctic Basin by the fragmentation of Pangea beginning in the Early Jurassic is shown in Figures 1C and 1D. Figure 1C shows the Arctic Basin during the early Aptian, about 120 Ma, following creation of the Amerasia Basin by two stages of extension during the Jurassic and Early Cretaceous. Stage 1 extension created ocean-continental transitional crust by the stretching of continental crust during the Jurassic and possibly the early Early Cretaceous. Stage 2 extension created mid-ocean ridge basalt (MORB) in the center of the Amerasia Basin by seafloor spreading during the Hauterivian and Barremian (about 136 to 125 Ma) (see Timescale, Plate 2). Figure 1D shows the configuration of the present-day Arctic Basin after the creation of the Eurasia Basin by seafloor spreading along Gakkel Ridge between the late Paleocene, about 58 Ma, and the present. As a result of its late Phanerozoic tectonic history, the many types of sedimentary successions associated with late Mesozoic and Cenozoic convergence of oceanic crust with continental margins at subduction zones in other regions (e.g. Busby and Ingersoll, 1995, Bally and Snelson, 1980)

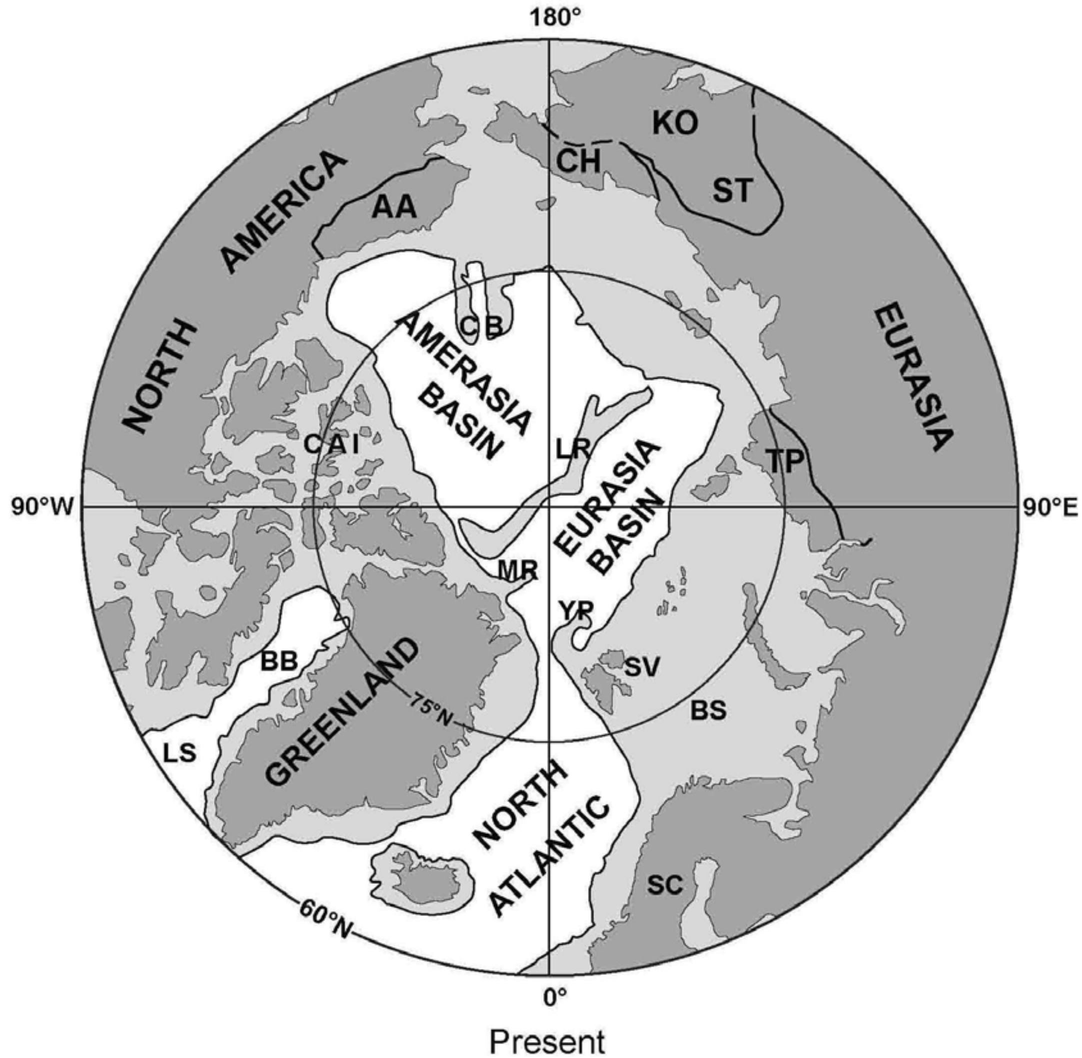


Figure 1D. Map showing the configuration of the continents and ocean basins of the present-day Arctic Region and location of the ridges in the Arctic Ocean (CB, LR, MR and YP) that consist of continental crust. The Amerasia Basin was created by rotational rifting within Pangea during the Jurassic and early early Cretaceous and the Eurasia Basin by rifting of the northern margin of Eurasia beginning in the late Paleocene. As shown on Plate 1, the extension created both thinned continental (transitional) and oceanic (MORB) crust. With the exception of the Anadyr Fore-arc Basin, which formed in the northern part of the Pacific Rim from the late Early Cretaceous through the Cenozoic, none of the existing oceanic basins or sedimentary successions in the Arctic Region formed at convergent continental margins.

are largely absent in the Arctic Region. The one exception is the Anadyr Fore-arc Basin of the Pacific Rim at 64° N, 180°E/W. Consequently, most of the sedimentary successions that we have identified in the Arctic Region (70.0

percent) rest on continental crust (supra-continental in Figure 2A), 17.5 percent lie across the passive or strike-slip margins of existing ocean basins and 12.6 percent lie in modern ocean basins. The two extinct passive margin sedimentary successions identified in the East Siberian Quadrant (Eastern South Taimyr Fold Belt and Western Zone of Verkhoyansk Fold Belt) were tectonically incorporated into Eurasia but are grouped with the sedimentary successions that occur in continental margins in Figure 2A.

Features displayed on the map

Sedimentary successions.

The primary features of the Arctic Region displayed on the accompanying map are first-order, unconformity-bounded stratigraphic sequences (sedimentary successions) that lie at or near the land surface of continents or the seafloor, or across continental margins. Most of the sequences fill morphologic basins, but some are primarily tabular sedimentary bodies deposited on continental shelves or platforms or seaward-dipping sedimentary prisms that prograded basinward across modern or ancient continental margins. Each succession was assigned to one of thirteen tectonic/morphologic classes on the basis of its geologic character, and morphology. Each class is designated by a characteristic color in the Explanation and the sedimentary successions are colored accordingly on the map and in the Synoptic Boxes that are related, by a leader or numeral, to each sedimentary succession shown on the map. The Synoptic Boxes (see Explanation, Plate 2), present minimal summaries of the stratigraphic content of each of the sedimentary successions shown on the map.

Many of the sedimentary successions are underlain by one or more older successions that are separated from them by first-order unconformities or hiatuses that mark one or more tectonic events or the passage of significant intervals of geologic time. Some of these older successions are exposed at the surface beyond the limits of the overlying near-surface successions, but others are known only in the subsurface. Where adequate subsurface or seismic data are available, the areal extent of the highest sedimentary successions that directly underlie the near-surface successions are shown on the map by stripes of the color that represent their tectonic/morphologic character. We did not attempt to map the areal extent of yet deeper successions, which are known to occur in many areas, but the presence, age and tectonic/morphologic character of these deeper successions are summarized by one or more layers of inclined stripes in the Synoptic Box that accompanies each near-surface sedimentary succession on the map (see Explanation, Plate 2).

Synoptic Boxes

A summary of the first-order stratigraphy of each sedimentary succession shown on the map, and of all successions known to underlie the mapped successions down to economic basement, is presented in a 'Synoptic Box' (see Explanation, Plate 2) that is tied to each succession by a leader or numeral. The "Synoptic Boxes" are highly condensed stratigraphic columns that show the age and tectonic character of the near-surface sedimentary succession to which it is tied, the age and character of all known underlying sedimentary successions and the age and character of economic basement. The near surface or selected deeper sedimentary successions represented by Synoptic Boxes on the map are outlined by red lines in each box. A key to the symbols that designate the age of the stratigraphic units in the Synoptic Boxes is presented in the Time Scale, Plate 2. Each underlying sedimentary succession in the Synoptic Box is indicated by a striped pattern of the color that represents its tectonic/morphologic character. Where the lateral extent of the highest underlying succession is known, it is represented in the Synoptic Boxes by vertical stripes of its representative tectonic color, and stripes of the same color show its known areal extent on the map.

Where the lateral extent of the highest underlying unit is unknown, it is represented in the Synoptic Boxes by diagonal stripes of its characteristic color, as are any deeper successions known to be present. The areal extents of sedimentary successions represented by diagonal colored stripes in the Synoptic Boxes are not shown on the map. All of the sedimentary successions shown in the Synoptic Boxes are separated by known or inferred significant unconformities or hiatuses, and the base of the prospective sedimentary section in each Synoptic Box is indicated by a double black line. Significant secondary unconformities are shown by backward slashes within the string of letters and numerals that represent the chrono-stratigraphic content of each sedimentary succession depicted in the Synoptic Boxes. Below the double line the age and general character of the upper part of economic basement are presented and, where appropriate, the name of the last compressional orogeny known to have deformed the basement.

The Synoptic Boxes allow map users to ascertain at a glance the general character and age of each of the near-surface sedimentary successions displayed on the map, the character and age of any underlying sedimentary successions that may be present and what is known about the age, character and deformation of economic basement. They also permit rapid comparisons to be made between the first order character and age of all of the 143 sedimentary successions of the Arctic Region, and their economic basement, shown on the map.

Isopachs

The partial or total thicknesses of many of the mapped near-surface sedimentary successions, plus all or part of the underlying successions down to economic basement, are shown on the map by colored isopachs. The stratigraphic interval represented by the isopachs within each mapped sedimentary succession is enclosed by an ellipse or irregular outline in the associated Synoptic Box that is the same color as the corresponding isopachs on the map. For successions in ocean basins where ellipses enclose the entire sedimentary section, the isopachs record the total thickness of the sedimentary section between the sea floor and economic basement. In some continental areas the total thickness and configuration of prospective sediment down to economic basement was approximated from structural contours, which indicate the depth of economic basement relative to a designated datum, commonly sea level. Isopachs approximated from structural contours in such areas may therefore omit the thickness of the sediment that lies between sea level and the land surface. Where sedimentary basins underlie low-lying areas with gentle topographic relief, as is commonly the case, structural contours provide a useful approximation of the total thickness of the sediment in a basin. In other areas, the thickness of sediment between sea level and the land surface would have to be added to the structural contours to obtain a close correspondence to the total sedimentary section that is present. These structural contours were used as proxies for isopachs because the adjustments required to convert them to true isopachs were relatively small and exceeded the requirements of the present study.

Faults, deformation fronts and structural transitions

Faults, deformation fronts and structural transitions, all shown by ornamented red lines, locally bound or crosscut the sedimentary successions shown on the map (see Explanation, Plate 2). Faults are ornamented by conventional symbols, but the deformation fronts and structural transitions are ornamented with specialized symbols to delineate those parts of locally deformed or altered sedimentary successions thought to be prospective for hydrocarbons (see Explanation, Plate 2). Deformation fronts, red lines ornamented with open (unfilled) rectangles, mark the boundaries between areas of sedimentary successions that lack, and those that contain contractional structures that might affect hydrocarbon prospectivity. Deformational boundaries, red lines ornamented with partially filled rectangles, separate areas with numerous thrust faults and associated folds from areas of folded strata with relatively few faults. Structural fronts, red lines ornamented with solid (filled) rectangles, separate undeformed to moderately deformed sedimentary successions that may retain hydrocarbon prospectivity from parts of the same successions thought to have been deformed or altered to a degree that makes it unlikely they retain economic hydrocarbon deposits. Only those parts of sedimentary successions thought to retain prospectivity are colored on the map. The strongly deformed or metamorphosed areas on the opposite sides of the structural fronts were not colored.

Time Scale

A single set of symbols consisting of combinations of letters and numerals indicate both the rock-stratigraphic position and the time-stratigraphic age of the sedimentary sequences, rock suites and structural or tectonic features shown in the Synoptic Boxes and on the map (see Time Scale, Plate 2). The symbols thus designate the age (Era, Period or Epoch) of structural or tectonic events and/or the stratigraphic position (Erathem, System or Series) of rock units or stratigraphic sequences. These terms are virtually synonymous and the context indicates unambiguously whether a specific symbol indicates age or stratigraphic position. Use of separate sets of symbols to distinguish between time-stratigraphic and rock-stratigraphic terminology in the Synoptic Boxes and map would provide no additional information than is conveyed by the single set of symbols adopted for this report. The Time Scale on Plate 2 is adapted from Gradstein et al. (2004 a and b).

In both the Synoptic Boxes and on the map a lower case "e" at the end of a time symbol of any rank indicates that the symbol (e.g., J2e) represents only the early/lower part of the defined time range/stratigraphic interval. A lower case “m” or “l” at the end of a symbol indicates that it represents only the middle part or the late/upper part of the defined time range/stratigraphic interval, respectively.

Sedimentary successions of the Arctic Region

Each of the 143 sedimentary successions of the Arctic Region identified in this study were assigned to one of the thirteen tectonic/morphologic classes presented in the Explanation (Plate 2) and in the Tables that appear in the margins of each map quadrant. Each class is represented by a characteristic color on the map and in the Synoptic Box that accompanies each sedimentary succession on the map. Nine of the thirteen classes (see Plate 2 and the Tables in the map margins) were originally deposited on continental crust, three across continental margins, and one within ocean basins underlain by mid-ocean ridge basalt (MORB) or ocean-continent transitional crust.

Selection criteria

Simple screens that could be applied more or less objectively in a region with unevenly distributed, and commonly sparse geologic knowledge were used to identify sedimentary successions in the Arctic Region that might be prospective for hydrocarbons. The first screen, the presence of oil or gas in natural seeps or as shows or accumulations in exploratory wells, indicates that at least 44 (30.8 percent) of the 143 sedimentary successions displayed on the map contain hydrocarbons that were either generated internally or expelled from other successions (Fig. 2C).

The second screen examined whether a sedimentary succession is sufficiently thick to have reached the temperature necessary to generate oil in at least its deeper beds. The top of the oil lies at depths corresponding to vitrinite with a reflectance value of Ro 0.6 percent (Bird et al. 1999, Fig. VR1; Johnsson et al., 1999). These reflectance values correspond to temperatures of 80° to 90° C in sedimentary basins older than 30 m.y. (mid-Oligocene) (Sweeney and Burnham, 1990). The depth at which 80°-90°C is reached in a sedimentary section can be roughly gauged from its geothermal gradient, but in the absence of specific geothermal data we had to estimate the expected depth of the 80°-90°C geotherm and the top of the oil window for most of the sedimentary successions in the Arctic Region from average geothermal gradients. The worldwide average geothermal gradient is approximately 24° C/km (Allaby and Allaby, 1999) or 25°C/km (Neuendorf et al., 2005) and on continental areas unaffected by young tectonics or volcanic activity the gradient ranges from 20° to 40° C/km (ibid.). If the worldwide average gradient of about 25°C/km is used, the top of the oil window in mid-Oligocene and older sedimentary successions lies at a depth of about 3.4 km; if the median continental gradient of 30°C/km is used it lies at a depth of about 2.8 km below the surface. In the absence of specific geothermal data we used a near minimal value of 3.0 km as the thickness of sediment required for at least the deepest beds of a sedimentary succession to extend downward into the oil window. The choice of 3.0 km as the minimum thickness of sediment required for thermogenic petroleum in a sedimentary basin is supported by the observation that all of the world's 100 largest oil accumulations lie at depths greater than 3 km (U.S. Geological Survey World Energy Assessment Team, 2000). We therefore assumed that all sedimentary successions in the Arctic Region containing >3 km of sediment could be petroliferous if adequate quantities of gas- and/or oil-prone kerogen were present in at least their deeper beds

Geophysical or subsurface data indicate that 64 (almost 45 percent) of the sedimentary successions of the Arctic lack direct evidence for the presence of hydrocarbons but are underlain by >3 km of sedimentary strata. They may, therefore have attained temperatures sufficiently high to have generated hydrocarbons in their deeper beds. These successions, together with the 44 that are known to contain at least some oil or gas, constitute 77.6 percent of the sedimentary successions identified in the Arctic Region. The Synoptic Boxes related to these successions are outlined by solid borders on the map. The remaining 35 successions (about 24.5 percent of the total) appear to be no more than about 3 km thick and are therefore considered unlikely to be prospective for hydrocarbons. The borders of the Synoptic Boxes associated with these 35 successions are bordered with dashed lines on the map. They are shown on the map because they might be thicker than suggested by the available data and because their thermal history and the character and abundance of kerogen that they may contain could be atypically favorable for the generation of hydrocarbons. A few smaller sedimentary successions of limited extent (less than ~5,000 km^2 in area) are also shown on the map, but are considered to be too small or too thin to be prospective for hydrocarbons and have not been supplied with Synoptic Boxes.

The third screen attempted to identify sedimentary successions that were subjected to deformation or alteration that would have dispersed or destroyed any oil or natural gas accumulations that might have been created within them, or which seeped into them from other successions. This screen rejected sedimentary successions, or sub-areas of successions having complex structure (such as isoclinal folding or imbricate thrust faults) or moderate to severe thermal alteration (top of zeolite facies, about 200°C or higher) that might have dispersed or destroyed pre-existing oil or gas successions. The boundaries between the undeformed or moderately deformed parts of sedimentary successions and those parts that were strongly deformed or altered are depicted on the map by structural fronts—red lines ornamented with filled (solid color) rectangles (see Explanation, Plate 2). The strongly deformed or altered parts of sedimentary successions that lie outboard of these lines are thought to lack prospectivity for hydrocarbons and therefore remain uncolored on the map.

A fourth screen identified sedimentary successions that are too deeply and extensively breached and (or) thinned by erosion to contain oil or gas accumulations in even their deepest beds. This screen commonly acted to reduce the perceived prospectivity of a sedimentary succession from hydrocarbon accumulations “May occur” to hydrocarbon accumulations “Unlikely to occur” (See Figure 2C).

Stratigraphic character was not used as a formal screen for evaluating the character or prospectivity of the sedimentary successions because many of them are known only from bathymetric or commonly sparse or irregularly distributed geophysical data. Where subsurface or outcrop data were available, however, stratigraphy was a primary consideration in establishing the tectono-morphologic classification, and evaluating the hydrocarbon prospectivity, of the sedimentary successions.

Sedimentary successions deposited on continents

Nine of the thirteen tectonic/morphologic classes of sedimentary successions identified in the Arctic Region, representing 70.0 percent of the total, were deposited on continents (Fig. 2A). These successions, 100 in number,

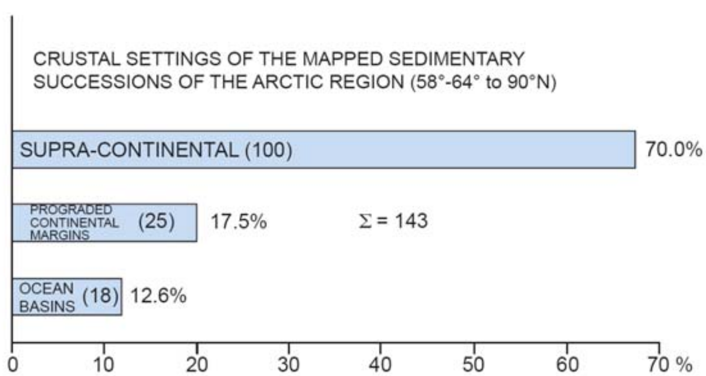
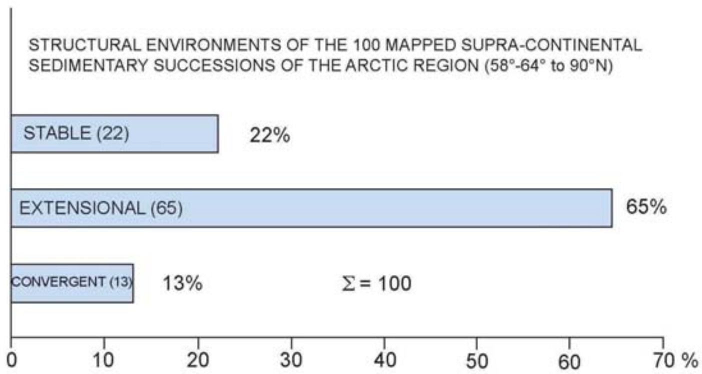


Figure 2A. Crustal settings of the 143 sedimentary successions of the Arctic Region that contain, or which may be prospective for hydrocarbon deposits.

overlie Eurasia, North America and Greenland, which encircle the Arctic Ocean basin and occur on the Lomonosov Ridge, Northwind Ridge, Chukchi Plateau and Yermak Plateau micro-continents, which lie within the Arctic Ocean, and on Jan Mayen Land, which lies in the North Atlantic. The structural environments of the 100 supra-continental sedimentary successions of the Arctic Region are summarized in Figure 2B. Twenty two percent of these formed in tectonically stable (cratonic) environments, 65 percent in extensional environments and 13 percent in convergent environments. Representatives of one of the classes, "Prograded sedimentary succession across passive margin of an extinct ocean basin" (dark yellow on the map) have been tectonically incorporated into the Siberian craton. They are grouped with prograded continental margin successions in Figure 2A and excluded from the tabulation of the structural environments of the supra-continental sedimentary successions in Figure 2B.

Sedimentary successions in stable (cratonic) structural environments. Two of the nine supra-continental tectonic/morphologic classes were formed in stable structural environments but placed in separate tectonic/morphologic classes. The "Coastal plain and marine shelf" successions are younger, thinner and less continuous than the "Stable shelf and platform" successions, and unlike them lack carbonate deposits. The "Coastal plain and marine shelf" successions were grouped separately because they appear to lack significant hydrocarbon potential, whereas several of the "Stable shelf and platform" successions, which are older and deposited at lower latitudes, are known to contain hydrocarbon deposits.

Sedimentary successions in extensional structural environments. Five classes among the 100 supra-continental sedimentary successions mapped in the Arctic Region (Fig. 2B) were deposited in extensional environments and 32 percent of these successions were deposited in "Basins created by multiple rift and thermo-isostatic (sag) events" (colored purple on the map). The deformation that formed the rifts and sags thinned, but did not sever, the underlying continental crust. Post-orogenic collapse and extension in the areas of the Timanide (Vendian to Middle Cambrian) and Uralian (Late Devonian to Early Carboniferous) orogens created multiple supra-continental rift and sag basins in which thick, extensive and economically important sedimentary successions were deposited in Northwestern Russia and the Barents shelf. Extension in these areas stopped short of crustal rupture and the creation of new oceanic crust, but the nature of basement beneath the South Barents basin is uncertain because it is overlain by about 20 km of sediment. In addition, a number of large extensional basins in the old Siberian Craton are related to Neoproterozoic (Riphean) aulacogens.



Accumulations formed in stable environments [22 percent]
Stable shelves and platforms [17%]
Coastal plains and marine shelves [5%]
Accumulations formed in extensional environments [65 percent]
Basins created by multiple rift and thermo-isostatic (sag) events [32%]
Transtensional rift basins [8%]
Extensional basins on continental crust at the lateral margins of ocean basins containing MORB [18%]
Extensional basins on continental crust on strike with ocean basins containing MORB [4%]
Extensional basins of undetermined origin [3%]
Accumulations formed in convergent environments [13 percent]
Foreland basins [12%]
Fore-arc basins [1%]

Figure 2B. Structural environments of the 100 supra-continental sedimentary successions of the Arctic Region that may be prospective for hydrocarbons.

In northwestern North America, Northern Greenland, Svalbard, the western Barents Shelf and Norway deposits of the Early Paleozoic Iapetus Ocean, which were deformed during the Scandian (Silurian) and Svalbardian (Late Devonian) phases of the Caledonian orogeny, are overlain by Devonian, Carboniferous and younger stable shelf and platform successions and large supra-continental rift and sag basins. In Northern Alaska the Iapetus-equivalent deposits were deformed during the latest Silurian and/or Early Devonian (Moore et al., 1994 and 2007), which in general correlates with the Scandian phase of the Caledonian orogeny. In Northwest Canada, however, Caledonian-age deformation did not occur until the latest Devonian and earliest Early Carboniferous Ellesmerian orogeny (Trettin, 1991), which correlates with the Svalbardian phase of the Caledonian orogeny. These correlations suggest (Moore et al., 2007) that the Caledonian orogeny of northwest Europe extended into northern North America.

In Scandinavia and the western Barents shelf the Iapetus deposits, which were deformed during the Scandian phase of the Caledonian orogeny, are overlain by coarse post-orogenic clastic deposits of Devonian and Early Carboniferous age in supra-continental rift and sag basins and by stable shelf and platform deposits of Pennsylvanian to Early Cretaceous age. To the east, beneath the Kara Sea and West Siberian Lowland, economic basement consists of an accretionary collage that was assembled during the Late Devonian and Carboniferous closure of the Uralian Ocean (the Uralian orogeny) and includes part of the Kazakhstan Micro-continent. This collage is basement for the latest Permian or Triassic to Paleogene sedimentary successions of the hydrocarbon-rich South Kara and West Siberian basins. Beneath the southeastern Barents Sea and adjacent Northern Russia, the Ordovician to Cretaceous beds of the Timan-Pechora and South Barents sedimentary successions rest on passive margin and volcanic arc complexes deformed during the Vendian/Ediacaran (latest Neoproterozoic) to Middle Cambrian Timanide orogeny.

Eight of the supra-continental sedimentary successions of the Arctic Region were deposited in “Transtensional rift basins” (colored pink) that overlie splaying terminations or bends in transcurrent fault systems that created significant components of extensional displacement (Fig. 2B). These basins comprise 8 percent of the supra-continental sedimentary successions of the Arctic Region. Examples include the Hope, Norton and Yukon Flats Basins on the Alaska quadrant of the map.

Twenty two (22 percent) of the supra-continental sedimentary successions of the Arctic Region were created by two classes of pre-breakup or syn- to early post-breakup extension in continental crust adjacent to ocean basins. These classes are related to the opening of the adjacent new ocean basins, which are at least partly underlain by mid-ocean ridge basalt (MORB) (see Fig. 2B). One class, consisting of “Extensional basins on continental crust at the lateral margins of ocean basins containing MORB” (colored olive) constitutes 18 percent of the supra-continental sedimentary successions in the Arctic Region. Examples include the Dinkum Graben of the Alaskan continental margin, the riftogenic basins at the margins of Baffin Bay and the riftogenic basins that flank the North Atlantic Ocean (Thetis and Voring Basins of the Greenland and Norwegian margins). The second class of sedimentary successions associated with the opening of ocean basins consists of “Extensional basins on continental crust on strike with ocean basins containing MORB” (color medium green). The four examples of this class that have been recognized constitute 4 percent of the supra-continental successions mapped in the Arctic Region. All of them underlie the Laptev Shelf and occupy grabens and half-grabens that are coeval with, and along the strike of the spreading axis of the late Paloecene to Recent Eurasian Basin.

Successions in convergent structural environments. The third group of supra-continental sedimentary successions in the Arctic Region (Fig. 2B) consists of two tectonic/morphologic classes that are the products of tectonic convergence. They constitute 13 percent of the supra-continental sedimentary successions of the Arctic Region. Twelve are "Foreland basins" (colored medium blue on the map), which are the product of crustal loading by flexural loading, overthrusting and foreland sedimentation created by intra-continental convergence. A prime example is the Colville Foreland Basin of Arctic Alaska. In contrast the Anadyr Fore-arc basin (colored reddish-brown on the map) formed in the arc-trench gap at the convergent Pacific Rim near 180° W. It is the only sedimentary succession that we have recognized in the Arctic Region that formed at a convergent (active) continental margin.

Sedimentary successions across passive continental margins

Twenty five (17.5 percent) of the sedimentary successions in the Arctic Region were prograded across continental margins (Fig. 2A). Eighteen of these (12.6 percent of the 143 sedimentary successions identified in the Arctic Region) were prograded across rifted passive margins (color light yellow). Successions of this class overlie the margins all of the circum-Arctic continents. Five of these (3.5 percent of the total) were prograded across margins created by strike-slip displacement (color orange). Only two sedimentary successions belong to the third class, successions prograded across the margins of extinct ocean basins (color dark yellow). Both have been tectonically incorporated into the Eurasian continent and it is unlikely that either of these basins remain attached to the oceanic crust upon which they were in part deposited. They retain their original depositional character, however, and are grouped with the prograded continental margin successions, rather than with the supra-continental successions, in Figure 2A. They constitute only 1.4 percent of the 143 sedimentary successions that we mapped in the Arctic Region.

Sedimentary successions on oceanic crust

Eighteen (12.6 percent) of the sedimentary successions mapped in the Arctic Region are "Ocean basin" deposits (Fig. 2A), and are colored light green on the map. They rest on both mid-ocean ridge basalt (MORB) produced by sea floor spreading and, in some basins, on flanking belts of ocean-continent transitional crust produced by strong extension and thinning of continental crust during the initial stages of ocean basin development. In the Canada Basin, Labrador Sea and Baffin Bay the areas underlain by these distinctive types of ocean crust are mapped separately from the basins underlain by MORB because the transitional crust, which is older than the MORB crust, is commonly overlain by sedimentary section that is absent from the areas underlain by MORB. The approximate age of the additional section, which attains thicknesses of one km or more in parts of the Canada Basin and as much as 2-3 km in the Saglek Basin, is shown in the Synoptic Boxes associated with the oceanic sedimentary successions that overlie transitional crust.

The location and age of the sedimentary successions that rest on MORB were determined principally from maps that show the sea floor magnetic lineations of the Arctic and North Atlantic Oceans. For areas as far North as 72° N, the lineations were taken principally from Cande et al. (1989) and L.M. Gahagan, University of Texas (personal communication, 2007). For the Arctic Ocean the lineations were taken from Roest et al., 1996 and J.M. Brozena, U.S. Naval Research Laboratory (personal communication, 2002). For the Eurasia Basin the lineations are from Kristoffersen (1990) and Brozena et al. (2003). For each of these sources the ages of the magnetic lineations were modified, as required, to conform to the geologic time scale of Gradstein et al. (2004a and b).

Treatment of the Lena and Mackenzie delta systems

The Lena and the Mackenzie, Earth's ninth and nineteenth largest rivers as estimated from present-day river-mouth discharge (Dai and Trenberth, 2002), flow into the southern Eurasia and Amerasia Basins. Both created major delta systems that extend from their mouths to the farthest reaches of their associated abyssal plains. In the Amerasia Basin the relatively thin sediments of the delta plain and delta front of the Mackenzie Delta system are included in the "Beaufort-Mackenzie Basin "of the southeastern Canada Basin, but the thicker and morphologically and sedimentologically distinct deposits of the 'Mackenzie Prodelta' and the deep abyssal plain deposits of the distal part of the delta system are mapped separately as subbasins of the Canada Basin. In the Eurasia Basin the relatively thin delta plain deposits of the Lena Delta system are mapped with the West Lena, Ust'Lena and East Lena rifted-related sedimentary successions of the Laptev Shelf but the delta front is included in the 'Lena Prograded Margin' sedimentary succession. The thick 'Lena Prodelta' deposits and the deep abyssal plain deposits of the distal part of the Lena delta system are mapped as separate sedimentary successions in the oceanic Eurasia Basin. Because the Gakkel mid-ocean ridge longitudinally bisects the Eurasia Basin the abyssal plain deposits of the Lena Delta system are split between the Nansen and Amundsen sedimentary successions of the Eurasia Basin that lie, respectively, south and north of Gakkel Ridge. In aggregate these sedimentary successions show the full extent and morphology of both the Mackenzie and Lena Delta Systems, which constitute most of the sedimentary fill in the Canada and Eurasia Basins.

Summary and conclusions

This study identified 143 unconformity-bounded sedimentary successions in the Arctic Region between 58°-64°N and the North Pole. The location, extent and structural setting of these successions and their subdivisions are shown on Plate 1 at a scale of 1:6,760,000 . Tables summarizing the location, classification and apparent hydrocarbon prospectivity of the sedimentary successions on each map quadrant are presented in the margins of the map adjacent to that quadrant.

The landlocked Arctic Ocean Basin was created in two stages. The first stage involved amalgamation of the paleocontinents of Laurentia, Siberia and Baltica to create Laurussia by closure of the Iapetus Ocean during the Silurian and Devonian followed by the amalgamation of Laurussia with Gondwana to close the Rheic Ocean during the Middle Devonian and Early Carboniferous. These collisions created the super-continent of Pangea by the Late Permian (Fig. 1B). The second stage consisted of crustal stretching and sea floor spreading beginning at the close of the Triassic, about 200 Ma, that sundered Pangea and created the Arctic and North Atlantic Oceans and the approximate configuration of the present-day Arctic continents in stages during the Jurassic, Cretaceous (Fig. 1C) and the Cenozoic (Fig. 1D). Because of this history of massive continental accretion and subsequent more limited dispersion, 70.0 percent of the sedimentary successions of the Arctic Region rest on (or have been tectonically incorporated into) continental crust, 17.5 percent overlie the margins of the post-Pangea continents or micro-continents, and only 12.6 percent rest on oceanic crust (Fig. 2A). Only one of the 143 sedimentary successions, the Anadyr Fore-arc basin of the Pacific Rim in Northeastern-most Russia, was deposited at a convergent (active) continental margin. Two of the supra-continental successions were deposited across the passive margins of extinct ocean basins that were subsequently tectonically incorporated into the Eurasian continent.

One hundred eight (76 percent) of the 143 sedimentary successions in the Arctic Region developed in extensional environments. These include 65 of the supra-continental sedimentary successions (Fig. 2B), 18 that were deposited in ocean basins and 25 that were prograded across passive or strike-slip continental margins (Fig. 2A). In contrast only 22 (about 15 percent) were deposited on stable platforms or shelves and 13 (9 percent), mostly foreland basins, in convergent environments.

Oil or gas in natural seeps, or in shows or accumulations in test wells, indicate that at least 30.8 percent of the 143 sedimentary successions of the Arctic

Region contain indigenous hydrocarbons, or hydrocarbons expelled from other successions (Fig. 2C). Another 44.8 percent are known to be

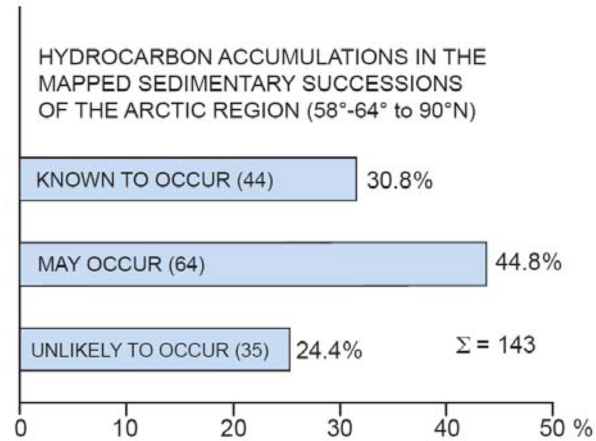


Figure 2C. Relative hydrocarbon prospectivity of the 143 sedimentary successions of the Arctic Region identified in the present study. The successions "Known to contain hydrocarbons" contain oil or gas in natural seeps, or as shows or deposits in test wells, and therefore have either generated hydrocarbons or contain hydrocarbons expelled from other sedimentary successions. The successions that "May contain hydrocarbons" are more than 3 km thick and may be sufficiently thick to have generated hydrocarbons, but direct evidence is lacking. The successions that are "Unlikely to contain hydrocarbons" are no more than about 3 km thick but the available data do not preclude the possibility that some of them may have generated hydrocarbons, or received them by migration from other successions.

at least 3 km thick and could have generated hydrocarbons if suitable varieties and quantities of kerogen occur in at least their deeper beds. The sedimentary successions known to contain indigenous hydrocarbons, or hydrocarbons that were expelled from other successions, together with those that are more than about 3 km thick and therefore may have generated hydrocarbons, constitute 75.6 percent of the mapped sedimentary successions of the Arctic Region. The Synoptic Boxes for these successions are encased with solid outlines on the map. The remaining 24.4 percent of the successions may be no more than about 3 km thick and are therefore unlikely to be prospective for hydrocarbon deposits. We include them, however, because in the absence of firm data on their thickness, the thermal state of their deeper beds and the character of kerogen that their deeper beds may contain, it is at least possible that some of these successions may have generated hydrocarbons. They are identified on the map by Synoptic Boxes with dashed outlines.

Our map and tables indicate that there are significant variations in the occurrence of hydrocarbons among the thirteen classes of tectono-stratigraphic/morphologic sedimentary successions of the Arctic Region that are mapped on Plate 1. Tables in the margins of the plate show that of the forty-one supra-continental sedimentary successions of the Arctic Region reported to contain hydrocarbons in seeps, or in shows or accumulations in test wells, seven (17 percent) occur on stable shelves or platforms, twenty (62.5 percent) in compound rift and sag basins, seven (17percent) in extensional basins marginal to oceanic basins and a combined total of seven (17 percent) in foreland and fore-arc basins. In contrast, none of the remaining four types of supra-continental sedimentary successions (coastal plain and shelf, transtensional basin, extensional basin on strike with oceanic basins containing MORB, and extensional basin of uncertain origin) are reported to contain hydrocarbons. While data are inadequate to evaluate the prospectivity of the tectono-stratigraphic/morphologic sedimentary successions in most of the Arctic Ocean Basin it is significant that three (17 percent) of the eighteen prograded margins of the Arctic Basin that overlie rifts contain hydrocarbons. It may be premature, however, to attach negative connotations to the absence of reports of hydrocarbons in the five prograded margins of the Arctic Ocean Basin that overlie strike slip-fault zones or to the absence of such reports concerning the oceanic basins of the Arctic Ocean.

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Illustrations

Figure 1. Synopsis of the amalgamation and dispersal of the continents of the Arctic Region from the Ordovician to the present, generalized and modified from Lawver et al. (2002). Dark gray areas represent the reconstructed positions of modern continents and islands during the Late Ordovician to Early Silurian (Fig. 1A), the Early Permian (Sakmarian) (Fig. 1B), the mid-Early Cretaceous (Aptian) (Fig. 1C.) and the present (Fig. 1D). Light gray areas are the inferred positions of continental shelves. The dark gray areas in Figure 1D show the position of the modern continents and the light gray areas the modern continental terraces. Unshaded areas represent mainly ocean basins but in places they contain narrow continental terraces surrounding the continents. AA-Arctic Alaska, AFR-Africa, AS-Angayucham Sea, BB-Baffin Bay, BS-Barents Shelf, CAI-Canadian Arctic Islands, CB-Chukchi Continental Borderland, CH-Chukotka, IB-Iberia, KS-Kara Shelf, LR-Lomonosov Ridge, LS-Labrador Sea, MR-Morris Jesup Rise, NOAM-North America, OM-Omolon Massif, SC-Scandinavia, SV-Svalbard, TP-Taimyr Peninsula, YP-Yermak Plateau. Alphanumeric symbols, e.g. D2-C1, indicate geologic age as shown in Time Scale, Plate 2.

1A. Palaeogeography of the present Arctic Region during the Late Ordovician (450 Ma) to Early Silurian (435 Ma) showing 1.) the position of the Iapetus Ocean between Laurentia and Siberia-Baltica prior to the amalgamation of Laurussia by the closure of Iapetus during the Caledonian orogeny and 2.) the position of the Rheic Ocean between Laurentia and Gondwana prior to the amalgamation of Pangea by closure of the Rheic Ocean during the Late Devonian and Early Carboniferous. The convergence that closed Iapetus produced the Caledonides in Scandinavia, northeastern Greenland and Svalbard during the late Early Silurian to Late Devonian and the Ellesmerides in the Canadian Arctic

Islands and North Greenland during the Late Devonian and early Early Carboniferous.

1B. Palaeogeography of the present Arctic Region after closure of the Rheic Ocean created the super-continent of Pangea by the amalgamation of Gondwana and Laurussia during the Kasimovian (Late Pennsylvanian), about 305 Ma. All of the present-day continents and micro-continents of the Arctic Region (58°-64° to 90°N) were once part of Pangea.

1C. Paleogeography of the present Arctic Region after the final amalgamation of Pangea at the end of the Triassic and opening of the Amerasia Basin by two stages of rotational rifting within Pangea during the Jurassic and early Early Cretaceous. Rifing was accomplished by crustal thinning and extension and the creation of ocean-continent transitional crust during the Jurassic and possibly the early Early Cretaceous and by sea-floor spreading and the creation of MORB during the mid-Early Cretaceous. Rotation was about a pole in the lower Mackenzie Valley (indicated by a star) and along the right-lateral Amerasia Basin Transform Fault along the Amerasian margin of the Late Paleocene and younger Lomonosov Ridge (LR). The projection of the Amerasia Basin Transform Fault to the fault to the Pacific Rim has been tectonically overridden and its path is conjectural.

1D. Map showing the configuration of the continents and ocean basins of the present-day Arctic Region and location of the ridges in the Arctic Ocean (CB, LR, MR and YP) that consist of continental crust. The Amerasia Basin was created by rotational rifting within Pangea during the Jurassic and early early Cretaceous and the Eurasia Basin by rifting of the northern margin of Eurasia beginning in the late Paleocene. As shown on Plate 1, the extension created both thinned continental (transitional) and oceanic (MORB) crust. With the exception of the Anadyr Fore-arc Basin, which formed in the northern part of the Pacific Rim from the late Early Cretaceous through the Cenozoic, none of the existing oceanic basins or sedimentary successions in the Arctic Region formed at convergent continental margins.

Figure 2. Graphs summarizing the crustal setting, structural environment and hydrocarbon prospectivity of the 143 sedimentary successions of the Arctic Region (58°-64° to 90° N) identified in the present study.

2A. Crustal settings of the 143 sedimentary successions of the Arctic Region that contain, or which may be prospective for hydrocarbon deposits.

2B. Structural environments of the 100 supra-continental sedimentary successions of the Arctic Region that may be prospective for hydrocarbons.

2C. Relative hydrocarbon prospectivity of the 143 sedimentary successions of the Arctic Region identified in the present study. The successions "Known to contain hydrocarbons" contain oil or gas in natural seeps, or as shows or deposits in test wells, and therefore have either generated hydrocarbons or contain hydrocarbons expelled from other sedimentary successions. The successions that "May contain hydrocarbons" are more than 3 km thick and may be sufficiently thick to have generated hydrocarbons, but direct evidence is lacking. The successions that are "Unlikely to contain hydrocarbons" are no more than about 3 km thick but the available data do not preclude the possibility that some of them may have generated hydrocarbons, or received them by migration from other successions.

Plates

Plate 1. "Map showing the Sedimentary Successions of the Arctic Region (58°-64° to 90° N) that may be Prospective for Hydrocarbons", scale 1:6,760,000. Also shown are structural features associated with the creation of the sedimentary successions or with the enhancement or degradation of their hydrocarbon prospectivity. Map produced in GIS (Geographic Information Systems) format using ESRI® ArcGIS 9.1 software. Graphical elements for plot files in both Plates 1 and 2 produced with Adobe Illustrator CS3. See Plate 2 for Explanation and Time Scale.

2. Explanation and Time Scale for Plate 1, "Map showing the Sedimentary Successions of the Arctic Region (65°-90° N) that may be Prospective for Hydrocarbons."

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Appendix A. Data sources and references for published data used to compile the **Alaska and Arctic Canada Quadrant** of Plate 1.

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Appendix B. Data sources and references to published data used to compile the **East Siberia Quadrant** of Plate 1.

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