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Geology and Assessment of Undiscovered Oil and Gas Resources of the Yukon Flats Basin Province, 2008

Chapter F of
The 2008 Circum-Arctic Resource Appraisal

Professional Paper 1824

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

Cover. Northwestward view across the southern foothills of the Brooks Range along Akmagolik Creek, approximately 150 miles southwest of Prudhoe Bay, Alaska. Exposed rocks are part of the Mississippian–Pennsylvanian Lisburne Group and include a thrust-fault ramp at left. Photo includes two helicopters for scale, a blue-and-white one near the center and a red one at center-right at creek level. U.S. Geological Survey photograph by David Houseknecht.

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RYAN K. ZINKE, Secretary

U.S. Geological Survey
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Chapter F

Geology and Assessment of Undiscovered Oil and Gas Resources of the Yukon Flats Basin Province, 2008

By Kenneth J. Bird and Richard G. Stanley

Abstract

The hydrocarbon potential of the Yukon Flats Basin Province in Central Alaska was assessed in 2004 as part of an update to the National Oil and Gas Assessment. Three assessment units (AUs) were identified and assessed using a methodology somewhat different than that of the 2008 Circum-Arctic Resource Appraisal (CARA). An important difference in the methodology of the two assessments is that the 2004 assessment specified a minimum accumulation size of 0.5 million barrels of oil equivalent (MMBOE), whereas the 2008 CARA assessment specified a minimum size of 50 MMBOE. The 2004 assessment concluded that >95 percent of the estimated mean undiscovered oil and gas resources occur in a single AU, the Tertiary Sandstone AU. This is also the only AU of the three that extends north of the Arctic Circle.

For the CARA project, the number of oil and gas accumulations in the 2004 assessment of the Tertiary Sandstone AU was re-evaluated in terms of the >50-MMBOE minimum accumulation size. By this analysis, and assuming the resource to be evenly distributed across the AU, 0.23 oil fields and 1.20 gas fields larger than 50 MMBOE are expected in the part of the AU north of the Arctic Circle. The geology suggests, however, that the area north of the Arctic Circle has a lower potential for oil and gas accumulations than the area to the south where the sedimentary section is thicker, larger volumes of hydrocarbons may have been generated, and potential structural traps are probably more abundant. Because of the low potential implied for the area of the AU north of the Arctic Circle, the Yukon Flats Tertiary Sandstone AU was not quantitatively assessed for the 2008 CARA.

Introduction

The Yukon Flats Basin is located south of the Brooks Range in east-central Alaska, covering an area of ~36,000 km^2 (fig. 1). About one-third of the basin (~12,000 km^2) lies north of the Arctic Circle. When assessed by the USGS in 2004 as part of an update to the National Oil and Gas Assessment (see http://energy.usgs.gov/OilGas/AssessmentsData/NationalOilGasAssessment.aspx#.Vykg8GQrKWZ), three hypothetical assessment units (AUs) were identified and assessed using a somewhat different methodology than that of the Circum-Arctic Resource Appraisal (CARA). An important difference is that the 2008 CARA included specification of a minimum accumulation size of 50 million barrels of oil equivalent (MMBOE), while the 2004 assessment used a smaller minimum accumulation size, 0.5 MMBOE (Stanley and others, 2004). In that (2004) assessment, >95 percent of the mean undiscovered oil and gas resources were estimated to occur in a single AU, the Tertiary Sandstone AU. Because most of the resources were estimated to occur in that AU—the only one in the province that extends north of the Arctic Circle—we reviewed the Tertiary Sandstone AU as part of the 2008 assessment, for which the minimum technically recoverable accumulation size was set at 50 MMBOE.

Geologic Setting and Stratigraphy

The broad Yukon Flats lowland is inferred from seismic reflection, gravity, and magnetic surveys (Saltus and others, 2007) to be underlain by a sedimentary basin filled with as much as 8 km of Upper Cretaceous(?) and Cenozoic nonmarine sedimentary and volcanic rocks (figs. 1, 2). No deep exploratory wells have been drilled in the Yukon Flats region, and the character of the basin fill is inferred from studies of shallow coreholes (Barker and others, 2005) and outcrops in the basin and surrounding region (Dover, 1994; Kirschner, 1994; Patton and others, 1994; Till and others, 2006, 2008; Troutman and Stanley, 2003). The basin appears to be filled by Late Cretaceous(?) and Tertiary sedimentary strata that include sandstone, mudstone, shale, and coal of fluvial and lacustrine origin, as well as volcanic rocks that range in composition from basalt to rhyolite (Rowan and Stanley, 2008). The origin of the basin is uncertain; it may be a product of latest Cretaceous(?) and early Tertiary extension and right-lateral movement along the Tintina Fault System (Till and others, 2005) or mid-Paleocene to early Eocene crustal extension related to subduction of an oceanic spreading center (Bradley and others, 2003). Seismic reflection profiles from south of the

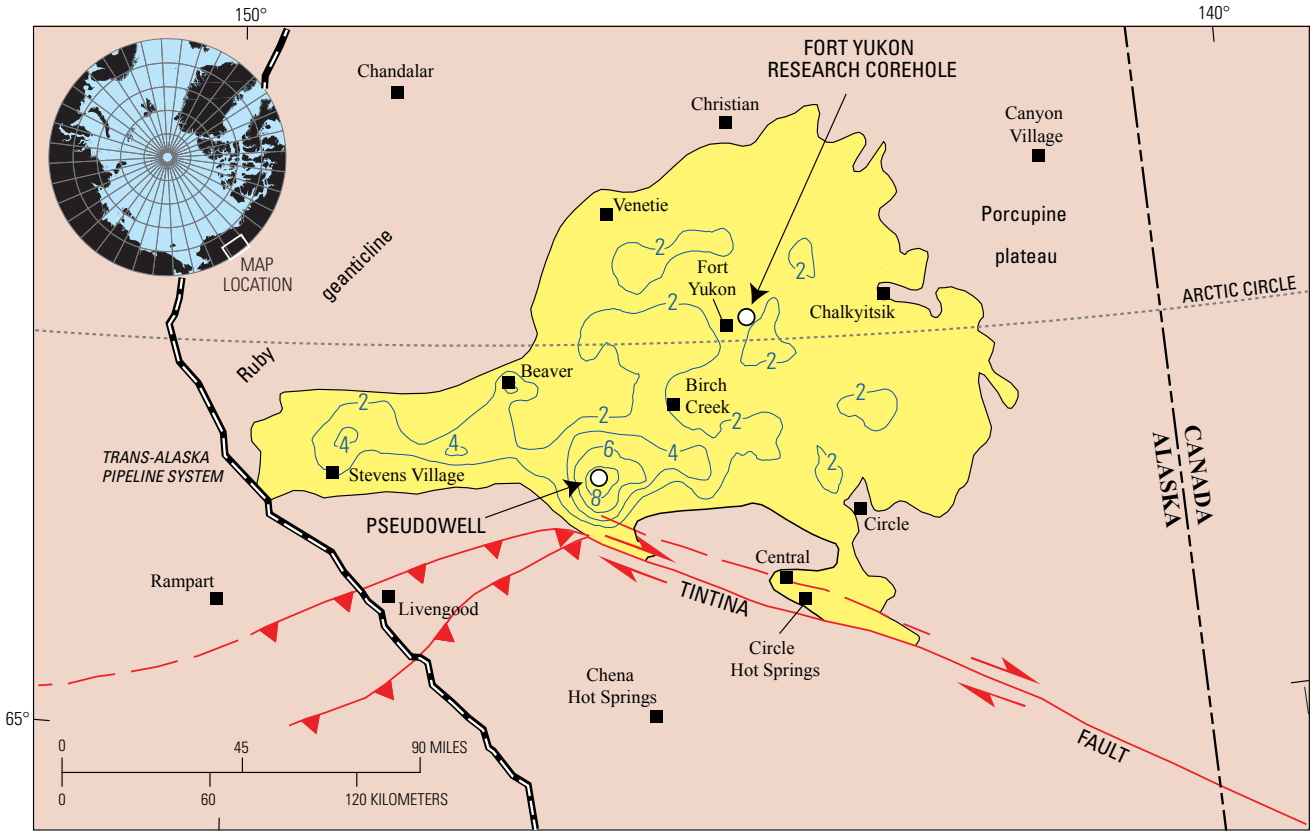

Figure 1. Map of Yukon Flats Basin (yellow area) in central Alaska showing interpreted depth to basement (blue contours), in thousands of meters, and location of 2,300-feet-deep (700 meters) Fort Yukon research well (fig. 2). Red lines are faults; sense of motion is indicated with arrows where known, and teeth are shown on overriding side of thrust faults. Adapted from Grantz and others (2010) and Rowan and Stanley (2008).

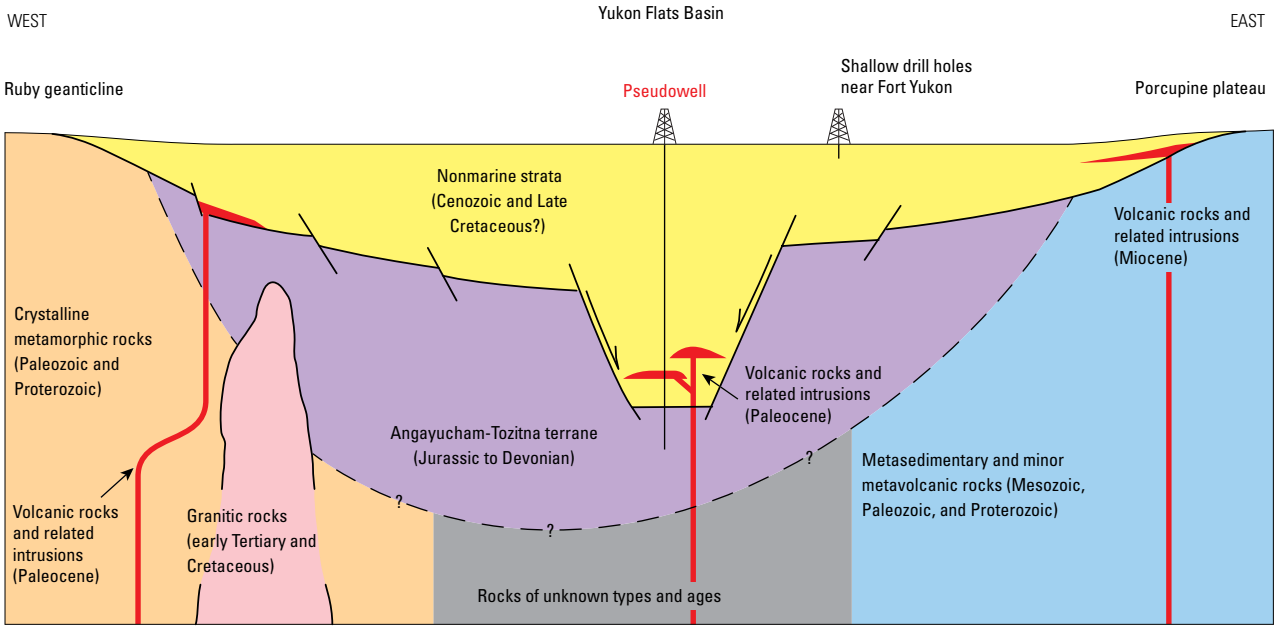

Figure 2. Schematic cross section of Yukon Flats Basin, as much as 200 miles (320 kilometers) wide and 25,000 feet (8,000 meters) deep, showing location of pseudowell used in burial history analysis. Adapted from Rowan and Stanley (2008).

Arctic Circle show that the basin fill is folded and faulted near the Tintina Fault and that the intensity of deformation decreases northward with increasing distance from the fault. No seismic-reflection profiles are available from north of the Arctic Circle in the Yukon Flats Basin.

Petroleum Systems

A single petroleum system, the Yukon Flats Tertiary composite total petroleum system, is hypothesized to exist in the Yukon Flats Basin (Stanley and others, 2004). Potential source rocks are postulated to be coal, shale, and lacustrine mudstone. The only hydrocarbons identified in the basin consist of an undetermined amount of gas encountered in Miocene coal beds in the 2,300-ft-deep research corehole at Fort Yukon (fig. 1; Barker and others, 2005). Thermal maturity and the timing of petroleum generation have been modeled in the southern (deepest) part of the basin (Rowan and Stanley, 2008). Using a relatively high heat flow characteristic of young extensional basins, analysis of a pseudowell (fig. 3) suggests that the onset of petroleum generation could have occurred following ~ 2 km (6,500 feet) of sedimentary burial and as early as 57 Ma. In the Yukon Flats Basin, most of the areas with inferred sedimentary deposits >2 km thick occur south of the Arctic Circle.

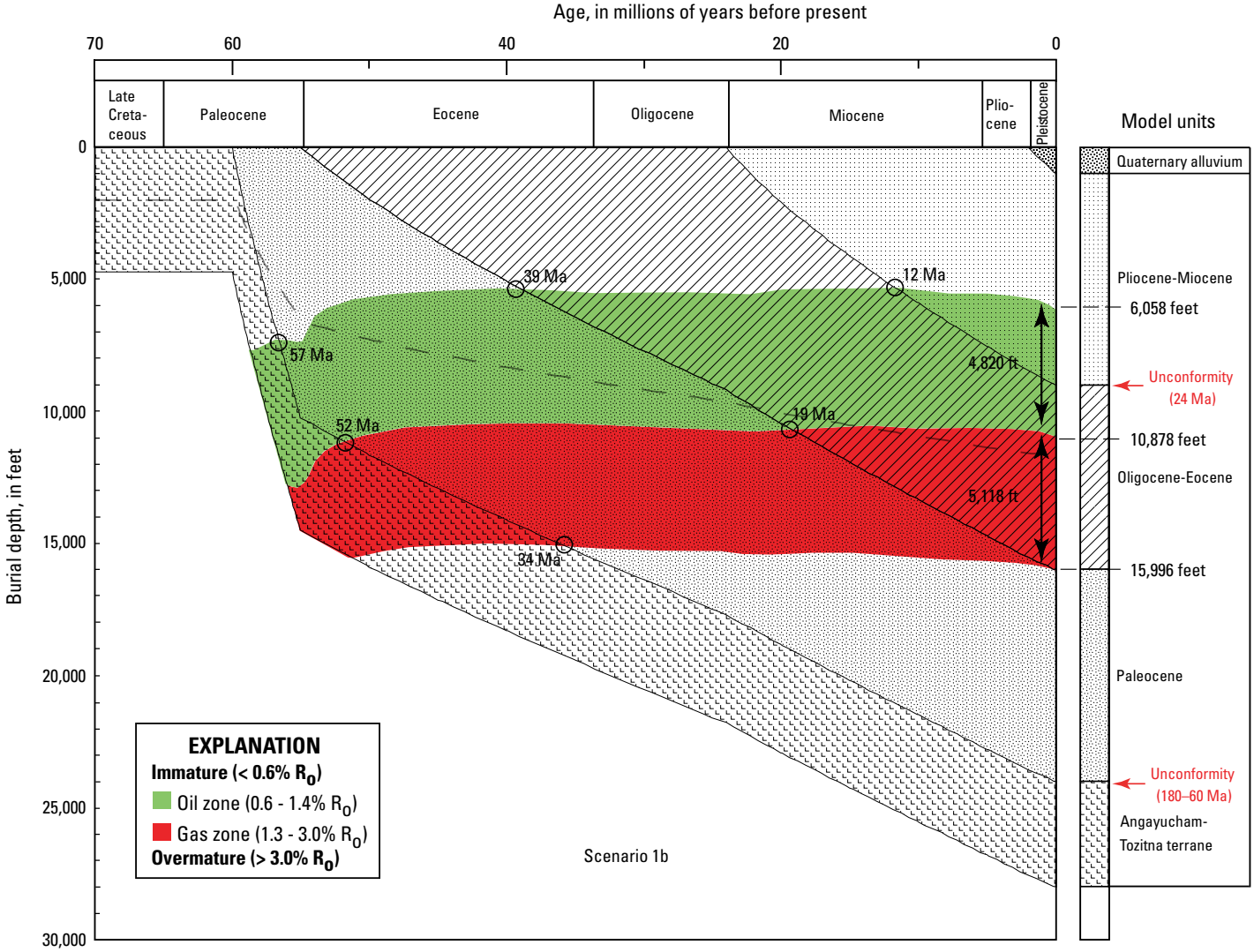

Figure 3. Example of scenario 1b burial-history plot, one of several constructed by modeling a constant heat flow (77 milliwatts per square meter) at a pseudowell located in the southern, deepest part of Yukon Flats Basin (fig. 1). Ro, vitrinite reflectance, in percent (%); Ma, millions of years ago. From Rowan and Stanley (2008).

AU Description

The Tertiary Sandstone AU encompasses the entire Yukon Flats Basin, an area of ~36,000 km^2 (fig. 1). This AU is inferred to consist of as much as 8 km of Cenozoic nonmarine sandstone, conglomerate, volcanic rocks, shale, lacustrine mudstone, and coal. Petroleum source rocks are postulated to be coal, shale, and lacustrine mudstone. Burial-history modeling using a relatively high heat flow characteristic of young extensional basins indicates that the onset of petroleum generation could occur at depths of slightly less than 2 km (Rowan and Stanley, 2008).

Geological Analysis of Assessment Unit Probability

Data used for the 2004 National Oil and Gas Assessment of the Yukon Flats Tertiary Sandstone AU (Stanley and others, 2004) included size distributions for oil and gas fields that were based on a minimum size of 0.5 MMBOE (0.5 million barrels of oil [MMBO] or 3 billion cubic feet of gas [BCFG]). Using those field-size distributions, the estimated mean numbers of undiscovered oil and gas fields (13.67 oil fields and 67 gas fields, unrisked), and the probability of at least one undiscovered field in the AU (0.81), one can calculate mean estimates of undiscovered oil and gas fields of at least 50 MMBOE, the minimum for CARA: 0.67 oil fields and 3.52 gas fields.

The proportion of the Yukon Flats Tertiary Sandstone AU north of the Arctic Circle is 34 percent. Thus, if the resource is assumed to be evenly distributed across the AU, then 0.23 oil fields and 1.20 gas fields larger that 50 MMBOE are expected in the part of the AU north of the Arctic Circle. The geology suggests, however, that the area north of the Arctic Circle has lower potential than the area to the south where the sedimentary section is thicker, larger volumes of hydrocarbons may have been generated, and potential structural traps are probably more abundant. Because of the low potential implied for the area north of the Arctic Circle, the Yukon Flats Tertiary Sandstone AU was not quantitatively assessed for CARA.

Acknowledgments

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