CENTRAL ALASKA PROVINCE (002)

by Richard G. Stanley

With a section on the Kandik Basin by David G. Howell

INTRODUCTION

The Central Alaska Province is a remote and thinly populated region that includes most of the central third of Alaska. Generally, the province includes mountainous areas underlain by rocks of Precambrian to Mesozoic age, and swampy lowlands underlain by nonmarine deposits of Cenozoic age. The province is bounded on the north by the Brooks Range, on the south by the Alaska Range, on the east by the Canadian border, and on the west by the Bering Sea and the State 3-mi limit offshore. The main onshore part of the province (excluding the islands) is about 800 mi wide from west to east at the latitude of the Seward Peninsula, about 620 mi long from north to south at the longitude of Cape Peirce (sic), and occupies an area of about 300,000 sq mi.

The Central Alaska Province is geologically diverse and complex; many important aspects of its stratigraphy, structure, geologic history, and petroleum potential remain to be deciphered. In general, Cenozoic nonmarine basins and remnants of Mesozoic flysch basins overlie a diverse assortment of Precambrian, Paleozoic, and lower Mesozoic metamorphic and igneous rocks. Some geologists believe that large tracts of pre-Cretaceous rocks in central Alaska belong to allochthonous tectonostratigraphic terranes that were assembled in roughly their present position during Late Cretaceous or early Tertiary time. However, there is much controversy as to how this happened, or whether it happened at all. Plutonic igneous rocks of Cretaceous and Tertiary age are widespread; some granitoids yield K-Ar ages as young as 37 Ma. Cretaceous and Cenozoic volcanic rocks are locally important, and in places are interbedded with sedimentary rocks.

No petroleum production has been obtained from this province. Fewer than a dozen exploratory wells have been drilled.

Three hypothetical plays are discussed below: the Central Alaska Cenozoic Gas Play (0201); the Central Alaska Mesozoic Gas Play (0202); and the Central Alaska Paleozoic Oil Play (0203). In addition, two hypothetical plays in the Kandik Basin are discussed in the section by David G. Howell: the Kandik Pre-Mid Cretaceous Strata Play (0204) and the Kandik Upper Cretaceous and Tertiary Non-Marine Strata Play (0205). The most attractive petroleum exploration objectives in the Central Alaska Province are hypothetical accumulations of dry gas in mildly deformed, generally nonmarine, coal-bearing strata of Cenozoic age. The Cenozoic basins are almost entirely unexplored, despite some important geologic similarities to the petroliferous Cook Inlet Basin. Some geologists have speculated that accumulations of dry gas might occur in turbiditic and deltaic strata in the Mesozoic flysch basins; in most places, however, the Mesozoic strata are moderately to strongly deformed and thermally overmature, and have little or no petroleum potential. Much of the Central Alaska Province is underlain by rocks of Paleozoic to early Mesozoic age; for the most part, these are metamorphic rocks with no petroleum possibilities, but unmetamorphosed Paleozoic rocks occur in some areas (such as the Holitna and Kandik Basins) and may have potential for oil and gas.

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CONVENTIONAL PLAYS

0201. CENTRAL ALASKA CENOZOIC GAS PLAY (HYPOTHETICAL)

This play includes hypothetical accumulations of hydrocarbons, mainly nonassociated gas, in undeformed to moderately deformed strata generally of Cenozoic age. The Central Alaska Cenozoic Gas Play includes more than a dozen sedimentary basins in interior Alaska, including the Yukon Flats and Nenana Basins. The area of the play is about 96,000 sq mi.

Most of the Cenozoic basins are floored by igneous and metamorphic rocks of Precambrian to Mesozoic age, which generally are regarded as economic basement. The basin fill is chiefly of Tertiary and (or) Quaternary age, but in places is as old as Late Cretaceous (Kirschner, 1988). These strata consist mainly of conglomerate, sandstone, mudstone, and coal and are predominantly of nonmarine (fluvial and lacustrine) origin; however, marine sandstones and mudstones of Tertiary age occur in the Bethel and Kotzebue Basins. The Cenozoic basins, because they are filled by materials that are commonly less dense than the surrounding rocks, are often associated with gravity lows. Gravity modeling in the Nenana and some other basins suggest that the Cenozoic section in these areas may be 10,000–16,000 ft thick (Barnes, 1961; Kirschner, 1988). Cenozoic strata in the Yukon Flats basin may be thicker than 15,000 ft, based on gravity and seismic reflection data obtained by the oil industry (Dean L. Morgridge, consultant, oral commun., 1993).

The origin of the Cenozoic basins is unclear and controversial; much debate focuses on the relative roles of extensional and strike-slip tectonism and tectonic rotations of small crustal blocks. Some geologists believe that the Cenozoic basins are primarily of extensional origin and that major episodes of basin development and sedimentation occurred during the Paleocene to early Eocene, late Eocene to late Miocene, and late Miocene to Pliocene. However, most of the basins exhibit evidence of only one or two of these episodes. In many areas, Cenozoic strata have been mildly to moderately deformed by compression, resulting in broad open folds and high-angle reverse faults.

Reservoirs: The most likely potential reservoirs in the Central Alaska Cenozoic Gas Play are conglomerates and sandstones, many of which represent fluvial channel deposits. Direct measurements of reservoir properties such as porosity and permeability are generally not available. However, reservoirs in the Cenozoic basins of central Alaska may be similar to reservoirs in the 20 producing fields of the Cook Inlet Beluga-Sterling Gas Play (0303), which exhibit porosities of 18-35 percent (mean of 25 percent), permeabilities of 3.5-4,400 millidarcies (mean of 1,225 millidarcies), and net pay thicknesses of 20-455 ft (mean of 108 ft). Water saturations in the Cook Inlet reservoirs are about 35-50 percent (Magoon and Kirschner, 1990).

Source rocks and hydrocarbon migration: The most likely potential source rocks in the central Alaska Cenozoic Gas Play are coals and organic-rich mudrocks of fluvial and lacustrine origin. Available organic geochemical data from surface and subsurface samples indicate mainly gas-prone kerogens (Stanley, 1987, 1988; Stanley and others, 1990; R.G. Stanley, unpub. data), suggesting that the principal hydrocarbon resource in the play is likely to be nonassociated gas. As a working hypothesis, I propose that the Cook Inlet Beluga-Sterling Gas Play (0303) (see also Magoon and Kirschner, 1990) may be an analog for the Central Alaska Cenozoic Gas Play of the Central Alaska Province. Geochemical data indicate that most of the dry-gas accumulations in the Beluga-Sterling Gas Play are of microbial origin (Claypool and others, 1980); therefore, if the proposed analogy is valid, there may also be substantial amounts of undiscovered biogenic gas in the Cenozoic basins of central Alaska.

Available vitrinite reflectance R_o and Rock-Eval T_{max} data indicate that most of the potential source rocks of Late Cretaceous and Tertiary age are thermally immature with respect to oil generation (Stanley and others, 1990; Grether and Morgan, 1988; R.G. Stanley, unpub. data). However, depending on the geothermal gradient, the top of the zone of oil generation ($R_o = 0.6$) in the Cenozoic basins may be at depths of 5,000–10,000 ft or more; thus, Tertiary strata in some of the deeper basins (such as the Yukon Flats and Nenana Basins) may have been buried as deep as the zone of oil generation and may have generated thermogenic gas (Stanley and others, 1990). Furthermore, mature and overmature rocks have been found locally, most notably in the Cantwell Formation of the Central Alaska Range (Stanley, 1987) and in unnamed Tertiary nonmarine strata along the Tintina fault (Dean L. Morgridge, consultant, oral commun., 1993). Elevated levels of thermal maturity may be the result of circulating hydrothermal waters in fault systems, frictional heating along faults, or heating by nearby igneous intrusions. Cenozoic volcanic and shallow intrusive rocks are common in central and western Alaska; quite possibly, thermogenic gas may have been generated locally near Cenozoic igneous intrusions that lie buried in the subsurface.

There are numerous reports of marsh gas in seeps and water wells in the Cenozoic basins (Miller and others, 1959; Magoon and Kirschner, 1990). Several oil seeps have been reported in the province, but many of these have been investigated and disproved, whereas the remainder are unconfirmed and doubtful (Miller and others, 1959).

The potential for liquid hydrocarbons in the Cenozoic basins is unclear but probably low. Marine, oil-prone source rocks of Middle Jurassic age, similar to those in the Tuxedni Group of the Cook Inlet Province (Magoon and Kirschner, 1990), have not been recognized anywhere in the Central Alaska Province. In the offshore Norton Basin of western Alaska, the Exxon OCS Y-0430 No. 1 well found small amounts of high-sulfur (about 2 percent S) oil while coring quartz schist; this oil is believed to have been generated from carbonate rocks of Paleozoic and (or) early Mesozoic age (DesAutels, 1988, p. 522 and p.

525). In the Holitna Basin, unpublished organic geochemical data suggest that graptolitic shales of Ordovician and Silurian age may be oil prone; speculatively, oil generated from these rocks may have accumulated in overlying Tertiary strata. Tasmanite, an organic-rich, oil-prone shale consisting mainly of the marine alga *Tasmanites*, has been reported from the margins of the Yukon Flats Basin. These shales are probably of Triassic age and may have generated oil that accumulated in the overlying Tertiary section (Dean L. Morgridge, consultant, oral commun., 1993). However, the lateral continuity, thickness, and stratigraphic distribution of tasmanite in the subsurface are unknown, and the volume of oil that may have been generated is uncertain.

The potential of the Tertiary nonmarine rocks to generate oil is unclear. The Norton Basin COST No. 2 well found a show of paraffinic oil that appears to have been generated from a nonmarine source rock of Tertiary age (DesAutels, 1988, p. 518-519). Rock-Eval pyrolysis results from outcrop samples of the Tertiary Usibelli Group in the Nenana coal field indicate some potential for liquid hydrocarbons, but this result should be viewed with caution until confirmed by more detailed geochemical analyses (Stanley and others, 1990, p. 73). Given the weak shows and ambiguous geochemical data, the likelihood of an undiscovered oil field larger than 1 MMBO somewhere in the interior Cenozoic basins of Alaska is provisionally considered to be less than 10 percent.

Traps: Many structural and stratigraphic trapping situations are possible in the Cenozoic basins. Likely seals include fluvial and lacustrine mudstones. Available published geologic maps and cross sections show that, in places, Cenozoic strata are mildly deformed into broad, open folds and cut by steeply dipping faults, including high-angle reverse faults. Seismic profiles obtained by the oil industry reportedly exhibit dip reversals that suggest folds comparable in size to some in Cook Inlet (Dean L. Morgridge, consultant, oral commun., 1993). Fault traps may occur along the margins of grabens and half-grabens, as along the eastern edge of the Minto Flats area in the Nenana Basin. Stratigraphic traps are probably abundant in fluvial strata, which include many stacked, fining-upward, channel-fill sequences in which lenticular bodies of sandstone--the potential reservoirs--are encased within shales and coals that are the potential source rocks and seals (Stanley and others, 1992).

Exploration status and resource potential: No producing fields have been found in this play, and only a handful of exploratory holes have been drilled. Two wells in the Nenana Basin penetrated coal-bearing nonmarine strata of Cenozoic age and bottomed in schist; both wells found minor gas shows associated with coal beds, but no signs of oil (Stanley and others, 1990). Two wells in the Kotzebue Basin of western Alaska encountered thick sections of Neogene marine and nonmarine strata and Eocene volcanic rocks, then bottomed in schist and marble (Fisher and others, 1982; Fisher, 1988; Decker and others, 1988). Neither of the Kotzebue Basin wells reported any shows of hydrocarbons. At least three wells in the

Bethel Basin penetrated marine and nonmarine strata of Tertiary age and found minor coal but no signs of petroleum.

In summary, the Cenozoic basins of the Central Alaska Province appear to have good potential for nonassociated gas, especially biogenic gas, but the potential for liquid hydrocarbons is unclear and probably low. The most prospective Cenozoic basins include the Nenana and Yukon Flats Basins, which are believed on the basis of gravity and seismic reflection data, wells, and nearby outcrops to comprise thick sections of gently to moderately folded Cenozoic strata. The potential of most of the other basins is unknown owing to sparse data. Some Cenozoic basins are clearly nonprospective; one example is the Cantwell basin of the Central Alaska Range, where Late Cretaceous and Paleocene nonmarine coal-bearing strata have been strongly folded and faulted and intruded by granite (Csejtey and others, 1992).

The following estimates of the sizes and numbers of undiscovered fields in the Central Alaska Cenozoic Gas Play are based on comparison with 20 discovered accumulations of dry gas in the of the Cook Inlet Beluga-Sterling Gas Play (0303) (see also Magoon and Kirschner, 1990). The median undiscovered field in the Central Alaska Cenozoic Gas Play may be the same size as the median discovered field in the Cook Inlet Beluga-Sterling Gas Play, about 20 BCFG. The largest accumulation expected at a 5-percent chance in the Central Alaska Cenozoic Gas Play is estimated to be the same as the largest discovered field in the Beluga-Sterling Gas Play, the Kenai field, at about 2.5 TCFG. The largest number of undiscovered accumulations in the Central Alaska Cenozoic Gas Play is perhaps five times the number of discovered accumulations in the Beluga-Sterling Gas Play. This determination was made by examining Kirschner's (1988) map of Alaskan sedimentary basins and guessing, optimistically, that all of the interior basins collectively may be about five times the size of the productive part of the Beluga-Sterling Gas Play. More rigorous appraisals could be made by comparing precisely measured surface areas and sediment volumes, but reliable stratigraphic data are not presently available from many of the basins in the Central Alaska Province. The minimum number of undiscovered accumulations in the Central Alaska Cenozoic Gas Play is hypothesized to be 10, half the number of known accumulations in the Beluga-Sterling Gas Play. The median number of undiscovered accumulations in the Cenozoic Gas Play is surmised to be 20, the same as the number of known accumulations in the Beluga-Sterling Gas Play.

0202. CENTRAL ALASKA MESOZOIC GAS PLAY (HYPOTHETICAL)

This play includes hypothetical accumulations of hydrocarbons, probably nonassociated gas, in strata of Mesozoic (mostly Cretaceous) age. The Central Alaska Mesozoic Gas Play occupies an area of about 105,000 sq mi.

The Central Alaska Mesozoic Gas Play is in the thick sequences of so-called "flysch" deposits that cover large areas of central and western Alaska, most notably in the Yukon-Koyukuk, Kuskokwim, and Bethel

Basins. Reportedly, these deposits consist mainly of deep-marine turbidite sandstones and shales but also include shallow-marine, alluvial fan, and coal-bearing deltaic and fluvial facies. In places, the thickness of these deposits may be greater than about 40,000 ft (Decker, 1984). The composition of the sediments varies from place to place and indicates derivation from varied local sources (Nilsen, 1989). In places, much of the sediment consists of volcaniclastic debris, indicating that deposition was coincident with volcanism. In other areas, the sediment contains variable amounts of sedimentary and metamorphic rock fragments, indicating derivation from nearby uplifted continental highlands. The internal stratigraphy of the Mesozoic rocks is poorly understood owing to poor biostratigraphic control, a lack of laterally persistent marker horizons, and structural disruption (Patton, 1971). In most places, the Mesozoic strata are moderately to strongly deformed. Faults, tight to isoclinal and overturned folds, and steep dips are common, but broad, open folds reportedly occur in places.

The Mesozoic deposits are not found in well-defined sedimentary basins like the Cenozoic basins, but instead are in deformed basin fragments that have been dismembered along strike-slip faults. Subsidence of several of the Cretaceous basins evidently began after a Late Jurassic and Early Cretaceous period of crustal shortening related to the collision of oceanic and continental terranes with the North American continent (Patton and Box, 1989; Box and Elder, 1992). The origins and tectonic settings of the Cretaceous basins are controversial; initial subsidence has been variously attributed to back-arc spreading, regional extension, and transtension.

Reservoirs: Potential reservoir rocks are scarce (Patton, 1971). The turbidite sandstones contain abundant rock fragments of volcanic and metamorphic origin, and porosity is generally occluded by close packing of deformed ductile grains, clayey matrix, and authigenic phases including calcite, quartz, and laumontite. Lyle and others (1982) examined 44 outcrop samples from the Kuskokwim Group and undifferentiated Cretaceous strata and found no visual porosity. Laboratory measurements on the same samples indicate low porosity (0.2-7.4 percent, with a mean of 2.8 percent) and virtually no permeability. Cross-bedded fluvial and shallow marine sandstones reportedly occur in places and contain fewer volcanic grains and more metamorphic and polycrystalline quartz; some of these sandstones reportedly have potential as reservoirs (Hite and Nakayama, 1980), but I have no further information on their reservoir properties. Fractured reservoirs are possible in sandstones, mudstones, and volcanic rocks, but the sizes and characteristics of such reservoirs in the Central Alaska Province are unknown. No potential reservoirs were found in Cretaceous rocks in either of the two wells drilled in this play (see discussion below).

Source rocks . Potential source rocks include shales and coals within the Mesozoic deposits. However, little information is available to the public on the source potential and thermal maturity of these rocks. Unpublished results from outcrop samples of shales in the Cretaceous Kuskokwim Group of the Holitna

Basin area (T.N. Smith, Alaska Division of Oil and Gas, written commun., 1994) show generally low values of TOC (range 0.61-1.59 percent, with a mean of 0.92 percent). Even lower values of TOC (0.07-1.05 percent with a mean of 0.37 percent) were reported by Lyle and others (1982) for 45 outcrop samples from the Kuskokwim Group and other Cretaceous rocks in southwestern Alaska. Visual and geochemical analyses from outcrops and wells indicate that kerogens in the Cretaceous rocks are gas prone and dominated by herbaceous, woody, and coaly material.

Available data indicate that the thermal maturity of strata in the Mesozoic basins is variable but generally high, in most places mature to overmature with respect to the zone of oil generation (Johnsson and others, 1993). The variable thermal maturities indicate that thermal histories differed from place to place, but the reasons for these differences are poorly understood. Broadly speaking, wide-ranging but generally high levels of thermal maturity may have resulted from deep burial (probably during the Late Cretaceous) followed by differential uplift, or alternatively from locally high-heat flow near igneous intrusions that accompanied Late Cretaceous and early Tertiary regional magmatism. Most of the thermogenic gas generated during these episodes probably escaped to the atmosphere during subsequent structural deformation, uplift, and erosion. The remaining ability of the Mesozoic shales to generate hydrocarbons is uncertain but probably low and poses a serious exploration risk.

No confirmed shows or surface seeps of oil or gas have been reported from this play.

Traps. Large tracts of Mesozoic strata in western Alaska are intensely folded and faulted, with ubiquitous faults and abundant steeply dipping and overturned beds. This intense deformation implies small trap size, as well as a high likelihood of breaching and escape of accumulated hydrocarbons to the surface. However, parts of the Yukon-Koyukuk and Kuskokwim Basins evidently have broad, open folds that may provide trapping possibilities (Patton, 1971). In the Bethel Basin, Cretaceous strata in the Pan American Petroleum Corporation Napatuk Creek Unit No. 1 well exhibit gentle dips and apparently are only mildly deformed (S.E. Box, U.S. Geological Survey, Spokane, WA, oral commun., 1993). According to unconfirmed industry rumors, however, seismic reflection data in the Bethel Basin show only incoherent reflections from the Cretaceous rocks that underlie a thin veneer of Cenozoic deposits. Published reports on both the Yukon-Koyukuk and Kuskokwim Basins mention lateral changes from deep-marine turbidites to deltaic and shallow-marine facies (Patton, 1971; Nilsen, 1989; Box and Elder, 1992); these changes imply opportunities for stratigraphic traps, if structural disruption is not too severe.

Exploration status. No producing fields have been discovered in this play, and only two deep exploratory holes have been drilled. Neither well reported significant shows of hydrocarbons nor any good reservoir rocks. The earliest deep exploratory well drilled in the Central Alaska Province apparently was the Paul G. Benedum Nulato Unit No. 1, drilled in 1960 in the Koyukuk Basin of western Alaska to a total depth of 12,015 ft. The well was located on the axial trace of a northeast-trending surface anticline, and the primary objective was to test Mississippian and Devonian strata, which were projected to lie beneath Cretaceous rocks at a depth of about 4,500-6,000 ft. As it turned out, the well spudded and bottomed in Cretaceous rocks, and no Paleozoic rocks were encountered. Sample descriptions indicate that the Cretaceous in this well consists of a monotonous, interbedded sequence of hard gray sandstone, hard gray siltstone, and hard dark-gray to black shale, with minor coal. Ten cores were taken; the rocks in all 10 exhibit abundant fractures, slickensides, and brecciation. Steep dips (60 degrees or more) were observed on bedding in two cores. The sample and electric logs reportedly show that several intervals in the well are duplicated, suggesting that the well drilled through a system of thrust faults. Visual kerogen studies show that samples from throughout the well are dominated by gas-prone kerogens. Vitrinite reflectance results show that the entire sequence penetrated by the well is thermally overmature.

The Pan American Petroleum Corporation Napatuk Creek Unit No. 1 well was drilled in 1961 in a shallow gravity low, about 45 mi west of Bethel, to a total depth of 14,910 ft. This well penetrated about 2,000 ft of Tertiary strata and nearly 13,000 ft of Cretaceous and older(?) hard sandstone, siltstone, and shale, with minor coal. Cores from below 3,100 ft exhibit numerous fractures and slickensides, and bedding with dips less than 10 degrees. Visual kerogen studies show that samples from throughout the well are dominated by gas-prone kerogens. Vitrinite reflectance studies indicate that the Cenozoic strata are thermally immature to marginally mature with respect to the oil window, whereas the Cretaceous rocks range from mature to overmature.

Resource potential: The petroleum potential of the Mesozoic basins appears bleak, but cannot yet be completely written off. Good reservoirs appear to be scarce; and potential source rocks appear to be organically lean and generally of high thermal maturity. Large parts of the play are strongly folded and faulted, implying small trap size and a high likelihood that hydrocarbons have been lost. The sparse available information, taken at face value, suggests a low probability (less than 10 percent) of the occurrence of an undiscovered accumulation larger than 1 MMBO or 6 BCFG.

0203. CENTRAL ALASKA PALEOZOIC OIL PLAY (HYPOTHETICAL)

This highly speculative play includes hypothetical accumulations of oil and gas in unmetamorphosed Paleozoic rocks in the Holitna Basin of southwestern Alaska. No producing fields, no exploratory wells, and no confirmed seeps or shows of oil or gas have been reported from this play, which occupies an area of about 6,500 sq mi.

In the Holitna area, geologic mapping is incomplete and largely unpublished. However, Robert B. Blodgett (U.S. Geological Survey, Reston, Va.) and Thomas N. Smith (Alaska Division of Oil and Gas, Anchorage) kindly provided copies of a preliminary 1:250,000-scale geologic map, a stratigraphic column, and much other useful information summarized here. Southeast of the Farewell Fault, the Holitna area is underlain by a sequence of Late Proterozoic to Devonian sedimentary rocks, as thick as 12,000 ft, assigned to the Farewell terrane (which includes the Nixon Fork, Dillinger, and Mystic terranes of some authors). The stratigraphic sequence in the Holitna area includes dolostones and coarse siliciclastic redbeds of Late Proterozoic age; limestone, chert, and siltstone of Middle Cambrian and Early Ordovician age; a package of Early Ordovician to Early Devonian graptolitic shales and platy limestones that pass laterally into a shelf-margin algal reef complex and shallow-water platform limestones and dolomites; and argillite of undetermined but pre-Late Pennsylvanian age.

Reservoirs: Potential reservoirs within the Paleozoic carbonate section include dolostones, lime grainstones, and reef limestones, some of which reportedly have good intergranular porosity. Some of the dolostones exhibit as much as 10 percent vuggy porosity (Smith and others, 1984, 1985). In places, the Paleozoic shales contain allochthonous carbonate debris flows that could serve as reservoirs or as conduits for migration of oil into shallow-water carbonate facies.

Source rocks : Potential source rocks include Ordovician, Silurian, and Lower Devonian graptolitic shales and platy limestones that may be 6,000 ft thick. Little is known about the organic geochemistry of these rocks. Unpublished values of TOC from outcrop samples reportedly are mostly less than 0.5 percent, although some range as high as 3.5 percent. These rocks may be potential sources of oil, by analogy with graptolitic shales that occur elsewhere in North America, North Africa, and the Middle East that generally contain type II, or oil-prone, kerogen (Klemme and Ulmishek, 1991).

A limited number of visual kerogen analyses and conodont alteration indices, all from outcrop samples in the Holitna area, suggest a range from mature to overmature with respect to the thermal zone of oil generation. According to unconfirmed rumors, at least one oil company that studied the Holitna area during the 1980's decided that the thermal maturity of these Paleozoic source rocks was too high to warrant further exploration. The Paleozoic rocks may have reached their present level of thermal maturity during Late Cretaceous and early Tertiary regional magmatism and igneous intrusion. Any petroleum generated at that time probably was lost during subsequent episodes of folding, faulting, and uplift. The remaining ability of the Paleozoic shales to generate oil is uncertain but probably low and poses a serious exploration risk.

Traps: Little is known about the styles and sizes of potential traps in this play. A wide variety of trapping conditions are possible. The largest and most likely potential traps probably are anticlines, but stratigraphic traps also may occur. No structural cross sections are available from this area, so there is insufficient information to estimate possible closures and trap sizes. Reportedly, the structural style of the Paleozoic rocks is variable, ranging from broad, open folds in some places to closely spaced small folds in others. Areas of steep to vertical dips are evident. A potential regional seal within the Paleozoic rocks is a widespread and thick argillite unit of unknown but post-early Middle Devonian and pre-Late Pennsylvanian age.

Exploration status: There are no producing fields in this play, nor have any exploratory wells been drilled. A lease sale originally scheduled for this area during the 1980's was canceled, apparently due to lack of interest from the oil industry.

Resource potential: The petroleum potential of Paleozoic rocks in the Holitna Basin is uncertain and risky. Good potential reservoirs reportedly are present, but virtually nothing is known about potential reservoir volumes or trap sizes. Source-rock and thermal-maturity data are sparse, but suggest that oil-prone Paleozoic shales exposed at the surface are mature to overmature with respect to the oil-generation window. There is no direct evidence that oil was ever generated from these rocks. The timing of oil-generation in this area, if it occurred at all, is unknown and critical to resource evaluation. If generation occurred during the Late Cretaceous and (or) early Tertiary, which seems likely, much or all of the petroleum resource was probably lost or destroyed during subsequent deformation, uplift, and exposure to the surface. If oil generation and migration occurred later in the Tertiary (as it did in the Hemlock-Tyonek Play of the Cook Inlet Province), there may be significant accumulations of Paleozoic-sourced oil in overlying Tertiary nonmarine strata.

In western Alaska, unmetamorphosed Paleozoic and Triassic rocks crop out locally on the western Seward Peninsula and on St. Lawrence Island. Sparse organic geochemical data from these rocks show values of TOC as high as 2.1 percent, gas-prone kerogens, and thermal alteration index values that are immature to mature with respect to the oil-generation window (Fisher, 1982). The petroleum resource potential of these areas is unknown but probably very low, considering their limited lateral extent. Consequently, they are not included in this or any other play. Unmetamorphosed Paleozoic and (or) early Mesozoic strata may have generated a small amount of oil found in the offshore Exxon OCS Y-0430 No. 1 well in the Norton Basin (DesAutels, 1988, p. 522), as well as some hydrocarbon microseeps detected offshore in the Bering and Chukchi Seas (Kirk Sherwood, Minerals Management Service, written commun., 1993).

KANDIK BASIN

By David G. Howell

Within the Central Alaska Province, the eastern part of the Kandik Basin (about 1,800 sq mi) is a unique region; it is an extension of cratonic North America. Elsewhere in the province, the underlying framework geology represents a mosaic of accreted tectonostratigraphic terranes. The sedimentary rocks in the eastern part of Kandik Basin are within the zone of thermal maturity for oil- and (or) gas generation. To the south, these rocks are bounded by the translational Tintina Fault and crystalline igneous and metamorphic strata. To the west and north of the northeast-southwest-trending Glenn Creek Fault Zone lie structurally higher sedimentary units that are everywhere thermally overmature with respect to oil and gas generation. The eastern boundary is defined by the United States–Canadian border.

In the Kandik Basin, the Paleozoic to Triassic strata, representing a subsiding margin sequence and lying southeast of the Glenn Creek Fault, constitute a fragment of cratonic North America. West of the fault, a poorly exposed Paleozoic clastic sequence is thrust upon a continuous sequence consisting of Middle Jurassic to Lower Cretaceous shale, Lower Cretaceous shallow-marine quartzarenite, and a thick Lower Cretaceous clastic sequence interpreted to be foreland basin fill. The northwesternmost and structurally highest rocks lie northwest of an unnamed thrust fault and consist of marine volcanic rocks that are similar in many respects to rocks of the Angayucham terrane of the southern Brooks Range. Rocks on both sides of the Glenn Creek Fault are overlain unconformably by an Upper Cretaceous and Tertiary nonmarine clastic sequence (Brabb and Churkin, 1969).

The Paleozoic and Mesozoic rocks of the Kandik Basin region exhibit a thermal maturity anomaly: vitrinite reflectance (R_o), illite crystallinity, and isotopic data indicate that the younger, structurally higher strata are thermally more mature than the older strata exposed southeast of the Glenn Creek Fault. The boundary between rocks of low thermal maturity (R_o of 0.9–1.6 percent) and rocks that have been highly thermally altered (R_o of 1.6–5.0 percent) does not correspond precisely to the trace of the Glenn Creek Fault but, rather, lies southeast of and parallel to the fault. Like the Mesozoic rocks, Paleozoic rocks lying west of the fault are generally overmature to supermature. The nonmarine clastic sequence unconformably overlying Paleozoic and Mesozoic rocks on both sides of the Glenn Creek Fault generally is undermature.

The average vitrinite reflectance of the Paleozoic rocks lying southeast of the Glenn Creek Fault in the Kandik area (R_oÅ0.8 percent) suggests an average maximum burial temperature of about 125¡C. Assuming a geothermal gradient of 20¡C / km for a typical foreland basin and a middle Cretaceous mean annual surface temperature of 10¡C, maximum burial depths of 16,000–20,000 ft are indicated. This range is about equal to the combined thickness of the Mesozoic strata exposed west of the fault plus the maximum preserved thickness of the unconformable nonmarine sequence. Thus, burial beneath foreland-basin and younger deposits is one possible mechanism to account for the degree of thermal alteration of the Paleozoic strata lying west of the Glenn Creek Fault.

The thermal-maturity data from the Kandik Basin region, combined with structural, sedimentologic, petrographic, and paleomagnetic data, suggests that during Paleozoic through Early Cretaceous time, rifted- and passive-margin sedimentation was the rule throughout the region (Play 204). This passive-margin setting was interrupted in the Barremian by the obduction of an ophiolite terrane. Subsequent east-west crustal shortening resulted in the formation of a foreland basin. Foreland basin deposits reached sufficient thickness to drive the underlying Paleozoic strata into the thermal zone of oil generation. With continued crustal shortening, thrust sheets advanced toward the southeast in the present reference frame and tectonically buried the northwestern part of the recently deposited foreland-basin strata. These same nappes covered the area just east of the Glenn Creek Fault, explaining the high thermal maturity of those rocks as compared with the rest of the region southeast of the fault. The unconformably overlying Cretaceous through Tertiary nonmarine sedimentary deposits (Play 205) may represent nonmarine foreland-basin deposition evincing the long life of this fold-and-thrust belt system.

0204. KANDIK PRE-MID CRETACEOUS STRATA PLAY (HYPOTHETICAL)

Because of the abundance of potential source and reservoir rocks, the Kandik Basin region has been of interest to petroleum geologists for many years (Brabb and Churkin, 1969). Upper Precambrian through upper Paleozoic continental-margin strata are unconformably overlain by an organic-rich Triassic-Jurassic horizon. Interest in the petroleum potential of this area was stimulated in 1970 by the spudding of the Doyon No. 1 well in Mesozoic strata about 25 mi west of the Glenn Creek fault (see fig 1). It is unclear why this exploratory well was located so far from the outcroppings of the Paleozoic and Mesozoic strata that lie within the thermal zone of oil generation. Instead, the well penetrated more than 10,800 ft of Jurassic-Cretaceous shale and siltstone with no hydrocarbon shows. Thermal-maturity data indicate that the lack of hydrocarbons is hardly surprising; these rocks are thermally supermature and the Glenn Creek Fault was not penetrated, precluding the possibility of a major overthrust play between rocks east and west of the fault. Structural models, based in part on the thermal data, suggest that such an overthrust play is unlikely in rocks west of the Glenn Creek fault. Because of their thermal maturity and together with the apparent lack of porosity in any of the potential reservoir rocks, the area west of the Glenn Creek Fault does not appear to be hydrocarbon prospective. The abundant thermally mature organic-rich shales in the Precambrian, Paleozoic, and Mesozoic section of the region southeast of the fault, however, could generate hydrocarbons.

Reservoirs: The principal structure within Play 204 in the east part of the Kandik Basin is the southwest-plunging Michigan Creek Anticlinorium. Strata younger than Precambrian have been variously stripped off the axis of this anticlinorium; thus, fundamentally compromising the reservoir integrity of this structure, especially for the units lying above the organically very rich Triassic Glenn Shale. Lapping on this structure with angular discordance is a sequence of Upper Cretaceous to lower Tertiary nonmarine strata that have themselves been folded into broad folds. These strata make up the principal components of the Play 205.

Source rocks: Several formations within the upper Precambrian through Middle Mesozoic section contain potential source rocks. None, however, are richer than the Triassic Glenn Shale, which is equivalent to the petroliferous Shublik Shale of the North Slope. The Glenn Shale locally contains more than 10 percent organic carbon. This unit was deposited on a broad shelf region that presumably covered much of northern Alaska. Thus, this organic shale, in combination with older black shales, indicates that the play is not limited as a consequence of the source rock.

Traps: The Kandik Basin is characterized principally by one major anticlinorium, the so-called Michigan Creek Anticline. Though highly dismembered, the overall integrity of the southwest anticlinorium is evinced by the map patterns of Precambrian rocks in the core and the younger strata cropping out along the northern and southern flanks. To the west of this major feature is the Glenn Creek Fault, a major east-verging thrust. The Michigan Creek Anticline itself is likely a ramp anticline that lies above a major blind thrust, a subsurface extension of the system of thrusts of which the Glenn Creek Fault is but one. This part of Alaska lies within the part of the cordillera of North America characterized by Late Mesozoic craton-directed crustal shortening. The integrity of this trap is suspect because of deep-seated erosion along the crest of the anticline. The existence of ultradeep subthrust traps was not considered owing to a lack of data.

Exploration status: The Doyon No. 1 well is the only exploratory borehole within 30 mi of the play. This well, located about 28 mi northwest of the Michigan Creek Anticline, penetrated the Mesozoic strata west of the Glenn Creek Fault. Vitrinite reflectance data from cuttings from this well indicate very high thermal maturity (R_o of 4.0–5.0 percent) and relatively little variation with depth. A discontinuity in slope occurs in the plot of vitrinite reflectance versus depth at between 2,300 and 2,600 ft deep. Although stratigraphic correlations and formation picks are particularly difficult in this well, several thrust faults and section repetitions are inferred from cuttings and logs at depths below 2,600 ft. Structural repetition of thin thrust plates of similar thermal maturity may account for the remarkably small variation in thermal maturity with depth below 2,600 ft. No traces of either oil or gas were reported from this well.

Resource potential: Although this play contains a world-class source rock in the Glenn Shale, there are no obvious means to charge and preserve reservoirs sourced from this organic-rich shale. The risk associated with both reservoir and trap integrity is so large that we have eliminated this play from further consideration.

0205. KANDIK UPPER CRETACEOUS AND TERTIARY NONMARINE STRATA PLAY (HYPOTHETICAL)

Cropping out in two separate areas within the Kandik Basin are erosional remnants of a once regionally extensive blanket of fluvial strata. These strata lap onto and locally cross the crest of the Michigan Creek Anticline and the traces of the Glenn Creek and Tintina Faults. Deposition of this nonmarine sequence occurred during the waning stages of cordilleran thrusting roughly equivalent to the Laramide orogenic episodes. The debris is largely locally derived and represents the in-filling of large piggy-back basins in the fold and thrust belt that extends east into Canada.

Reservoirs: The strata of this play are represented by a heterogeneous mixture of conglomerate, sandstone, mudstone, and locally thin horizons of coal. The thicknesses of individual layers are highly varied along the strike, with numerous lateral pinch-outs. Because these are erosional remnants, the total sedimentary package is not preserved. Existing thicknesses are difficult to measure owing to the lack of marker horizons and overall poor exposures; nonetheless, it’s probable that the aggregate thickness is at least 6,500 ft. The smaller northern patch of strata is a broad, easterly dipping monocline that buttresses onto the northern flank of the Michigan Creek Anticline. The regionally more extensive southern patch of nonmarine strata evinces numerous folds with flanking dips generally ranging between 10 and 30 degrees. The axes of the folds parallel the regional Michigan Creek anticline and like this large fold, the southern portion of the axes swing to the west, displaying drag features associated with the right-lateral Tintina Fault. Based on the heterogeneity of the strata, the fluvial depositional style, and the occurrence of numerous folds, reservoirs would be characterized by numerous stratigraphic traps and a host of small structural possibilities.

Source rocks: Although some coal has been found in association with these nonmarine strata, the potential of these rock is limited to biogenic methane. These strata, however, lie above the organic-rich Triassic-Jurassic Glenn Shale as well as other potential source rocks of Paleozoic and late Precambrian age. The nonmarine strata are largely thermally immature, whereas the underlying potential source rocks that crop out on the surface remain today within the thermal zone of oil generation. Thus, from the point of view of maturation and charge, the source-rock situation of this play is excellent.

Traps: Because of extensive localized folding, numerous and varied small structural and stratigraphic traps are likely in this play.

Exploration status: Intermittently during the past 30 years, a variety of petroleum exploration companies have conducted field work in the Kandik Basin, drawn mostly by the occurrence of the organic-rich mudstones (particularly the Glenn Shale). To date, however, not a single exploratory well has been drilled in order to test some portion of the play.

Resource potential: Owing to the porous nature of the nonmarine package of strata, the absence of any significant oil seeps, and the abundance of prolific petroleum source rocks that remain in the oil-generating window, it seems highly likely that oil and gas accumulations reside within this play. The occurrence of numerous small folds and the extreme variability of strata along their strike also make it likely that any pools of petroleum will be numerous and small.

UNCONVENTIONAL PLAYS

There are no unconventional plays described in this province report. However, unconventional plays listed in the surrounding provinces may include parts of this province. Individual unconventional plays are usually discussed under the province in which the play is principally located.

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AGE	UNIT
CENOZOIC	Nonmarine and subordinate marine deposits; volcanic rocks; and minor intrusive igneous rocks
MESOZOIC	Marine and nonmarine sedimentary and volcanic rocks, in places moderately to highly metamorphosed; and intrusive igneous rocks
PALEOZOIC AND PRE-PALEOZOIC	Marine and subordinate nonmarine sedimentary rocks, in places moderately to highly metamorphosed; volcanic and intrusive igneous rocks; and minor ultramafic rocks