SOUTHERN ALASKA PROVINCE (003)

by L. B. Magoon, C.M. Molenaar, T.R. Bruns, M.A. Fisher, and Z.C. Valin

INTRODUCTION

by L.B. Magoon

Southern Alaska Province includes all of Alaska south of the Alaska Range (lat 64_N). This province is further subdivided into separately authored areas. To the southwest, the Alaska Peninsula includes two plays (0301, 0302) discussed by C.M. Molenaar. In southern Alaska, the Cook Inlet Basin, discussed by L.B. Magoon, is the only area that presently produces petroleum; it includes three plays (0303-0305). The Copper River Basin includes two plays (0306, 0307) and is discussed by L.B. Magoon and Z. C. Valin. The Gulf of Alaska, by T.R. Bruns, includes two plays (0308, 0309). The Kodiak Islands are discussed by M.A. Fisher. Southeastern Alaska is discussed by T. R. Bruns.

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ALASKA PENINSULA

By C. M. Molenaar

The Alaska Peninsula is a southwestern extention of the Southern Alaska Province. The peninsula is about 500 mi long and is an active continental margin and volcanic arc that is continuous with the Aleutian arc to the southwest. The southeastern half of the peninsula is hilly to mountainous, consisting of gently to moderately folded Mesozoic and Tertiary sedimentary rocks and Quaternary volcanoes. The northwestern half of the peninsula is an alluvial-cover lowland, that, except for the part northeast of Becharof Lake, is underlain by Tertiary sedimentary rocks that thicken to the west under Bristol Bay and the Bering Sea. In addition to the chain of volcanoes along the peninsula, numerous late Tertiary granitic stocks intrude the sedimentary section in the outcrop belt, but they are not expected to be found under the Bristol Bay lowlands on the northwest.

The cumulative thickness of Mesozoic strata is about 30,000 ft, but the average thickness at most localities is much less owing to lateral thickness variations, unconformities within the section, and late Tertiary and Quaternary erosion. Tertiary rocks have a maximum thickness of about 18,000 ft on the peninsula. Several significant oil and gas seeps are present, some of which are along the crests of large anticlines. In addition to 8 shallow wells drilled near two different seeps prior to 1925, 18 wildcat wells between 5,000 and 15,000 ft deep have been drilled on the peninsula for either Mesozoic or Tertiary prospects (table 1). Two more wells were drilled offshore; one a Continental Offshore Stratigraphic Test (COST) well in the Bering Sea northwest of the Herendeen Peninsula, and one an exploratory test in the Shelikof Strait east of Hallo Bay. There have been no discoveries. Bottom hole temperatures indicate that the present geothermal gradient is about 2°F/100 ft, which is higher than normal.

In the central part of the Alaska Peninsula south of Becharof Lake, an inferred large, down-to-the-northwest fault separates the mostly hilly to mountainous outcrop belt of arc volcanoes and moderately deformed Mesozoic and Tertiary sedimentary rocks on the southeast from the alluvial-covered Bristol Bay lowlands on the northwest. This latter area, which is now in a back-arc setting, is underlain by a thick section of gently deformed Tertiary sedimentary rocks that rest on Jurassic basement. This basement, which crops out on the northwest side of the Bruin Bay fault northeast of Becharof Lake, consists of the eroded roots of the Jurassic arc that was the provenance for Jurassic and Cretaceous strata to the southeast. In the southwestern half of the Peninsula, the alluvial-covered lowland is underlain by a thick section of Tertiary sedimentary rocks that unconformably overly Mesozoic sedimentary rocks. Based on these differences across either the fault or the topographic break, two hydrocarbon plays are identified; the Alaska Peninsula Mesozoic (301) and Tertiary (302) Plays.

0301. ALASKA PENINSULA MESOZOIC PLAY (HYPOTHETICAL)

This is a hypothetical structural play for Mesozoic accumulations under large anticlines along the Alaska Peninsula. The play area includes the outcrop belt of Mesozoic rocks and part of the southwestern Bristol Bay lowlands where Mesozoic rocks are thought to be preserved. The play area is about 440 mi long and 30-50 mi wide, extending from lower Cook Inlet on the northeast to the last outcrops of sedimentary rocks in the Cold Bay area on the southwest. The southeast boundary is the national offshore 3-mi territorial limit along the Gulf of Alaska and the northwest boundary is the Bruin Bay Fault and its southwestern projection into the Port Heiden area.

Reservoirs: The primary reservoir objective of this play is Upper Triassic reefoid or biostromal limestone that underlies good oil source rocks. At least three wells penetrated the Upper Triassic section, but none found the biostromal limestone facies. Both the Jurassic sandstones, which are either volcaniclastic graywackes or first-cycle arkoses, and the Cretaceous sandstones, which are lithic rich, have poor reservoir potential.

Source rocks: Mesozoic strata consist of thick sections of deep marine to shallow marine to nonmarine mudstone, sandstone, conglomerate, and minor amounts of limestone. Large oil seeps and oil staining in Mesozoic rocks are found in several places on the peninsula, and good type II oil source rocks have been identified in Upper Triassic and possibly Middle Jurassic rocks. Other marine rocks do not seem to have source-rock potential, although nonmarine paludal rocks of the Chignik Formation (Upper Cretaceous) in the southwestern part of the peninsula may locally have lipid-rich rocks that may be potential oil source rocks. At Puale Bay, the only place on the peninsula where Triassic rocks are exposed, limited outcrop sampling of a 1,000-ft-thick section of interbedded petroliferous, argillaceous limestone and shale indicated total organic carbon contents of 1.3–2.8 weight percent (Magoon and Anders, 1992). These rocks are barely thermally mature (R_o = 0.6 percent) despite their having been buried by at least 14,000 ft of Jurassic rocks plus an unknown thickness of now-eroded Upper Cretaceous rocks. Well penetrations indicate that Triassic rocks at depth are much more mature, with R_o ranging from 1.0 to over 2.0 percent (Molenaar, in press). Some of this variation is due to nearby intrusive rocks, but it does seem that the geothermal gradient at the time of maximum burial (probably in latest Cretaceous or early Tertiary time) was very much lower than the present gradient, which ranges from 1.65° to over 2°F/100 ft based on bottom–temperature data from wells (Molenaar, in press).

Exploration status: Of the 18 significant wells drilled on the peninsula, 9 were drilled for Mesozoic prospects and most tested large structures without success (table 1). The last well was drilled in 1983 and since then, except for an offshore well drilled by Chevron in the Shelikof Strait in 1985, there has been no activity in the area. Drilling depths for the Triassic rocks would be 12,000–20,000 ft.

Resource potential: This is a very speculative play and it is very difficult to make a meaningful assessment. There are undrilled possibilities such as the Ugashik Anticline, which has large surface oil seeps and has only been drilled to shallow depths. The results of previous deep drilling on the nearby Bear Creek Anticline, which also has large oil seeps, and the nearby large Wide Bay Anticline were disappointing. The lack of adequate reservoir rocks seems to be the main drawback to this play.

0302. ALASKA PENINSULA TERTIARY PLAY (HYPOTHETICAL)

This is a hypothetical play for petroleum accumulations in Tertiary shallow marine and nonmarine sandstone in broad open folds underlying alluvium of the Bristol Bay lowlands on the northwestern side of the peninsula. The play area extends from about Becharof Lake, part way down the peninsula, to a narrow strip of coastline opposite Cold Bay, a distance of about 300 miles. The northwest boundary is the national 3-mi offshore territorial limit and it adjoins the offshore North Aleutian Basin. The average width is about 25 miles.

Reservoirs: Sandstone beds 50 to over 100 ft thick are generally common throughout the Tertiary section except in the central part of the play area near Port Heiden and the Gulf Port Heiden Unit No. 14 well. There, the Oligocene sequence consists of about 6,000 ft of volcanics, pyroclastics, flows, and agglomerates that grade into sandstones and mudstones to the northeast and southwest.

Source rocks: The source rocks are coaly and carbonaceous strata within the Tertiary section and possibly Mesozoic source rocks that may be present under the southwestern half of the play area. Mesozoic strata are not present under the lowlands in the northeastern two-thirds of the Peninsula because of pre-Tertiary erosion. Hence, except for the possibility of Mesozoic oil source rocks, this is most likely a gas play although there is the possibility that lipid-rich paludal rocks in the nonmarine section could be oil prone. Marginal thermal maturation for hydrocarbons (R_O = 0.6 percent) seems to be at a depth of about 9,000–10,000 ft in the play area (Molenaar, in press). Geothermal gradients range from 1.65° to 2.07°F/100 ft and average about 1.86°F/100 ft. Because the Tertiary section is now at its greatest depth of burial, any hydrocarbon generation from Tertiary source rocks is probably still progressing.

Exploration status: Between 1959 and 1983, nine tests ranging in depths from 8,000–15,000 ft were drilled for Tertiary prospects (table 1). Gas shows were encountered and one test had a slight oil show. Although not as indurated as the Mesozoic sandstones, Tertiary sandstones are generally volcanogenic or lithic and of poor reservoir quality. However, good to fair amounts of water were recovered on a few drill-stem tests.

Resource potential: Because the play area is alluvial covered, seismic surveys are necessary to delineate the structure. Nothing has been published on this, but by analogy with adjacent offshore seismic data, it seems that the structures are broad and gentle. The abundance of coal in the section and the low thermal maturity suggests that the area may be favorable for biogenic gas or coalbed methane. There is little information with which to make resource estimates.

COOK INLET BASIN

By L. B. Magoon

The Cook Inlet Basin produces oil and gas from Tertiary sandstone reservoir rocks that were deposited in a forearc basin. Biogenic gas is produced from the late Tertiary sandstone reservoir rocks, whereas oil with associated gas is produced from the early Tertiary conglomeratic sandstone and sandstone reservoir rocks. Minor amounts of oil have been recovered from late Mesozoic sandstone unconformably underlying the Tertiary rocks. The source rock is the Middle Jurassic Chuitna Formation in upper Cook Inlet, whereas the Upper Triassic and Middle Jurassic are the source rocks for the oil shows in lower Cook Inlet. In upper Cook Inlet, oil generation began as early as the Eocene and peaked in the Pliocene. Until recently, discovered resources were about 1.2 BBO, but with the Sunfish discovery and the McArthur River extension, discovered resources may exceed this amount in upper Cook Inlet. The Cook Inlet area has been divided into three plays.

0303. BELUGA-STERLING GAS PLAY

This confirmed play for additional gas accumulations described here covers 12,318 sq mi of the Cook Inlet Basin and includes 18 gas fields with discovered reserves of 6.14 TCFG. The three largest fields are Kenai (2.52 TCFG), North Cook Inlet (1.44 TCFG), and Beluga (0.86 TCFG). Many of the gas fields are undeveloped because they are too small and too expensive to produce.

Most of the gas is produced from the Sterling Formation, followed by the Beluga Formation and Tyonek Formation. The reservoir rocks in these formations are siliclastic sandstones of late Tertiary age whose average thickness ranges from 24 to 600 ft. The porosity of these reservoirs ranges from 18 to 35 percent and permeability ranges from 3.5 to 4,400 mD. The seals for these accumulations are siltstones associated with these reservoirs. The traps, which can be more than one per field, are mostly structural, but include some combined structural and stratigraphic traps. Structural traps include anticlines and faulted anticlines.

The natural-gas field sizes range from 6 BCFG to 2.52 TCFG. The gas is believed to be biogenic. The stratigraphic section is thermally immature and unable to generate methane. Biogenic gas generated locally would have migrated to adjacent structures or other types of traps.

0304. HEMLOCK-TYONEK OIL PLAY

This confirmed play for additional oil accumulations described here covers 7,335 sq mi of the Cook Inlet Basin and includes eight oil fields, two of which were just discovered. So little information is available for the new fields that they are excluded from this discussion. The three largest producing fields are McArthur River (590 MMBO), Swanson River (230 MMBO), and Middle Ground Shoal (182 MMBO).

Eighty percent of the oil is in the Oligocene Hemlock Conglomerate, a conglomeratic sandstone, with the remainder coming from the Oligocene and Miocene Tyonek Formation, a siliciclastic sandstone, and the Eocene West Foreland Formation, a volcaniclastic sandstone. The reservoir thickness ranges from 100 to 1,320 ft. Reservoir porosity ranges from 11 to 20.5 percent, and permeability from 10 to 4,960 mD. The seals for these accumulations are siltstones associated with these reservoirs. The traps are all structural.

The oil has an API gravity that ranges from 31 to 42° and a low sulfur content (<0.2 percent). It originated from the Middle Jurassic Chuitna Formation between the Swanson River and Middle Ground Shoal fields. Based on burial history of the source rock, the oil was generated as early as the Eocene and continued into the Pliocene.

0305. COOK INLET LATE MESOZOIC OIL PLAY (HYPOTHETICAL)

This hypothetical play for accumulations in structural traps covers 8,518 sq mi in the Cook Inlet Basin. The section unconformably underlies the Tertiary sedimentary rocks. Oil has been recovered from the Mesozoic from several wells in the Outer Continental Shelf in lower Cook Inlet and from wells in the Swanson River field area on the Kenai Peninsula.

Potential reservoir rocks are shallow marine and turbidite sandstones within the Upper Cretaceous Matanuska and Kaguyak Formations, Lower Cretaceous calcarenite, and feldspathic sandstones in the Upper Jurassic Naknek Formation. Where these units are penetrated by wells or found in outcrop, they are of poor reservoir rock quality. Seals are siltstones adjacent to these reservoirs and in the unconformably overlying Eocene West Foreland Formation.

The traps are mostly faulted anticlines that are truncated by the overlying Tertiary rocks, which in many cases contain the oil that migrated up through the Mesozoic section. Other possibilities are unconformities and stratigraphic traps, but these would be very difficult to map using such poor-quality seismic data.

As in the Hemlock-Tyonek Oil Play (0304), the oil is expected to have an API gravity that ranges from 31 to 42° and a low sulfur content (<0.2 percent) and to have originated from the Middle Jurassic Chuitna Formation between the Swanson River and Middle Ground Shoal fields. Based on the burial history of the source rock, the oil was generated as early as the Eocene and continued into the Pliocene.

COPPER RIVER BASIN

By L. B. Magoon and Z.C. Valin

The Copper River Basin contains sedimentary rocks that range in age from Middle Jurassic to Holocene and only minor gas shows of unknown composition reported in one well. Eleven wildcat wells were drilled that penetrated rocks as old as Early Jurassic. Except of a fetid oil smell in the Nelchina Limestone in outcrop, no reported live oil shows in either outcrop or subsurface have been reported even though the geology is similar to the Cook Inlet Basin, an oil and gas producing area. Apparently, the Middle Jurassic rocks are a sandstone rather than a source rock. Thermal-maturity data from three wells where the sedimentary rocks are thickest indicate that the top of the oil-generation window is about 8,000 ft. Both plays in this province are hypothetical.

0306. COPPER RIVER UPPER CRETACEOUS-TERTIARY BIOGENIC GAS PLAY (HYPOTHETICAL)

This hypothetical play covers an area of 1,783 sq mi where the mostly Tertiary nonmarine sedimentary rocks are thickest and capable of generating and trapping biogenic gas. The reservoir rocks are Tertiary siliciclastic sandstones in the Matanuska Formation, and the seals are adjacent siltstone and shale(?) in the same unit. Anticipated traps are expected to be anticlines, faulted anticlines, or stratigraphic traps. The source rocks can be associated coal and organic-rich shale(?) in Tertiary sedimentary rocks and in the Upper Cretaceous Matanuska Formation. Because these possible source rocks are probably thermally immature, the hydrocarbon type is expected to be biogenic gas. The play probability is low because evidence is lacking for traps or sufficient gas to fill the traps.

0307. COPPER RIVER MESOZOIC OIL PLAY (HYPOTHETICAL)

This hypothetical play covers the area of 3,309 sq mi adjacent to and within the thickest part of the Copper River Basin because if oil is generated, it should be trapped in close proximity to the mature source rock. The reservoir rocks are siliciclastic sandstones in the Upper Jurassic Matanuska Formation, and the seals are the siltstone in the same formation. The traps are expected to be structural (faulted anticlines), stratigraphic, and a combination of the two. The source rock, if it is in this basin, is postulated to be the same one that is in the Cook Inlet Basin, the Middle Jurassic shale(?). If the source rock is thermally mature, it is expected to generate oil with associated gas. The play probability is low because evidence is lacking for sufficient oil to fill the traps.

GULF OF ALASKA

T. R. Bruns

The Gulf of Alaska area stretches about 400 miles from near Cross Sound to Prince William Sound, and extends seaward from lat 61_N and the United States-Canada border to include islands and offshore waters of the 3-mi territorial limit. The province is underlain by several tectonostratigraphic terranes, chiefly the Prince William and Yakutat terranes. Mesozoic and early Tertiary rocks of the Prince William terrane, the Valdez and Orca Groups respectively, have no resource potential. The Yakutat terrane includes rocks of the Mesozoic Yakutat Group, which roughly underlie the northern margin of the terrane, and Cenozoic rocks that underlie the southern two-thirds of the onshore regions and extend beneath the adjacent continental margin. Offshore, these Cenozoic rocks overlie a Paleocene oceanic basaltic basement between Kayak Island and the Dangerous River Zone and overlie the Yakutat Group east of the Dangerous River zone; presumably, the continuation of these basements underlies the onshore Cenozoic rocks. The Yakutat terrane is currently moving with the Pacific Plate and is colliding with and subducting beneath southern Alaska.

On the onshore Yakutat terrane, the Paleocene through Oligocene Stillwater Formation is composed of continental siltstone and sandstone prodelta deposits with a maximum thickness of about 10,000 ft. The Kulthieth Formation consists of thick, interfingering, coal-bearing alluvial-plain, delta-plain, barrier-beach, and shallow-marine deposits at least 9,000 ft thick. The Tokun Formation is the deltaic marine equivalent of the Kulthieth Formation and is up to about 2,000 ft thick. Oligocene through Miocene rocks of the Yakutat terrane compose the Poul Creek Formation, up to 6,000 ft thick and composed of shallow- to deep-water marine shales, in part organic-carbon rich, and characteristically glauconitic. The overlying Miocene and younger Yakataga Formation, up to 20,000 ft thick, is composed of interbedded siltstone, mudstone, sandstone, and most characteristically, glaciomarine diamictites.

The Cenozoic rocks, forming a band up to 6 mi wide along the shoreline near Lituya Bay, have been sampled in exploratory wells near Yakutat Bay and beneath the adjacent coastal plain east of Yakutat Bay. They crop out in an up to 45-mile-wide area of the coastal plain and foothills from about Yakutat Bay to the Ragged Mountain Fault west of Kayak Island. Cenozoic rocks are also found beneath Middleton Island and the submerged continental margin surrounding it. The Gulf of Alaska area, underlain by

Cenozoic rocks, is about 7,240 sq mi (Miller and others, 1959; Stoneley, 1967; Plafker, 1967; 1971; 1987).

A small oil field at Katalla produced 154,000 BO between 1902 and 1933. Yet, despite subsequent moderately extensive hydrocarbon exploration efforts onshore (25 wells and coreholes drilled and abandoned onshore between 1954 and 1963, and one well drilled in State waters near Middleton Island in 1969; Miller and others, 1959; Plafker, 1967, 1971, 1987) and in the adjacent offshore basin areas (12 wells drilled and abandoned between 1975 and 1983; Bruns, 1983, 1988; Bruns and Schwab, 1983; Plafker, 1987), no commercial hydrocarbon field has been discovered. Attributes indicative of a hydrocarbon province are present, including extensive onshore oil and gas seeps and numerous anticlinal traps (Blasko, 1976; Plafker, 1987). The Kulthieth, Tokun, Stillwater, and Poul Creek Formations and offshore equivalents are known to have some sections with favorable hydrocarbon characteristics, including source and reservoir rocks and thermal maturity. The late Cenozoic Yakataga Formation may have some reservoir potential, but no good source rocks are known within the formation (Plafker, 1987). Hydrocarbons, if present, must migrate into traps in the Yakataga Formation from the underlying early Tertiary rocks.

The structural complexity, the young development age of the potential hydrocarbon traps, and the overall poor reservoir characteristics of the Yakataga Formation have apparently prevented formation of commercial accumulations of hydrocarbons in the anticlines that have so far been tested, either onshore or on the adjacent continental margin. Although the resource potential of the area based on the unsuccessful drilling results must at present be considered as low, some unexplored targets remain to be tested.

Two hypothetical plays are identified for the Gulf of Alaska onshore province. They are: (1) the Yakataga Fold Belt Play (0308); and (2) the Yakutat Foreland/Lituya Bay Play (0309). The Yakataga Fold Belt Play includes the folded and faulted Cenozoic rocks lying between the Ragged Mountain Fault and the eastern edge of the fold belt that stretches from the east side of Icy Bay north along the northern margin of the Malaspina Glacier. The small region of State lands around Middleton Island is included in this play, although the geology is different. The Yakutat Foreland/Lituya Bay Play includes the less deformed Cenozoic rocks underlying the region between Icy Bay and Cross Sound.

0308. YAKATAGA FOLD BELT PLAY (HYPOTHETICAL)

This hypothetical play includes accumulations of petroleum, mainly oil and associated gas, in folded and thrust-faulted strata of Cenozoic age. Except for a small area around Middleton Island, the play lies in the fold and thrust belt that extends from the Ragged Mountain Fault-Kayak zone to the Pamplona zone at Icy Bay. Only the lower and middle Tertiary rocks are petroleum-prospective; the overlying Yakataga Formation is considered unprospective, mainly due to lack of organic carbon for source potential and poor reservoir potential. The play could also include oil generated in Tertiary rocks that have been carried deep beneath southern Alaska during the collision and subduction of the Yakutat terrane. Areas west of the Ragged Mountain Fault and north of the Chugach-Saint Elias Fault are mainly complexly deformed, metamorphosed rocks of the Paleocene and Eocene Orca Group and Late Cretaceous Valdez Group that have no petroleum potential. The lower Tertiary sedimentary rocks are as much as 13,000 ft total thickness in the Stillwater (10,000 ft maximum thickness), Kulthieth (9,000 ft maximum thickness), and Tokun (2,000 ft maximum thickness) Formations consisting of Eocene lagoon, barrier beach, and deltaic deposits, and about 6,000 ft in the Oligocene and Miocene Poul Creek Formation, consisting of a transgressive sequence of dominantly shaley strata, in part organic rich.

The play area includes Middleton Island and the contiguous state waters, thus encompassing an oval area about 12 mi long by 7.5 mi wide. An exploratory well was drilled into these rocks in 1969 and abandoned. Basement rocks are presumed to be of the Orca Group, which lie at an unknown depth. At least 13,000 ft of Cenozoic sedimentary rocks overlie the Orca Group, with a late middle Eocene age for the oldest dated samples from the bottom of the Middleton Island well. At least the upper 3,000 ft of this sequence is composed of late Cenozoic rocks of the Yakataga Formation. The play area lies on a broad, faulted high at the edge of the Middleton Shelf; rocks within the play area generally dip away from the high at less than about 20º, based on nearby marine seismic reflection data, but dip as much as 28º on Middleton Island. This area is geologically similar to the Kodiak region rather than to the Yakataga area, because the Middleton Shelf lies on the Prince William terrane rather than on the Yakutat terrane. In this case, hydrocarbon potential of the shelf is low based on stratigraphic drilling on the geologically similar Kodiak Shelf. Potential source rocks from the Kodiak region had low total organic carbon (TOC) content and contained mainly herbaceous, woody, or coaly kerogen which would generate mainly gas.

Reservoirs: Potential sandstone reservoir rocks are present in all the Cenozoic sequences. In the lower Tertiary sequences, the sandstones are characteristically poorly sorted, thermally immature, and mineralogically unstable. Diagenetic alteration of framework grains has produced widespread zeolite cement and pseudomatrix. Hence, permeabilities and porosities in these rocks are generally poor. In the Yakataga Formation, permeabilities are characteristically poor, or sands are tightly encased in shales and therefore not available to act as reservoirs for migrating hydrocarbons. Production in the Katalla field was primarily at shallow depths and aided by fracture porosity in the Poul Creek Formation. Reservoir characteristics for the Middleton Island are presumed to be the same as for the rest of the play area. The depth range of the Paleogene-age major source and reservoir rocks is from the surface to at least 30,000 ft (maximum observed thickness just offshore).

Source rocks: Potential source rocks are present in the Paleogene sedimentary rocks and the Poul Creek Formation. These rocks are thermally immature to mature in outcrop and well samples. Oil from onshore seeps away from the Katalla area is derived primarily from the Eocene rocks, based on a comparison of the hydrocarbon composition of the seep oil and the extractable hydrocarbons from potential source rocks. Oil in the Katalla area is derived from source rocks in the Poul Creek Formation. Samples from the Neogene and Quaternary Yakataga Formation are low in organic carbon and immature. The Yakataga Formation is therefore not considered a viable source rock. No source rocks were sampled in the Middleton Island well, but source rocks could be present in Paleogene rocks in the adjacent continental-margin areas.

Timing and migration: Development of the major onshore and offshore anticlinal traps occurred during late Cenozoic and Quaternary time, probably mostly during the Pliocene and later. Generation and migration of hydrocarbons from the Paleogene rocks is most likely to have occurred during the late Cenozoic, concurrent with burial by the thick Yakataga Formation, therefore allowing the generated hydrocarbons to migrate into structural traps. Migration of hydrocarbons appears to be largely fault controlled, based on the fact that onshore seeps are located mostly along faults. Hydrocarbons could also be generated in the thick sedimentary basins of the adjacent continental margins and migrate updip into the onshore areas or into the Middleton Shelf.

Traps: The play area is part of a fold and thrust belt formed by the complex deformation of the allochthonous Yakutat terrane during collision with southern Alaska. Numerous faulted anticlinal traps developed during the late Cenozoic. At least one anticline that developed in the Paleogene or early Neogene is present offshore eastward of the fold and thrust belt; similar Paleogene or early Neogene-developed traps could have been present in the fold and thrust belt region, and could have been overprinted by the late Cenozoic deformation. Traps could also have formed by structural or stratigraphic closure against faults. Structural complexity is so extreme as to make trap potential unfavorable on many, if not most, of the exposed onshore structures and may increase with depth. Shales in both the Poul Creek and Yakataga Formations could provide seals for underlying reservoir rocks.

Exploration status and resource potential: The play area is moderately explored. The Katalla field is the only field in the Gulf of Alaska that has produced commercial oil. Forty-four wells were drilled on or near this field between 1901 and 1930, all to depths less than 2,300 ft (Miller and others, 1959). Sixteen wells have been drilled elsewhere in the play area, mainly on the major anticlines, to depths as great as 14,700 ft (Plafker, 1971). Thus, the most favorable accessible structures have been tested. The failure to find commercial quantities of hydrocarbons is a result of the complicated structure, poor reservoir quality, thermal immaturity, or poor source rocks. Future exploration is justified on the basis of the known presence of oil. Prospects may be largely in hard-to-define traps lying below the surface structures and major thrust faults that cut the region.

The Middleton Island well may have effectively tested the entire area around Middleton Island, and future drilling here for hydrocarbons is probably unjustified unless significant accumulations are discovered in nearby areas of the Middleton or Kodiak continental-margin regions.

0309. YAKUTAT FORELAND/LITUYA PLAY (HYPOTHETICAL)

This hypothetical play includes hypothetical accumulations of petroleum, mainly oil and associated gas, in relatively undeformed strata of Cenozoic age. The play lies between Icy Bay and Cape Fairweather, seaward of the Fairweather and Boundary Faults. The play includes the areas beneath the ice of the Malaspina Glacier and the waters of Yakutat Bay, beneath the Yakutat Foreland, the coastal plain between Yakutat Bay and Cape Fairweather, and the Lituya Bay area. Since much of the play is covered by ice, water, or Quaternary alluvium, little is directly known of subsurface structure. The part that lies north or northeast of the onshore continuation of the Dangerous River zone is underlain by rocks of the Yakutat Group; these rocks have been sampled in coreholes east of Yakutat Bay. Tertiary strata dip steeply away from, and thicken seaward along and south of, the Dangerous River zone. Seaward of and along the Dangerous River zone continuation, thick sedimentary rocks are present and are inferred to include equivalents of the Paleogene Stillwater, Kulthieth, and Tokun Formations, the Oligocene and Miocene Poul Creek Formation, and the Miocene and younger Yakataga Formation. Onshore, Paleogene and Poul Creek Formation strata thin to the east; these strata are as much as 13,000 ft and 6,000 ft thick, respectively, west of Icy Bay but are not known to be exposed in the Lituya Bay area. The Yakataga Formation is as thick as 13,000 ft thick at Icy Bay and also thins to the east. However, just offshore, Paleogene rocks are up to 13,000 ft thick, and Yakataga Formation equivalents are up to 17,000 ft thick. Thus, thick sequences of Paleogene rocks are likely present beneath Malaspina Glacier and Yakutat Bay, and they have been sampled in wells near the shoreline in both Icy Bay and Yakutat Bay, and near the town of Yakutat.

Reservoirs: Potential reservoir rocks are the same as in the Yakataga Fold Belt Play. Overall reservoir potential in any of the formations is most likely poor to fair at best. The depth range of potential lower Tertiary reservoirs is from about 1,500 ft to perhaps 30,000 ft. These estimates are based on well results for the minimum figure and on estimated depth to the base of Paleogene rocks immediately offshore for the maximum figure.

Source rocks: Source rocks are the same as in the Yakataga Fold Belt Play and would lie in the Paleogene sequence. Rocks of the Cretaceous Yakutat Group and the late Cenozoic Yakataga Formation have no source-rock potential. No source rocks are known to be present in the Lituya Bay area; the Paleogene rocks found to the west are not known to be present in the Lituya Bay area either onshore or in the adjacent offshore.

Timing and migration: Generation and migration of hydrocarbons could have occurred anytime after deposition of the Paleogene strata, but may have occurred mostly during the late Cenozoic, concurrent with burial by the thick Yakataga Formation. The Dangerous River zone and the entire onshore region lie updip from the offshore Yakutat terrane basin axis. Thus, hydrocarbons generated in offshore Paleogene rocks during late Cenozoic burial could migrate updip into the onshore region. Some hydrocarbons have been generated; an exploratory well near Yakutat had oil and gas shows and still leaks a small amount of gas to the surface. Traps other than along the Dangerous River zone could be present beneath Yakutat Bay or the Malaspina area, perhaps created during early deformation of the Paleogene rocks.

Traps: Known or presumed potential traps lie largely along the Dangerous River zone. This feature developed in the early Tertiary, and traps could have formed either during the initial development or during subsequent deposition of strata against and over the zone. Few data are available from onshore to determine actual subsurface structure. Based on prior exploratory drilling, three traps are inferred. Two of these are gentle closures in Icy Bay (inferred from the Standard Oil Co. of California Rioux Bay No. 1 well) and on the west side of Yakutat Bay (inferred from the Colorado Oil and Gas Corp. Malaspina 1A well). The third structure lies near the shoreline of the Yakutat Foreland, where seaward-dipping rocks are truncated and may be folded into anticlines, or where a footwall anticline could be present beneath a thrust fault. This area has been partly tested by three wells (Colorado Oil and Gas Corp. Yakutat 1, 2, and 3 wells). Other structures could be present along the continuation of the Dangerous River zone onshore or beneath Yakutat Bay and the Malaspina Glacier.

Exploration status: The play area is moderately explored. Ten wells and coreholes as deep as 13,800 ft have been drilled within the region on structures defined on seismic-reflection data. Further exploration depends on identifying subtle structural or stratigraphic traps, primarily along the Dangerous River zone, and also in the thick sedimentary rocks south and southwest of the Dangerous River zone. Further exploration would be warranted if significant accumulations of oil were found in the adjacent offshore, or if generation and migration of hydrocarbons from the thick offshore Paleogene sequences upward into the onshore sections could be shown or inferred to have occurred.

KODIAK ISLANDS

By M. A. Fisher

The Kodiak group of islands is located in the western Gulf of Alaska and covers an area of about 7,800 sq mi. Most rocks exposed on the Kodiak islands are so strongly deformed and highly indurated that neither traps nor reservoir rocks for hydrocarbons are expected. The strong deformation is the result of a protracted Mesozoic and Cenozoic history of convergent-margin tectonics. Although the bleak assessment does not pertain to Miocene and younger rocks, their limited onshore exposure means that they could contain significant hydrocarbons only in offshore areas. Furthermore, within 3 mi of the shoreline (the offshore National territorial boundary), seismic-reflection data indicate that these rocks are thin and unlikely to contain hydrocarbons in economic quantities. Values of vitrinite reflectance and thermal alteration index from samples obtained on the islands suggest that Eocene and Oligocene rocks, as well as Neogene rocks, are either thermally immature or just barely mature for generating hydrocarbons. These rocks generally have less than 0.4 percent organic carbon, which is contained in woody and herbaceous kerogen. Paleocene and older rocks are thermally overmature for hydrocarbon generation. Scattered measurements of porosity and permeability indicate that rocks of nearly all ages would make poor reservoirs for hydrocarbons.

The Kodiak group of islands is underlain by the Peninsular, Chugach, and Prince William tectonostratigraphic terranes. Along the northwest coasts of the islands, the Peninsular and Chugach terranes lie sutured along the Border Ranges Fault. The Peninsular terrane includes Triassic sandstone and greenstone as well as Early Jurassic plutonic and metamorphic rocks. The Chugach terrane includes a Cretaceous melange and strongly deformed, uppermost Cretaceous turbidite sequences. The Prince William terrane crops out along the southeast coasts of the islands and is represented by Paleogene strongly deformed turbidite sequences, melange, and locally exposed basalt. Post-Eocene rocks form an overlap sequence that crops out in scattered patches, and the sequence unconformably overlies the Eocene and older turbidite sequences. The overlap sequence includes Oligocene nonmarine and Miocene marine sandstone as well as upper Miocene sandstone and conglomerate.

Six Continental Offshore Stratigraphic Test (COST) wells were drilled offshore, but these wells led to no sustained offshore exploration activity, and the onshore area of this province has rightly been ignored. No plays were identified in this area, and no assessment of resources was made.

SOUTHEAST ALASKA AREA

By T.R. Bruns

The southeast Alaska area, about 400 mi long by 125–150 mi wide, encompasses all islands and lands of southeast Alaska from Dixon Entrance to northwest of Cross Sound and seaward of the United States–Canada border, and includes territorial waters that stretch 3 miles offshore of the islands. The terrain is heavily forested and mountainous, with deep channels separating the mainland and the offshore islands. The entire area is underlain by a diverse assemblage of moderately to highly metamorphosed, intruded, and deformed Paleozoic and Mesozoic rocks comprising parts of five fault-bounded tectonostratigraphic terranes. Cenozoic rocks are represented by numerous plutons and local, thin nonmarine or deltaic rocks (Berg, 1979; Monger and Berg, 1985).

No hydrocarbon exploration has occurred in the region, and no petroleum fields or seeps are known. None of the criteria required for petroleum generation and accumulation are known to be present onshore or in immediately adjacent offshore areas in southeast Alaska. With the exception of the thin nonmarine and deltaic Cenozoic deposits, all the rocks underlying the islands or beneath the 3-mile limit surrounding the islands are intruded, indurated, metamorphosed, and (or) deformed to a degree that makes these rocks effective economic basement for hydrocarbons. No potential source or reservoir rocks are known. Cenozoic rocks present in the adjacent offshore basins around southeast Alaska do not crop out onshore, and the petroleum potential of these offshore Cenozoic basins is also considered poor (Bruns and Carlson, 1987; Yorath, 1987; Bruns, 1988). Thus, little potential exists for migration of hydrocarbons from these Cenozoic basins updip into the onshore region, even if reservoir rocks and traps exist onshore. No meaningful hydrocarbon plays can be identified. This area of southeast Alaska must be considered as having negligible hydrocarbon resource potential.

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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Table 1. Alaska Peninsula and adjacent Outer Continental Shelf wells, listed chronologically
(GR, ground: KB, Kelly bushing; TD, total depth; Mz, Mesozoic; Tr, Triassic; LJ. Lower Jurassic; MJ, Middle Jurassic; UJ, Upper Jurassic; UK, Upper Cretaceous; BHT, bottom-hole temperature; DST, drill-stem test)

YEAR (and objective)	WELL (and formation at surface and total depth)	COMMENTS
1903 (Mz)	Pacific Oil and Commercial Pacific Oil No. 1 NW/4 Sec 3, T. 29 S., R. 40 W. GR. ? (MJ Shelikof), TD 1421 ft (MJ Shelikof)	Shallow well drilled near oil seeps at north end of Bear Creek anticline. (See well no. 3 below)
1903 (Mz)	J.H. Costello Costello No. 1 NW/4 Sec. 10, T. 29 S., R. 40 W. GR. ? (MJ Shelikof), TD 728 ft (MJ Shelikof)	Shallow well drilled near oil seeps at north end of Bear Creek anticline. (See well no. 3 below)
1904 (Mz)	Pacific Oil and Commercial Pacific Oil No. 2 SE/4 Sec. 3, T. 29 S., R. 40 W. GR. ? (MJ Shelikof), TD 1542 ft (MJ Shelikof)	Shallow well drilled near oil seeps at north end of Bear Creek anticline. (See well no. 3 below)
1904 (Mz)	J.H. Costello Costello No. 2 SE/4 Sec. 10, T. 29 S., R. 40 W. GR. ? (MJ Shelikof) TD Unknown (MJ Shelikof?)	Shallow well drilled near oil seeps at north end of Bear Creek anticline. (See well no. 3 below)
1923 (Mz)	Standard Lathrop No. 1 SE/4 Sec. 17, T. 29 S., R. 43 W. GR. ? (UJ Naknek), TD 500 ft (UJ Naknek)	Shallow well drilled near oil seeps on Pearl Creek dome (Ugashik anticline). (See well no. 1 below)
1923 (Mz)	Tidewater Associated Finnegan No. 1 NE/4 Sec. 30, T. 29 S., R. 43 W. GR. ? (UJ Naknek), TD 560 ft (UJ Naknek)	Shallow well drilled near oil seeps on Pearl Creek dome (Ugashik anticline). (See well no. 1 below)
1925 (Mz)	Standard Oil McNally No. 1 NW/4 Sec. 29, T. 29 S., R. 43 W. GR. ? (UJ Naknek), TD 510 ft (UJ Naknek)	Shallow well drilled near oil seeps on Pearl Creek dome (Ugashik anticline). (See well no. 1 below)
1923-25 (Mz)	Tidewater Assoc. Alaska No. 1 SW/4 Sec. 20, T. 29 S., R. 43 W. GR. 694 ft (UJ Naknek), TD 3033 ft (MJ Shelikof)	Shallow well drilled near oil seeps on Pearl Creek dome (Ugashik anticline). (See well no. 1 below)
1. 1923-26 (Mz)	Standard Lee No. 1 SW/4 Sec. 20, T. 29 S. R. 43 W. GR. 764 ft (UJ Naknek), TD 5053 ft (MJ Shelikof)	Deepest well on Pearl Creek dome. Cable-tool rig. Large oil seeps near axis of. structure.
2. 1938-40 (Mz)	Standard, et al Grammer No. 1 Sec. 10, T. 30 S., R. 41 W. KB 375 ft (MJ Shelikof), TD 7596 ft (Lower Jurassic)	Drilled on large closed structure (Bear Creek anticline). No data available (See well no. 11 below). Oil seeps in area
3. 1957-59 (Mz)	Humble-Shell Bear Creek Unit No. 1 Sec. 36, T. 29 S., R. 41 W. KB 927 ft (MJ Shelikof), TD 14,374 ft (Triassic)	Large closed anticline (Bear Creek anticline). Drilled mostly shale and tuff, minor gas and oil shows. No porosity in few sandstones drilled.
4.1959 (Tert.)	General Petroleum Great Basins No. 1 Sec. 2, T. 27 S., R. 48 W. reported. KB 231 ft (Qal), TD 11,080 ft (Mz granite)	Good porosity in Pliocene and Miocene down to 4000 ft, tight below. No tests BHT 183°F, 1.71°F/100 ft (AAPG*, 1.62°F/100 ft).
5. 1959 (Tert.)	General Petroleum Great Basins No. 2 Sec. 35, T. 25 S., R. 50 W. KB 105 ft (Qal), TD 8865 ft (Mz granite)	Fair to good porosity, no sample shows, no tests reported.

YEAR (and objective)	WELL (and formation at surface and total depth)	COMMENTS
6. 1961 (Mz)	Pure Canoe Bay No. 1 Sec. 8, T. 54 S., R. 78 W. KB 1221 ft (UK Hoodoo), TD 6642 ft (UJ Naknek)	Drilled sltst, sh, and some vf ss, minor sills, no shows. No cores or tests reported. BHT 160°F, 2.29°F/100 ft.
7. 1962-63 (Mz)	Richfield Wide Bay Unit No. 1 Sec. 5, T. 33 S., R. 44 W. minor tight ss in MJ, common light oil KB 54 ft (MJ Kialagvik), TD 12,568 ft (Triassic)	Very large closed anticline, 100,000+ acre areal closure. Drilled sh, sltst, & stain. Tuff, tuff sh, some basalt in LJ & Tr, some lst. No tests reported. Max BHT 283°F, 2.00°F/100 ft (AAPG*, 1.96°F/100 ft).
8. 1963 (Tert.)	Gulf Sandy River Fed. No. 1 Sec. 10, T. 46 S., R 70 W. KB 235 ft (Qal), TD 13,068 ft (Olig. Stepovak)	Good porosity (loose sand) to 10,000' (Bear Lake Fm), oil show in lower part of hole (Stepovak Fm). No tests reported. BHT 235°F, 1.86°F/100 ft (AAPG*, 1.82°F/100 ft).
9. 1966 (Tert.)	Great Basins Ugashik No. 1 Sec. 8, T. 32 S., R. 52 W. KB 142 ft (Qal), TD 9476 ft (Olig. Meshik)	Porous loose sand in Bear Lake Formation. Mostly Meshik Volcanics below 4000 ft. BHT 198°F, 2.08°F/100 ft.
10. 1967 (Mz)	Cities Service Painter Creek No. 1 Sec. 14, T. 35 s., R. 51 W. KB 394 ft (Plio. Milky River), TD 7912 ft (UJ Naknek)	Mostly conglomerate below 2000', vol & met clasts below; more granitics above, very little porosity, some oil stain BHT 150°F, 1.85°F/100 ft.
11. 1969 (Cretaceous?) (Tert.-Mz?)	Pan American David River No. 1-A Sec. 12, T. 50 S., R. 80 W. KB 70 ft (Plio. Milky River), TD 13,769 ft (UK Chignik?)	Three DSTs, recovered 545 barrels of water per day and 410 barrels of water per day (Tolstoi Fm), minor gas. BHT 285°F, 2.07°F/100 ft (AAPG*, 1.97°F/100 ft).
12. 1970 (Tert.)	Pan American Hoodoo Lake No. 1 Sec. 21, T. 50 S., R. 76 W. KB 141 ft (Plio. Milky River), TD 8048 ft (Olig. Stepovak)	One DST, recovered 7000' water (Stepovak or lower Bear Lake Formations). No shows. BHT 134°F, 1.65°F/100 ft.
13. 1970 (Tert.-Mz)	Pan American Hoodoo Lake No. 2 Sec. 35, T. 50 S., R. 76 W. KB 345 ft ((Plio. Milky River), TD 11,243 ft (UJ Naknek?)	Three DSTs, recovered 727 ft mud (Tolstoi or Chignik Fms). Trace to 6% porosity, tight, no shows, except some oil cut mud on DST. BHT 194F°, 1.73 to 2.27°F/100 ft.
14. 1972 (Tert.)	Gulf Port Heiden Unit No. 1 Sec. 20, T. 37 S., R. 59 W. KB 36 ft (Qal), TD 15,015 ft (Olig. Meshik)	In Meshik volcanics below 9200 ft. BHT 288°F, 1.75 to 1.91°F/100 ft
15. 1974 (Mz)	Amoco Cathedral River No. 1 Sec. 29, T. 51 S., R. 83 W. KB 178 ft (UJ Naknek), TD 14,301 ft (Triassic)	Nine DSTs, best recovery: 1500 ft gas cut mud & 3150' ft slightly salty water. BHT 278°F, 1.65 to 1.94°F/100 ft.
16. 1977 (Mz)	Phillips Big River No. A-1 Sec. 15, T. 49 S., R. 68 W. KB 281 ft (Olig. Stepovak), TD 11,371 ft (UJ Naknek)	No cores or tests, many sidewall cores, 6-12% porosity in Chignik Formation sandstones. BHT 398°F 3.21-3.61°F/100 ft (very high gradient).

YEAR (and objective)	WELL (and formation at surface and total depth)	COMMENTS
17. 1981 (Mz)	Chevron Koniag No. 1 Sec. 2, T. 38 S., R. 49 W. KB 62 ft (UJ Naknek), TD 10,905 ft (?)	
18. 1983 (Tert.)	Amoco Becharof No. 1 Sec. 15, T. 28 S., R. 48 W. KB 220 ft (Qal), TD 9022 ft (Mz basement)	

Offshore Wells

19. 1982-83 (Tert.)	Arco North Aleutian Basin COST No. 1 56.274° N. lat., 171.976° W. long. KB 74 ft (Quat.-Pleistocene), TD 17,155 ft (Eocene)	See Turner (1988) - (MMS Report 88-0089) for complete details. BHT (corrected) 316°F, 1.7°F/100 ft.
20. 1984-85 (Tert.-Mz)	Chevron Cardinal-1A (OCS Y-0248 No. 1-A) 58.341 N. lat., 153.542 W. long. KB ? TD 10,130 ft (TVD 9948 ft) in UK	Went from Tertiary (Tolstoi?) into Upper Cretaceous (Shelikof Strait) Kaguyuk (or Hoodoo) Formation at 2500 ft. TD in same.

Geothermal gradients: Tertiary ranges from 1.65° to about 2.07°F/100 ft. Average=1.86°F/100 ft.
Mesozoic ranges from 1.65° to over 3.20°F/100 ft Average= 2.01°F/100 ft not using 3+°F/100 ft value
or 2.19F°/100' ft using 3+°F/100 ft value.

AAPG* Geothermal gradient data from 1976 AAPG and USGS Geothermal Gradient Map of North America.

(To convert °F/100 ft to °C/km, multiply by 18.227)