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Maps Showing Sedimentary Basins, Surface Thermal Maturity, and Indications of Petroleum in the Central Alaska Province

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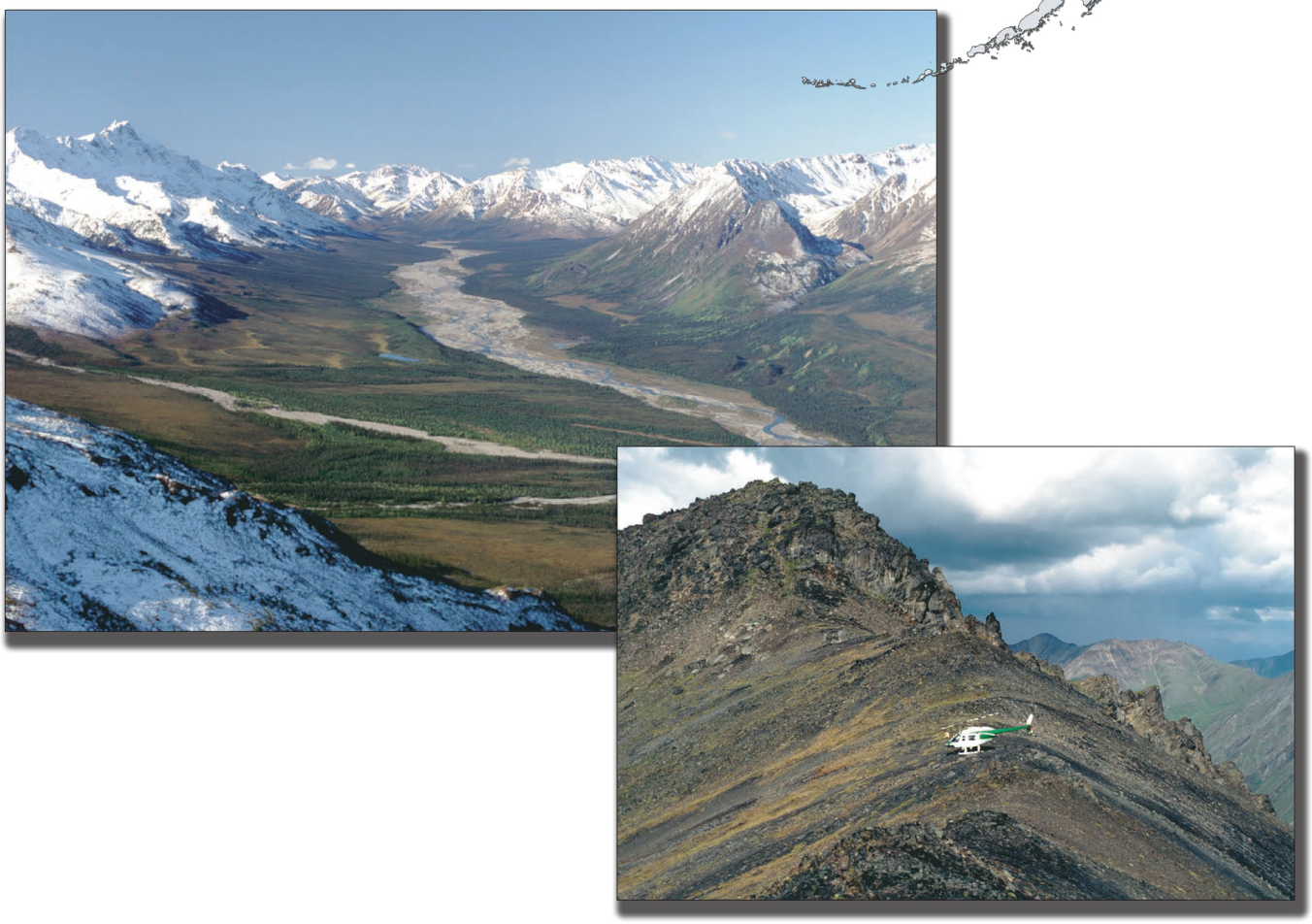

Pamphlet to accompany
Miscellaneous Field Studies Map MF-2428

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Table 1. Descriptions of reported indications of petroleum in central Alaska

Map No.	Feature	Description and source(s) of information
		Kotzebue basin and vicinity
1	Oil seep, reported but doubtful or disproved	A reported oil seep on the Noatak River was investigated by the U.S. Geological Survey and determined to be "very doubtful" (Miller and others, 1959, p. 81). The reported location of this seep is in Paleozoic sedimentary rocks (Smith, 1913; C.G. Mull and J.R. Dumoulin, oral and written communs., 2003). Samples from these rocks yielded conodont alteration index values of 4.5-5.0 (Johnsson and others, 1992) and, therefore, are at or near an igneous-metamorphic level of thermal maturity (*B*, map sheet), which is generally an unfavorable geologic setting for the occurrence of oil.
2	Well with gas show(s)	A hole drilled in 1949-1950 at Kotzebue to test for fresh water at depth found gas under high pressure in Quaternary deposits at a depth of about 73 m. The gas lifted the heavy string of drilling tools some distance into the air, showered the area with mud, and continued to flow at decreasing pressure for more than 24 hours. The well reportedly penetrated gravel to a depth of about 7 m, blue mud to a depth of about 24 m, thawed gravel containing salt water at 24-25 m, frozen blue clay or mud containing sand and gravel at 25-73 m, and thawed brown silt saturated with salt water from 73 m to the bottom of the hole at 99 m (Cederstrom, 1952, p. 35; Miller and others, 1959, p. 81). The gas is thought to have been derived from decaying vegetal material in the Quaternary deposits (Miller and others, 1959, p. 81).
3	Well with gas show(s)	The Standard Oil Company of California Nimiuk Point Well No. 1 was drilled for oil and gas exploration in 1974 to a total depth of 1,924 m and abandoned as a dry hole. The mudlog depicts small amounts of methane at about 120-180 m and trace amounts of gas, possibly including methane, at about 230 m, 1,145 m, and 1,190 m. The mudlog also shows a trace of tar contamination at about 230 m, but the source of the contamination is unclear. A formation test of the interval 1,078-1,145 m recovered salt water but no oil or gas. Rock-Eval pyrolysis (see Peters, 1986, for an explanation of the Rock-Eval technique) of ditch samples at depths of 241 m and 433 m found evidence of bitumen in the form of coalescing S1 and S2 peaks; organic geochemical analyses (including chromatograms) suggest that this bitumen is biodegraded, thermally immature, and probably derived from terrigenous organic material (unpub. oil industry data).
4	Well with gas show(s)	Gas was found at a depth of 27 m in a seismic shot hole drilled in 1973 by the Standard Oil Company of California on the Kobuk River Delta, about 53 km southeast of Kotzebue. Laboratory analysis of the gas (unpub. oil industry data) showed it to consist of about 66 % methane, 26 % nitrogen, 6 % oxygen, 2 % carbon dioxide, and trace amounts of ethane and higher alkanes. No isotopic data are available, but the high proportion of methane compared to ethane and higher alkanes suggest that the gas was mostly or entirely of microbial origin. Analyses of two samples of gas from a second seismic shot hole yielded 96-97 % methane, 1-2 % nitrogen, 1-2 % carbon dioxide, and trace amounts of ethane and higher alkanes (unpub. oil industry data). The high proportion of methane relative to ethane and higher alkanes in these samples suggests that most or all of the methane in these samples was microbially produced. The origin of the very small quantities of ethane and higher alkanes in the samples is uncertain and (1) may have been microbially produced, (2) may be contaminants that were introduced during drilling, or (3) may represent thermogenically produced gas that was generated at much greater burial depths and then migrated to shallower levels where it mixed with microbially produced gas. Methane from these samples yielded carbon isotopic ($\delta^{13}C$) values of –49.3 and –51.3 per mil. These values are generally heavier than the values of –50 to –60 ppm that are typical of microbially produced methane (Wiese and Kvenvolden, 1993) and may have resulted from (1) isotopic fractionation by methane-oxidizing bacteria, (2) mixing of thermogenic and microbial methane, (3) or a combination of these processes.
5	Well with gas show(s)	Gas was found at a depth of 20 m in a seismic shot hole drilled in 1973 by the Standard Oil Company of California on the Kobuk River Delta, about 64 km southeast of Kotzebue. A sample of the gas was found to consist of about 64 % methane, 19 % nitrogen, 17 % carbon dioxide, less than 1 % oxygen, and trace amounts of ethane and higher alkanes (unpub. oil industry data). No isotopic data are available, but the large proportion of methane compared to ethane and higher alkanes suggest that the gas was mostly or entirely of microbial origin.
6	Well with gas show(s)	The Standard Oil Company of California Cape Espenberg Well No. 1 was drilled for oil and gas exploration in 1975 to a total depth of 2,552 m and abandoned as a dry hole. No shows of oil or gas were reported in the well history, but the mudlog depicts small amounts of methane associated with coal-bearing

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Map No.	Feature	Description and source(s) of information
		strata. Formation tests of four intervals recovered some salt water but no oil or gas. Rock-Eval pyrolysis of ditch samples at depths of 442 m and 698 m found evidence of bitumen in the form of coalescing S1 and S2 peaks; organic geochemical analyses (including chromatograms) of this bitumen suggest that it is biodegraded, thermally immature, and probably derived from terrigenous organic material.
7	Oil seep, reported but doubtful or disproved	A reported oil seep located about 25 km southeast of Devil Mountain in the northern coastal plain of the Seward Peninsula is said to be marked by "a spring that never freezes and leaves a red stain, tasting like gasoline in the snow" (Miller and others, 1959, p. 81-82). This occurrence was later investigated by a bush pilot who reported a pond covered with slush ice in which there were five holes from which water was issuing, one of which smelled strongly of gasoline or crude oil. D.M. Hopkins (U.S. Geological Survey geologist) flew over the site in 1949 and later stated that he believed it to be a warm spring and that any gases present were marsh gases from decaying peat; but it was conceivable that it could be an oil seep (Miller and others, 1959, p. 81-82).
8	Oil seep, reported but unconfirmed	A reported oil seep in the headwaters area of the Nugnugaluktuk River, about 15-25 km south of Devil Mountain in the northern coastal plain of the Seward Peninsula, is said to have been marked by an oil slick on a small lake but has not been investigated by the U.S. Geological Survey (Miller and others, 1959, p. 81). A sample reportedly collected from the seep yielded gasoline upon distillation and therefore was undoubtedly a mineral oil, according to a laboratory report dated 1922 and cited by Miller and others (1959, p. 81).
		Norton Sound and vicinity
9	Oil seep, reported but unconfirmed	Oil seeps have been reported in the Sinuk Valley near the junction of the Sinuk and Stewart Rivers about 32 km northwest of Nome but have not been investigated by the U.S. Geological Survey (Miller and others, 1959, p. 80, plate 1). The Bartholomae Oil Company reportedly drilled several exploratory wells in the area but the precise locations and dates of these wells are uncertain (Miller and others, 1959, p. 80). The reported occurrence of oil is difficult to reconcile with the geologic map of Sainsbury and others (1972), which indicates that rocks on either side of the Sinuk River near its junction with the Stewart River are of metamorphic origin and consist mainly of Precambrian and Paleozoic schist and marble.
10	Oil seep, reported but doubtful or disproved	Oil seeps have been reported from the coastal plain near Nome but their existence was regarded as doubtful, without further explanation or discussion, by Miller and others (1959, p. 80, plate 1).
11	Well with gas show(s)	Four exploratory oil wells were drilled in the coastal plain near Nome (Cathcart, 1920, p. 196-197; Miller and others, 1959, p. 80). Two wells were drilled in 1906; the first well encountered gas at a depth of 37 m which pushed a heavy string of drilling tools about 23 m up the hole, whereas the second well was 57 m deep and reportedly yielded a trace of oil. Two more wells were drilled in 1918; the first well was abandoned at a depth of 64 m owing to the loss of a bailer in the hole, and the second well reached a depth of about 46 m before drilling was apparently stopped (Cathcart, 1920, p. 196-197; Miller and others, 1959, p. 80).
12	Gas seep, confirmed	In 1976, a submarine seep of gas was discovered in Norton Sound about 40-50 km south of Nome (Cline and Holmes, 1977; Kvenvolden and Claypool, 1980). Subsequent sampling and analysis showed that the gas consisted of about 98 % CO_2 with minor amounts of hydrocarbons consisting of gas-range (C_1 to C_4) and gasoline-range (C_5 to C_8) molecules (Kvenvolden and Claypool, 1980). The molecular and isotopic characteristics of the hydrocarbons suggest that they formed by thermal alteration of marine and (or) nonmarine organic matter buried within Norton basin, whereas the CO_2 probably formed from decarbonation of carbonate rocks by heat or fluids (Kvenvolden and Claypool, 1980).
13	Well with oil show(s)	The ARCO OCS Y-0436 Well No. 1 in Norton Sound was drilled in 1984 to explore for oil and gas on the Birch prospect. It penetrated to a total depth of 3,338 m and was abandoned as a dry hole. The well was located about 53 km southwest of Nome in about 20 m of water. The mudlog indicates strong shows of methane at depths of 366-1,097 m; sporadic, weak shows of oil at 2,377-2,560 m; and numerous minor shows of gas (including methane, ethane, and higher alkanes) at many intervals below 2,560 m. However, none of these shows were considered worthy of a drill stem test (Smith, 1994, p. 37).

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Map No.	Feature	Description and source(s) of information
14	Well with gas show(s)	The COST Well No. 1 in Norton Sound was drilled as a stratigraphic test in 1980 to a total depth of 4,475 m and abandoned as a dry hole. The well was located in about 30 m of water in the St. Lawrence subbasin, about 87 km southwest of Nome. Biogenic methane was reported at depths shallower than 1,800 m and traces of thermogenic hydrocarbons were found at depth, but no significant oil shows were encountered in this well (Turner and others, 1986, p. 103).
15	Well with gas show(s)	The Exxon OCS Y-0414 Well No. 1 in Norton Sound was drilled in 1984 to explore for oil and gas on the South Teton prospect. It reached a total depth of 1,108 m and was abandoned as a dry hole. The well was located about 101 km southeast of Nome in about 16 m of water. The mudlog shows moderate to strong shows of methane at about 366-640 m; minor shows of methane below 671 m; and a trace of oil at about 1,052-1,058 m. No drill stem tests were conducted (Desautels, 1988, p. 522-524; Smith, 1994, p. 37).
16	Well with gas show(s)	The Exxon OCS Y-0407 Well No. 1 in Norton Sound was drilled in 1985 to explore for oil and gas on the Yellow Pup prospect. It attained a total depth of 2,398 m and was abandoned as a dry hole. The well was located about 99 km southeast of Nome in about 17 m of water. The mudlog depicts moderate to strong shows of methane at about 640-945 m and sporadic, weak to moderate shows of gas associated with coal-bearing intervals at about 975-1,006 m, 1,600-1,783 m, and 2,179-2,316 m. Some of the gas is thought to be of thermogenic origin, but no oil shows were encountered (Desautels, 1988, p. 527) and no drill stem tests were conducted (Smith, 1994, p. 37).
17	Well with gas show(s)	The Exxon OCS Y-0398 Well No. 1 in Norton Sound was drilled in 1985 to explore for oil and gas on the Cascade prospect. It penetrated to a total depth of 2,107 m and was abandoned as a dry hole. The well was located about 99 km southeast of Nome in about 17 m of water. The mudlog depicts numerous small indications of methane throughout the well, and many of the methane shows at 853-1,646 m appear to be associated with coal-bearing intervals. Minor fluorescence was noted on the mudlog at 1,503-1,506 m and 1,637-1,655 m, but no oil shows were encountered and no drill stem tests were conducted (Desautels, 1988, p. 526; Smith, 1994, p. 37).
18	Well with oil show(s)	The COST Well No. 2 in Norton Sound was drilled in 1982 as a stratigraphic test to a total depth of 4,538 m and was abandoned as a dry hole. The well was located in about 15 m of water in the Stuart subbasin, about 110 km southeast of Nome. Biogenic gas was found in near-surface sandstones, and minor shows of gas, oil, and solid bitumen were reported from Eocene strata below depths of about 3,000 m (Turner and others, 1986, p. 117, 121). Oil from a show at 3,731 m is paraffinic and thought to have been generated from nearby nonmarine source rocks (Desautels, 1988, p. 518-519). A strong show of gas was encountered in sandstone at about 3,722 m (Smith, 1994, p. 43).
19	Well with gas show(s)	The Exxon OCS Y-0425 Well No. 1 in Norton Sound was drilled in 1985 to explore for oil and gas on the flank of the Chugach prospect. It reached a total depth of 1,857 m and was abandoned as a dry hole. The well was located about 124 km southeast of Nome in about 12 m of water. The mudlog depicts no indications of oil but evinces moderate to strong shows of methane at depths of about 366-914 m and minor shows of gas (including methane, ethane, and higher alkanes) in a coal-bearing interval at about 1,494-1,692 m. No drill stem tests were conducted (Desautels, 1988, p. 527; Smith, 1994, p. 37 and p. 39).
20	Well with oil show(s)	The Exxon OCS Y-0430 Well No. 1 in Norton Sound was drilled in 1984 to explore for oil and gas on the Chugach prospect. It attained a total depth of 1,509 m and was abandoned as a dry hole. The well was located about 132 km southeast of Nome in about 11 m of water. The mudlog exhibits numerous small to moderate shows of methane at depths of about 365-1220 m and sporadic, minor shows of methane and higher alkanes below 1,250 m. No indications of oil are shown on the mudlog, but a subsequent report by Desautels (1988, p. 522) states that small amounts of free oil containing about 2 % sulfur were found while coring Paleozoic(?) schist below 1,463 m. The source of this high-sulfur oil is unknown but may have been carbonate rocks within the Paleozoic(?) interval. No drill stem tests were conducted (Desautels, 1988, p. 522-525).
21	Oil seep, reported but unconfirmed	An oil seep reportedly occurs along the Inglutalik River, which drains into Norton Bay, but has not been investigated by the U.S. Geological Survey (Miller and others, 1959, p. 80).
22	Outcrop of oil shale or	Oil shale reportedly occurs on Besboro Island in Norton Sound (Miller and others, 1959, p. 80). A 1958

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Map No.	Feature	Description and source(s) of information
	oil-bearing rock	U.S. Geological Survey field investigation, however, found no oil shale and determined that Besboro Island consists mostly or entirely of altered volcanic and volcaniclastic rocks correlative with those of the Koyukuk terrane (W.H. Patton, oral commun., 2002). On the basis of this investigation and the apparently unfavorable geologic setting, the reported occurrence of oil shale is herein regarded as doubtful.
		Yukon Delta
23	Gas seep, reported but unconfirmed	A gas (or, possibly, oil) seep on the Yukon Delta about 24 km northwest of Kotlik was reported by a local resident (Foley and Enos, 1997) but has not been investigated by the U.S. Geological Survey.
24	Gas seep, reported but unconfirmed	A gas (or, possibly, oil) seep on the Yukon Delta about 16 km northwest of Kotlik was reported by a local resident (Foley and Enos, 1997) but has not been investigated by the U.S. Geological Survey.
25	Gas seep, confirmed	An accumulation of gas beneath recently formed lake ice was observed by Foley and Enos (1997) on the Yukon Delta about 14 km northwest of Kotlik. A sample of gas from this locality was found to consist almost entirely of air, but the sample also included a trace (0.05 %) of methane that presumably was derived from a natural gas seep and a trace (0.016 %) of hexanes and higher alkanes of unknown origin. No isotopic analysis was done because the amount of methane in the sample was insufficient. The site has not been investigated by the U.S. Geological Survey.
26	Oil seep, reported but unconfirmed	An oily sheen was observed on the ice-covered surface of a lake on the Yukon Delta about 8 km north of Kotlik. A sample of water from this locality was found to contain hydrocarbons in the C_{22-34} range (Foley and Enos, 1997), which is similar to the ranges of heavy gas oil and lubricating oil (Hunt, 1995, p. 39), but the specific identities and origins of the hydrocarbons from this locality are unknown (Foley and Enos, 1997). The site has not been investigated by the U.S. Geological Survey.
27	Gas seep, reported but unconfirmed	A gas (or, possibly, oil) seep on the Yukon Delta about 11 km west of Kotlik was reported by a local resident (Foley and Enos, 1997) but has not been investigated by the U.S. Geological Survey.
28	Gas seep, reported but unconfirmed	An accumulation of gas beneath recently formed lake ice was observed by Foley and Enos (1997) on the Yukon Delta about 6 km northeast of Kotlik. No sample was collected and the site has not been investigated by the U.S. Geological Survey.
29	Gas seep, reported but unconfirmed	A gas (or, possibly, oil) seep on the Yukon Delta about 6 km northeast of Kotlik was reported by a local resident (Foley and Enos, 1997) but has not been investigated by the U.S. Geological Survey.
30	Gas seep, reported but unconfirmed	A gas (or, possibly, oil) seep on the Yukon Delta about 14 km east of Kotlik was reported by a local resident (Foley and Enos, 1997) but has not been investigated by the U.S. Geological Survey.
31	Gas seep, reported but unconfirmed	An accumulation of gas beneath recently formed lake ice was observed by Foley and Enos (1997) on the Yukon Delta about 19 km east of Kotlik. No sample was collected and the site has not been investigated by the U.S. Geological Survey.
32	Gas seep, reported but unconfirmed	A gas (or, possibly, oil) seep on the Yukon Delta about 19 km east of Kotlik was reported by a local resident (Foley and Enos, 1997) but the site has not been investigated by the U.S. Geological Survey.
33	Gas seep, confirmed	An accumulation of gas beneath recently formed lake ice was observed on the Yukon Delta about 19 km southwest of Kotlik. A sample of gas from this locality (Foley and Enos, 1997) was found to consist mostly of air with about 5 % methane. The isotopic composition of the methane ($\delta^{13}C$ value of –68.38 per mil, δD value of -318.3 per mil) is consistent with a microbial origin (Wiese and Kvenvolden, 1993; Rice, 1993, p. 588). The site has not been investigated by the U.S. Geological Survey.
34	Gas seep, reported but unconfirmed	An accumulation of gas beneath recently formed lake ice was observed by Foley and Enos (1997) on the Yukon Delta about 8 km southwest of Kotlik. No sample was collected. The site has not been investigated by the U.S. Geological Survey.
35	Gas seep, confirmed	An accumulation of gas beneath recently formed lake ice was observed on the Yukon Delta about 6 km

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Map No.	Feature	Description and source(s) of information
		south of Kotlik. A gas sample from this locality (Foley and Enos, 1997) was found to consist of air (about 62 %) and methane (about 38 %) that presumably was derived from a natural gas seep. The isotopic composition of the methane ($\delta^{13}C$ value of –72.74 per mil, δD value of -301.9 per mil) is consistent with a microbial origin (Wiese and Kvenvolden, 1993; Rice, 1993, p. 588). The site has not been investigated by the U.S. Geological Survey.
36	Gas seep, confirmed	An accumulation of gas beneath recently formed lake ice was observed on the Yukon Delta about 6 km southeast of Kotlik. A gas sample from this locality (Foley and Enos, 1997) was found to consist of air (about 48 %) and methane (about 52 %) that presumably was derived from a natural gas seep. The isotopic composition of the methane ($\delta^{13}C$ value of –82.24 per mil, δD value of -294.1 per mil) is consistent with a microbial origin (Wiese and Kvenvolden, 1993; Rice, 1993, p. 588). The site has not been investigated by the U.S. Geological Survey.
37	Gas seep, confirmed	An accumulation of gas beneath recently formed lake ice was observed on the Yukon Delta about 21 km south of Kotlik. A sample of gas from this locality (Foley and Enos, 1997) was found to consist of air (about 68 %), methane that presumably was derived from a natural seep (about 32 %), and a trace of hexanes and higher alkanes (0.0015 %) of unknown origin. The isotopic composition of the methane ($\delta^{13}C$ value of –65.36 per mil, δD value of-335.6 per mil) is consistent with a microbial origin (Wiese and Kvenvolden, 1993; Rice, 1993, p. 588). The site has not been investigated by the U.S. Geological Survey.
38	Gas seep, reported but unconfirmed	A gas (or, possibly, oil) seep on the Yukon Delta about 21 km south of Kotlik was reported by a local resident (Foley and Enos, 1997), but the site has not been investigated by the U.S. Geological Survey.
		Yukon-Koyukuk flysch belt of Kirschner (1988)
39	Well with no oil or gas shows	The P.G. Benedum Nulato Unit Well No. 1 was drilled for oil and gas exploration in 1960. It penetrated to a total depth of 3,662 m and was abandoned as a dry hole. No shows of oil or gas were reported and no drill stem tests were conducted. The well was spudded in an Upper Cretaceous sequence of sandstone, shale, conglomerate, and minor coal of fluvial and deltaic origin (Patton and Moll-Stalcup, 2000). The thermal maturity of rocks in this well, as determined from values of vitrinite reflectance (Johnsson and others, 1999), ranged from overmature near the surface (mean vitrinite reflectance, about 2.6 %) to supermature near the bottom of the hole (mean vitrinite reflectance, about 4.4 %).
		Innoko basin and vicinity
40	Oil seep, reported but doubtful or disproved	A reported oil seep along the Innoko River about 135 km northeast of Aniak is regarded as doubtful on the basis of field investigations by the U.S. Geological Survey (Miller and others, 1959, plate 1).
41	Oil seep, reported but doubtful or disproved	A reported oil seep along the Yukon River about 65 km northeast of Aniak is regarded as doubtful on the basis of field investigations by the U.S. Geological Survey (Miller and others, 1959, plate 1).
42	Oil seep, reported but unconfirmed	A reported oil seep on the northwest side of the Innoko River, about 50 km northeast of Anvik, has not been investigated by the U.S. Geological Survey (Miller and others, 1959, plate 1).
43	Oil seep, reported but unconfirmed	A reported oil seep on the southeast side of the Innoko River, about 50 km northeast of Anvik, has not been investigated by the U.S. Geological Survey (Miller and others, 1959, plate 1).
44	Gas seep, reported but doubtful or disproved	A reported gas seep, located along the Yukon River about 30 km north of Anvik, is regarded as doubtful on the basis of field investigations by the U.S. Geological Survey (Miller and others, 1959, plate 1).
45	Gas seep, reported but unconfirmed	Pockets of gas reportedly collect beneath the ice of the Yukon River at Anvik. During the winter, children break the ice and ignite the gas, which burns for periods as long as a minute. The gas is thought to be derived from decaying vegetal material in the underlying alluvial deposits (Miller and others, 1959, p. 70).
		Bethel basin and vicinity

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Map No.	Feature	Description and source(s) of information
46	Oil seep, reported but doubtful or disproved	A reported oil seep, located about 50 km southwest of Anvik along the Stuyahok River, is regarded as doubtful on the basis of field investigations by the U.S. Geological Survey (Miller and others, 1959, plate 1).
47	Oil seep, reported but unconfirmed	A reported oil seep along the Yukon River near the village of Paimiut, about 70 km south of Anvik, has not been investigated by the U.S. Geological Survey (Miller and others, 1959, plate 1).
48	Oil seep, reported but doubtful or disproved	A reported oil seep along the Yukon River near Toklik (formerly called Bennetts), about 95 km north of Bethel, is regarded as doubtful on the basis of field investigations by the U.S. Geological Survey (Miller and others, 1959, plate 1, p. 79).
49	Oil seep, reported but unconfirmed	A reported oil seep near Whitefish Lake, south of the Kuskokwim River, has not been investigated by the U.S. Geological Survey (Miller and others, 1959, p. 79).
50	Oil seep, reported but unconfirmed	A second reported oil seep near Whitefish Lake, south of the Kuskokwim River, has not been investigated by the U.S. Geological Survey (Miller and others, 1959, p. 79).
51	Outcrop of oil shale or oil-bearing rock	Friable sandstone having an oil odor and causing a smudge on the hands has been reported on the north side of Nelson Island but has not been investigated by the U.S. Geological Survey. The sandstone is associated with coal beds and thought to be Cretaceous (Miller and others, 1959, p. 79; Coonrad, 1957; Waskey, 1946, p. 353).
52	Well with gas show(s)	The Pan American Petroleum Corp. Napatuk Creek Well No. 1 was drilled in 1961 to explore for oil and gas. It reached a total depth of 4,545 m and was abandoned as a dry hole. “Very, very slight bleeding of gas” along coal seams was observed in a core of Cretaceous rocks at depths of 951-957 m, and “some bleeding of gas from fractures or from air in drilling mud” was observed in a core of rocks of indeterminate age at depths of 3,541-3,546 m. No mudlog was made during drilling of this well (Mull and others, 1995), but subsequent analysis of drill cuttings found weak and questionable shows of oil in Cretaceous rocks at depths of 829 m, 2,201 m, and 3,103 m. Four drill stem tests were conducted, three of which had good to weak blows that died (Petrotechnical Resources of Alaska, LLC, 1999, p. 10). None of the drill stem tests found shows of oil or gas.
53	Well with no oil or gas shows	The Pan American Petroleum Corp. Napatuk Creek Core Hole No. 2 was drilled as a stratigraphic test in 1960 to a total depth of 434 m and abandoned as a dry hole. No shows of oil or gas were reported, and no drill stem tests were conducted.
54	Well with no oil or gas shows	The Pan American Petroleum Corp. Napatuk Creek Core Hole No. 2A was drilled as a stratigraphic test in 1960 to a total depth of 652 m and abandoned as a dry hole. No shows of oil or gas were reported, and no drill stem tests were conducted.
55	Well with no oil or gas shows	The Pan American Petroleum Corp. Johnston River Core Hole No. 1 was drilled as a stratigraphic test to a total depth of 367 m in 1963 and abandoned as a dry hole. No shows of oil or gas were reported, and no drill stem tests were conducted.
56	Well with no oil or gas shows	A water well drilled in 1952 at the Alaska Native Service Hospital in Bethel penetrated soft, unconsolidated deposits to a depth of 137 m and then encountered harder material, possibly sandstone, to the well’s total depth at 138 m. Permafrost was present to a depth of 123 m. No shows of hydrocarbons were encountered (Miller and others, 1959, p. 78).
57	Gas seep, reported but doubtful or disproved	A gas seep, located near the Eek River about 97 km southeast of Bethel, was reported by local residents and investigated by Sisson (1987) who found no indications of oil or gas. The geologic map of Box and others (1993) indicates that the reported location of the seep is near the concealed trace of the Golden Gate fault and that rocks in the vicinity of the seep are Early Proterozoic amphibolite-facies orthogneiss and amphibolite of the Kilbuck terrane. The site has not been investigated by the U.S. Geological Survey. However, on the basis of Sisson’s investigation and the apparently unfavorable geologic setting, the reported occurrence of a gas seep is herein regarded as doubtful.

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Map No.	Feature	Description and source(s) of information
58	Oil seep, reported but doubtful or disproved	A reported oil seep, located in the Eek Mountains about 113 km southeast of Bethel, was reported by local residents and investigated by Sisson (1987) who found no indications of oil or gas. The geologic map of Box and others (1993) indicates that the reported location of the seep is underlain by Paleozoic and (or) Mesozoic argillaceous melange of prehnite-pumpellyite metamorphic grade and within the Goodnews terrane. The site has not been investigated by the U.S. Geological Survey. However, on the basis of Sisson's investigation and the apparently unfavorable geologic setting, the reported occurrence of an oil seep is herein regarded as doubtful.
59	Oil seep, reported but unconfirmed	An oil seep near the Eek River is said to have been seen from the air and natives say they have seen oil in this area, but these reports have not been investigated by the U.S. Geological Survey (Miller and others, 1959, p. 79).
		Bristol Bay basin and vicinity
60	Oil seep, reported but doubtful or disproved	A reported oil seep near Togiak is regarded as doubtful because it is in an unfavorable geologic setting (Miller and others, 1959, plate 1).
		Kuskokwim flysch belt of Kirschner (1988)
61	Outcrop of oil shale or oil-bearing rock	Cinnabar at the Mountain Top mercury deposit, about 65 km southeast of Sleetmute, is accompanied by "small quantities of a light- to dark-brown liquid and solid hydrocarbon * * *. Most of the hydrocarbon is found as a transparent, light-brown liquid filling vugs and fractures within chalcedony veinlets. Many of the chalcedony veinlets contain close-packed shells of quartz and chalcedony, some of which contain solid dark-brown to black hydrocarbons" (Sorg and Estlund, 1972). The cinnabar occurs where faults cut olivine basalt that, in turn, intrudes shale and graywacke of the Upper Cretaceous Kuskokwim Group (Sorg and Estlund, 1972).
		Kobuk flysch belt of Kirschner (1988)
62	Oil seep, reported but doubtful or disproved	Reports of three oil seeps near Allakaket on the Koyukuk River are regarded as doubtful because the reports were based on observations "made by a prospector many years ago, and seeps have not been seen by, or reported to, geologists who have recently been in Allakaket" (Miller and others, 1959, p. 72).
		Nenana basin and vicinity
63	Well with gas show(s)	The Union Oil Co. of California Nenana Well No. 1 was drilled for oil and gas exploration in 1962. It attained a total depth of 933 m and was abandoned as a dry hole. The mudlog indicates minor amounts of gas associated with coal-bearing strata below about 625 m. No drill stem tests were conducted, and there were no reported shows of oil.
64	Well with gas show(s)	The ARCO Totek Hills Well No. 1 (fig. 4) was drilled as a stratigraphic test in 1984 to a total depth of 1,094 m and abandoned as a dry hole. The mudlog depicts numerous indications of gas, many of which appear to be associated with coal-bearing intervals but no indications of oil.
65	Oil seep, reported but doubtful or disproved	Oil seeps reportedly located near the mouth of the Nenana River were considered to be doubtful, without further explanation or discussion, by Miller and others (1959, p. 86, plate 1).
66	Oil seep, reported but doubtful or disproved	An oil seep along Totatlanika River (formerly Totatlanika Creek) was reportedly observed during the early 1920s, and a hole that did not strike oil was drilled to a depth of 12 m where it bottomed in sandstone. A sample of oily sand and gravel from the seep was submitted to a chemist and yielded about 5 oz of oil consisting of 88.5 % "illuminating oil" (Miller and others, 1959, p. 86). This analysis is consistent with kerosene, which may have been accidentally spilled or otherwise introduced into the sample.
67	Oil seep, reported but doubtful or disproved	A reported oil seep along California Creek, about 19-21 km east of Ferry, is regarded as doubtful on the basis of field investigations by the U.S. Geological Survey (Miller and others, 1959, plate 1).
68	Oil seep, reported but	A reported oil seep in the Nenana coal field along Healy Creek, about 11-13 km east of Healy, was the

Table 1. Descriptions of reported indications of petroleum in central Alaska

Map No.	Feature	Description and source(s) of information
	doubtful or disproved	subject of detailed field and laboratory investigations and found to be a natural coal tar produced by distillation from burning coal beds (fig. 5; Martin, 1923, p. 137-147; Miller and others, 1959, p. 61, plate 1).
69	Oil seep, reported but doubtful or disproved	A reported oil seep in the Nenana coal field about 25-30 km northeast of Healy is regarded as doubtful on the basis of field investigations by the U.S. Geological Survey (Miller and others, 1959, p. 61, plate 1).
70	Oil seep, reported but doubtful or disproved	Reports of oil-saturated tundra tussocks at a trail crossing along the Wood River, about 55 km south of Fairbanks, were investigated in 1954 by U.S. Geological Survey geologists who found iron-oxide scum on pond surfaces but no indications of oil (Miller and others, 1959, p. 86).
71	Oil seep, reported but doubtful or disproved	An oil seep was reported near the head of Clear Creek, about 40-50 km south of Fairbanks, but its existence was regarded as doubtful, without further explanation or discussion, by Miller and others (1959, p. 86, plate 1).
72	Well with gas show(s)	Numerous water wells and test holes in unconsolidated alluvium in the Fairbanks area have encountered marsh gas (Miller and others, 1959, p. 86).
73	Well with no oil or gas shows	In 1965, a well near Eielson Air Force Base was drilled to a total depth of 2,979 m for military purposes. The well spudded in schist of the Yukon-Tanana Upland and remained entirely in schist and amphibolite to total depth (Bunker and others, 1973; Forbes and Weber, 1975; Turner and Forbes, 1976; Naeser and Forbes, 1976; Dusel-Bacon and Murphy, 2001).
		Yukon Flats basin and vicinity
74	Outcrop of oil shale or oil-bearing rock	Small amounts of oil shale occur as chips and slabs in soil and float on a hill east of the Christian River, about 43 km north of Christian Village. Samples of the oil shale yielded 60-144 gal of oil per ton of rock; the oil was described as green in color with an API gravity of 31.1˚-33.4˚ (Mertie, 1929, p. 138-139; Mertie, 1930, p. 132; Ebbley, 1944; Miller and others, 1959, p. 56; Tailleur and others, 1967; Hawley and Garcia, 1976; Native Village of Venetie, 1981; Brosgé and Reiser, 2000). Pieces of the oil shale were formerly burned as campfire fuel by local people from the area formerly known as the Venetie Indian Reservation, but most of the oil shale is now gone (Ebbley, 1944; Hawley and Garcia, 1976; Brosgé and Reiser, 2000). Petrographic analysis revealed that the oil shale is tasmanite, a rock composed largely of the marine alga *Tasmanites* (Tailleur and others, 1967; Morgridge, 1995a,b; Brosgé and Reiser, 2000). The oil shale resembles "tough, dark, leathery wood" and is light in weight, weathering to a gray color, with polished and slickensided surfaces (Ebbley, 1944, p. 12). No in-place outcrops of the oil shale are known, despite numerous attempts to find them, including hand trenching, bulldozer excavations, and shallow auger drilling (Baggs and Blasko, 1979?). Some oil industry geologists speculate that the oil shale occurs as small, isolated pods that are sparsely distributed rather than as a single, laterally persistent stratigraphic horizon (Baggs and Blasko, 1979?). The oil shale is thought to be Permian or Triassic and is associated with igneous and sedimentary rocks of the Tozitna terrane (Brosgé and Reiser, 2000) with an igneous-metamorphic level of thermal maturity (Johnsson and others, 1992), which is generally an unfavorable geologic setting for the occurrence of oil.
75	Oil seep, reported but unconfirmed	The location of an oil seep along the Christian River is variously reported as either (1) about 6 km east of Brown Grass Lake at the junction of the Christian River and a large unnamed south-southeast-flowing creek (F.R. Weber, W.P. Brosgé, and I.L. Tailleur, written communs., 1960-1967), or (2) close to "the bend of the Christian River near the south endline of T32N" (Native Village of Venetie, 1981). However, neither the location nor the existence of the seep have been confirmed by field investigations (Hawley and Garcia, 1976, p. 4-2). The reported seep may have been along a fault that separates Mississippian to Jurassic volcanic rocks of the Tozitna terrane from Devonian sedimentary rocks (Brosgé and others, 2000). Rocks in the vicinity of this locality have an igneous-metamorphic level of thermal maturity (*B*, map sheet; Johnsson and others, 1992), which is generally an unfavorable geologic setting for the occurrence of oil.

Table 1. Descriptions of reported indications of petroleum in central Alaska

Map No.	Feature	Description and source(s) of information
76	Outcrop of oil shale or oil-bearing rock	In an area west of the Christian River about 27 km northwest of Christian village, oil shale (said to be tasmanite) was found in ground squirrel diggings near the head of Kocacho Creek and is associated with outcrops of chert and mafic volcanic rocks of the Tozitna terrane (Hawley and Garcia, 1976; Brosgé and Reiser, 2000, p. 6). Rocks in the vicinity of this locality are at an igneous-metamorphic level of thermal maturity (*B*, map sheet; Johnsson and others, 1992), which is generally an unfavorable geologic setting for the occurrence of oil.
77	Well with gas show(s)	In 1994, the U.S. Geological Survey drilled a stratigraphic core hole at Fort Yukon (fig. 6) to a total depth of 390 m. Gas, of unknown composition but widely presumed to be methane, was observed bubbling from cores taken from middle Miocene lignite-bearing strata in the lowermost 7-9 m of the hole (Ager, 1994; T.A. Ager, written commun., 2000). Nearby, Fort Yukon Water Well No. 2 was drilled in 1954 by the U.S. Army Corps of Engineers to a total depth of 134 m in Pleistocene or Tertiary lacustrine(?) silt and silty sand; no indications of oil or gas were reported from this well (Williams, 1962, p. 303).
78	Oil seep, reported but unconfirmed	A reported oil seep along the Coleen River has not been investigated by the U.S. Geological Survey (Miller and others, 1959, plate 1). Rocks in the vicinity of the reported seep are Paleozoic and range in thermal maturity from overmature to igneous-metamorphic (*B*, map sheet; Johnsson and others, 1992).
79	Oil seep, reported but unconfirmed	A reported oil seep along the Porcupine River near Old Rampart has not been investigated by the U.S. Geological Survey (Miller and others, 1959, plate 1). Rocks in the vicinity of the reported seep are Paleozoic and range in thermal maturity from supermature to igneous-metamorphic (*B*, map sheet; Johnsson and others, 1992).
80	Oil seep, reported but doubtful or disproved	An oil seep near Deacons Rock on the Porcupine River was reported during the late 1960s by an oil company field party. The seep was said to issue from the bottom of the river and was described as "a thread of dirty brown bubbles, foam, and froth, and coherent ribbons of brown material streaming downstream from the source area." At least two subsequent oil industry field parties (Morgridge, 1995a,b) and a field investigation by the U.S. Geological Survey and Alaska State Division of Geological and Geophysical Surveys (R.G. Stanley, D.L. LePain, and R.R. Reifenstuhl, 2002, unpub. data) were unable to find an oil seep or to see or smell evidence of petroleum at this locality. Samples of the "ribbons of brown material" (figs. 7, 8) and water from the vicinity of the reported seep were collected by the 2002 field team and submitted for laboratory analysis. The sample of brown material was examined microscopically and found to consist mainly of diatoms, pollen, spores, and amorphous organic material, with no evidence of petroleum (C.B. Lopez and S.W. Starratt, U.S. Geological Survey, oral and written communs., 2002). The water sample was chemically analyzed by the U.S. Geological Survey Organic Geochemistry Laboratory (Denver, Colo.) and found to consist of about 5 ppm of extractable hydrocarbons that included (1) rubber, plastics, and esters from human-caused pollution and (2) alkanes and biomarkers (including oleanane, gammacerane, steranes, and tricyclic terpanes) of unknown origin (P.G. Lillis, U.S. Geological Survey, written and oral communs., 2003). The presence of oleanane suggests that at least some of the alkanes and biomarkers were generated from Cretaceous or younger source rocks and possibly were derived from (1) human-caused pollution, as from spilled fuel or paving material, (2) an unidentified natural seep located upstream from Deacons Rock, or (3) a combination of pollution and natural seepage. Outcrops in the Deacons Rock area consist mainly of Paleozoic limestone and dolomite (Brosgé and others, 1966; A.G. Harris, oral commun., 2003). Cretaceous or younger petroleum source rocks have not been recognized near Deacons Rock. Thermal maturity data based on values of conodont alteration index indicate that Paleozoic strata in the general vicinity of Deacons Rock are supermature with respect to the oil window (Johnsson and Howell, 1996; J.A. Dumoulin and A.G. Harris, written and oral communs., 2002, 2003). The previously reported occurrence of an oil seep at Deacons Rock is herein regarded as doubtful on the basis of the aforementioned field and laboratory investigations, the absence of identified petroleum source rocks, and the high thermal maturity of Paleozoic rocks in the vicinity of the reported seep.
		Kandik region

Table 1. Descriptions of reported indications of petroleum in central Alaska

Map No.	Feature	Description and source(s) of information
81	Well with no oil or gas shows	The Louisiana Land and Exploration Co. Doyon Ltd. Well No. 3 was drilled in 1977 to explore for oil and gas. It reached a total depth of 4,125 m and was abandoned as a dry hole. Numerous occurrences of solid bitumen were reported from Paleozoic limestone and dolomite at 820-3,383 m. No shows of oil or gas were reported, but the mudlog shows a possible trace amount of methane at 710-713 m that may be a contaminant or an artifact related to resumption of drilling after casing was set to just above this depth.
82	Well with no oil or gas shows	The Louisiana Land and Exploration Co. Doyon Ltd. Well No. 2 (figs. 1, 9, 10) was drilled in 1977 to explore for oil and gas. It penetrated to a total depth of 2,781 m and was abandoned as a dry hole. Occurrences of solid bitumen were reported from Paleozoic dolomite at depths of 2,096 m and 2,256-2,320 m. No shows of oil or gas were reported, but trace amounts of methane appear at certain intervals on the mudlog, most notably at depths of 1,000-1,003 m, 1,067-1,070 m, 1,152-1,155 m, 1,445-1,454 m, 1,761-1,792 m, and 1,990-1,993 m. The gas at 1,761-1,792 m was labeled by the mudlogger as "methane possibly from makeup water," suggesting that the methane was a contaminant in water that was used to mix the drilling mud.
83	Well with no oil or gas shows	The Louisiana Land and Exploration Co. Doyon Ltd. Well No. 1 was drilled in 1976 to explore for oil and gas. It attained a total depth of 3,366 m and was abandoned as a dry hole. No shows of oil or gas were reported, but “small black particles of dead oil” were encountered at depths of about 442 m and a questionable occurrence of solid bitumen was noted at about 3,322 m. The mudlog shows evidence for trace amounts of methane at numerous intervals within the well, including 387-390 m, 439-445 m, 698-701 m, 1,430-1,439 m, 1,509-1,512 m, 2,185-2,188 m, 2,201-2,204 m, 2,877-2,880 m, and 3,018-3,042 m. The origin of this gas is uncertain. The methane may have been a contaminant in water used for drilling, as suggested for the Doyon No. 2 well; alternatively, the methane may be indigenous to the Mesozoic shale, siltstone, and quartzite that were penetrated by the No. 1 well. The thermal maturity of rocks in this well is supermature on the basis of values of mean vitrinite reflectance that range from about 3.9 % near the surface to about 4.8 % near the bottom of the hole (Johnsson and others, 1999).
84	Outcrop of oil shale or oil-bearing rock	Solid, brittle, vitreous bitumen reportedly occurs as a fracture filling in the Lower Cretaceous Keenan Quartzite(?) (Watts, 1992).
85	Outcrop of oil shale or oil-bearing rock	“Oil droplets” were reportedly found in a rock sample from the Devonian Nation River Formation (Van Kooten and others, 1997).
86	Outcrop of oil shale or oil-bearing rock	Upper Triassic oil shale is exposed along the Yukon River near the mouth of the Nation River (Mertie, 1930, p. 130-131; Mertie, 1937, p. 153-154; Miller and others, 1959, p. 56, 64). Fifteen samples of oil shale from the west bank of the Yukon River, opposite the mouth of the Nation River, were analyzed and found to contain 1.7 to 12.3 gal of oil per ton of shale, averaging about 4 gal per ton (Churkin and Brabb, 1969, p. 9).
87	Outcrop of oil shale or oil-bearing rock	Upper Triassic oil shale is exposed along Trout Creek near the Yukon River (Mertie, 1930, p. 131-132; Miller and others, 1959, p. 56, 64). A distillation test on a sample from this locality indicated about 28 gal of crude oil per ton of shale (Mertie, 1930, p. 132; Mertie, 1937, p. 263-264). This result led to an estimate of about 2 million barrels of oil-equivalent in near-surface deposits that could be mined, and a further estimate of about 200 billion barrels of oil-equivalent in presumed subsurface extensions of similar-grade deposits (Duncan and Swanson, 1965, p. 14). Subsequent work, however, demonstrated that these estimates were too high; eight additional analyses of oil shale from the Trout Creek locality ranged from 0.3 to 7.6 gal of oil per ton of shale and averaged about 4.8 gal per ton, and geologic mapping showed that the lateral extent of the oil shale deposits was much less than previously believed (Churkin and Brabb, 1969, p. 9).
88	Outcrop of oil shale or oil-bearing rock	Solid(?) bitumen reportedly fills vugs in stained limestone and occurs as veins up to 9 cm long in the Middle Triassic to Lower Cretaceous Glenn Shale (unpub. oil industry data).
89	Outcrop of oil shale or oil-bearing rock	Blebs of bitumen reportedly occur in the Middle Triassic to Lower Cretaceous Glenn Shale (Watts, 1992).

Table 1. Descriptions of reported indications of petroleum in central Alaska

Map No.	Feature	Description and source(s) of information
90	Outcrop of oil shale or oil-bearing rock	Solid bitumen reportedly occurs in coarse calcite veins and vugs in the Lower Permian Tahkandit Limestone (Watts, 1992).
91	Outcrop of oil shale or oil-bearing rock	Solid, brittle, vitreous bitumen reportedly occurs as a fracture filling in Precambrian rocks (Watts, 1992).
92	Outcrop of oil shale or oil-bearing rock	Strongly petroliferous limestone with bitumen blebs reportedly occurs in Precambrian rocks and is associated with gas bubbles in a nearby streambed (unpub. oil industry data).
93	Outcrop of oil shale or oil-bearing rock	Petroliferous limestone concretions occur intermittently in outcrops of black, laminated, very siliceous mudstone of the Upper Mississippian to Lower Pennsylvanian Calico Bluff Formation along the Yukon River at Calico Bluff (Laudon and others, 1966, p. 1871-1873).
		Northway lowlands
94	Well with gas show(s)	Gas was found in unconsolidated Quaternary deposits in a well drilled to total depth of about 107 m by the Alaska Propane Co., Inc., in the Northway lowlands (Miller and others, 1959, p. 86-87). The gas was found at depths of 59-67 m, and the bottom of permafrost was found at a depth of about 76 m.
95	Well with gas show(s)	Gas, presumably trapped beneath permafrost, was found in unconsolidated Quaternary deposits in a well drilled for water at a spot on the Alaska Highway known as Seaton's Service Station or Seaton's Roadhouse. The gas, mostly methane, was found at a depth of about 60 m and is thought to have been trapped by permafrost (Miller and others, 1959, p. 86-87; Kirschner, 1988).

Figure 2. Photograph showing gas accumulation beneath lake ice on the Yukon Delta, southwestern Alaska, signaling the presence of a gas seep. Photograph by J.Y. Foley, 1997.

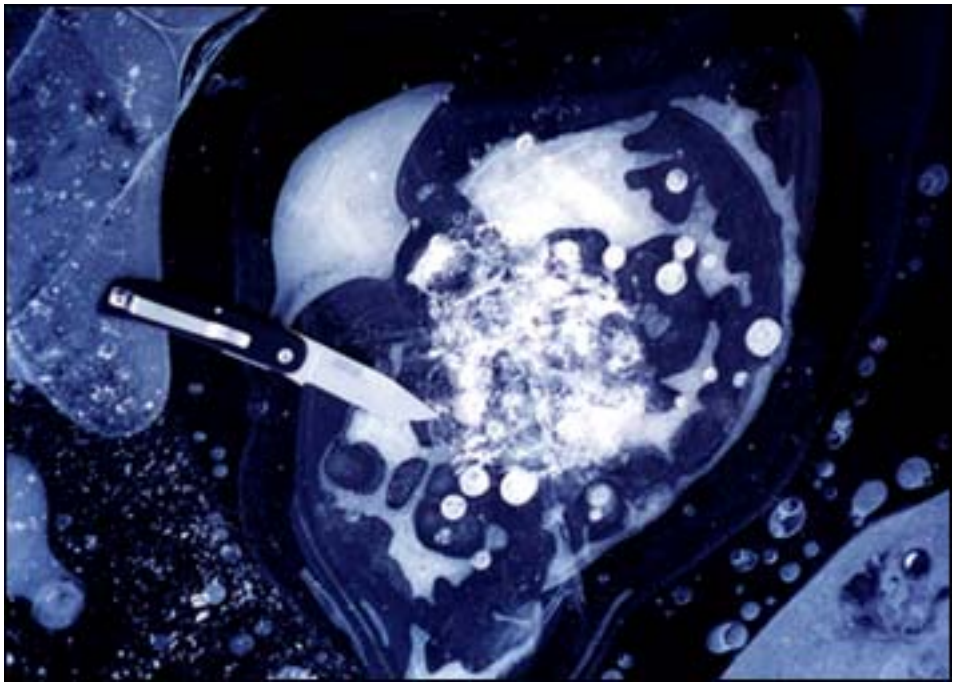

Figure 3. Photograph showing a closer view of the gas accumulation shown in figure 2. Knife blade is about 7 cm long. Photograph by J.Y. Foley, 1997.

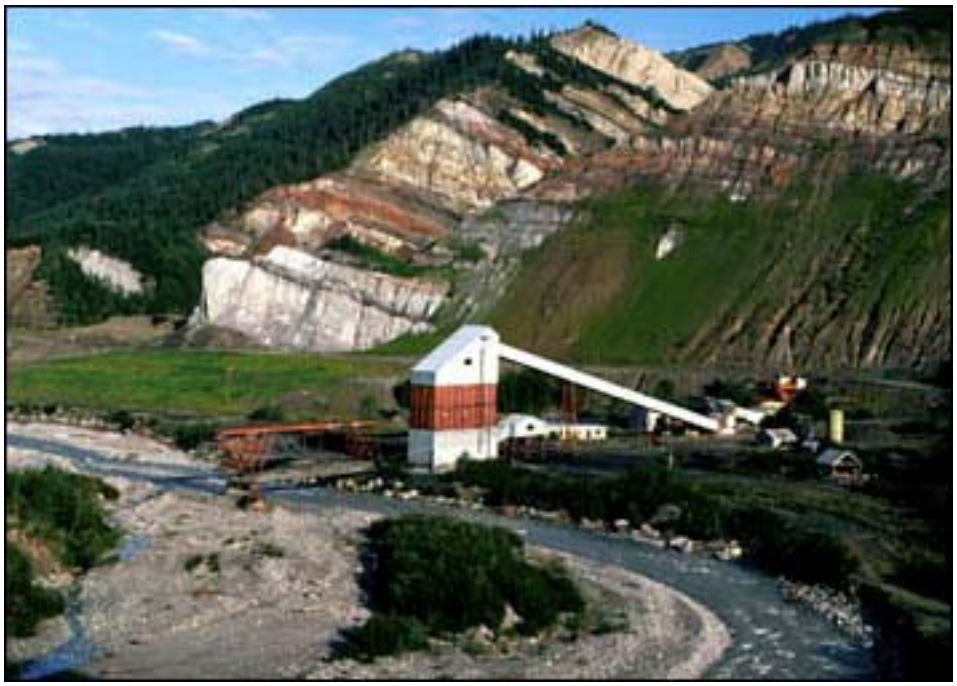

Figure 4. Photograph showing the abandoned tipple of the Suntrana coal mine (near Map No. 68, *A* and *B* on map sheet) along Healy Creek, about 125 km southwest of Fairbanks, Alaska. Behind the tipple are north-dipping, coal-bearing strata of the Eocene to Miocene Usibelli Group. Photograph by R.G. Stanley, 1985.

Figure 5. Photograph showing drilling operations at the ARCO Totek Hills Well No. 1 (Map No. 64), about 120 km southwest of Fairbanks, Alaska, 1984. The drilling rig was transported to the site by helicopter. Photographer unknown; photograph provided by Mark McDermott.

Figure 6. Photograph showing U.S. Geological Survey drilling operations (Map No. 77) at Fort Yukon, Alaska, looking approximately north-northwest. Photograph by T.A. Ager, 1994.

Figure 7. Oblique aerial photograph, looking approximately north-northwest, showing Deacons Rock (Map No. 80) on the Porcupine River, about 320 km northeast of Fairbanks, Alaska. In this image the river flows from right to left. Note the faint ribbons of light-brown material on the water surface; apparently, the brown material was thought by some earlier visitors to consist of petroleum that issued from a seep near the offshore rock. Photograph by R.G. Stanley, 2002.

Figure 8. Photograph showing Deacons Rock (Map No. 80), looking generally east (upstream) along the Porcupine River. Samples of water and the light brown material floating on the surface of the water were collected here and analyzed both chemically and microscopically; see table 1 for discussion. Photograph by R.G. Stanley, 2002.

Figure 9. Photograph showing drilling operations at the Louisiana Land and Exploration Company Doyon Ltd. Well No. 2 (Map No. 82), about 300 km northeast of Fairbanks, Alaska, looking approximately north-northeast. Photograph by Bruce Clardy, 1977.

Figure 10. Photograph showing drilling operations at the Louisiana Land and Exploration Company Doyon Ltd. Well No. 2 (Map No. 82), about 300 km northeast of Fairbanks, Alaska, looking approximately northwest. Photograph by Bruce Clardy, 1977.

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