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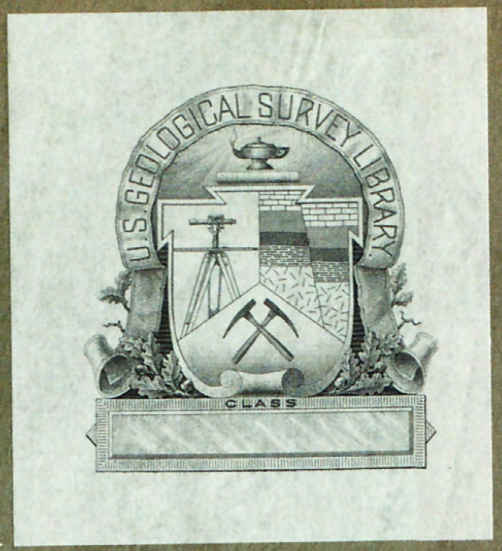
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PETROLEUM POSSIBILITIES OF THE YUKON-KOYUKUK PROVINCE, ALASKA

By

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INTRODUCTION

The recent discovery of major oil resources on Alaska's North Slope has rekindled interest in the petroleum possibilities of the Yukon-Koyukuk province, a vast tract of Cretaceous rocks stretching along the west coast of Alaska from the Brooks Range to the Yukon delta. Attention was first focused on this region in the early 1950's, after oil and gas were discovered in the Cretaceous of the North Slope by the U.S. Navy. The presence of similar Cretaceous strata in the Yukon-Koyukuk province and the possibility that some of the broad alluviated lowlands within the province might be underlain by Tertiary basins were pointed out by Gryc and others (1951) and Payne (1955). Between 1954 and 1961 large parts of the province were reconnoitered by oil company surface parties and a small amount of geophysical work was carried out in the Nulato-Kateel and Bethel areas. The explorational activity culminated in 1960-61 with the drilling of two deep tests, a 12,000-foot hole near Nulato on the Yukon River and a 15,000-foot hole at Napatuk Creek in the Yukon-Kuskokwim Coastal Lowland. Apparently neither test revealed oil shows or favorable reservoir rocks, as exploration and leasing activity in the province declined sharply thereafter.

Since 1954 the U.S. Geological Survey has maintained a modest but continuing program of reconnaissance geologic mapping of the province and its borderlands. Nearly all parts of this vast area have been visited

either by helicopter or river boat. Although information in many places is still sketchy, the broad outlines of the surface geology are now known. Subsurface data, however, are almost totally lacking.

The mapping indicates that the petroleum possibilities over most of the province are limited because of complex structure and scarcity of promising reservoir rocks. Two areas where further exploration seems warranted are the Yukon-Kuskokwim Coastal Lowland and the western part of the Kobuk-Selawik Lowland.

REGIONAL SETTING

The Yukon-Koyukuk province is a broad belt of Cretaceous rocks flanked on the west, north, and southeast by a metamorphic and volcanic complex of pre-Cretaceous age (fig. 1). It covers nearly 100,000 square miles, more than one-sixth the total land area of Alaska, and is equal in size to the State of Wyoming. Early workers (Payne, 1955; Miller and others, 1959) envisaged the province as a single large sedimentary basin or "geosyncline" comparable to the Colville basin of the North Slope. However, subsequent mapping suggests that it is more accurately described as a highly mobile volcanogenic belt. At least half of the rocks in the province are volcanic and plutonic rather than sedimentary. Furthermore, the province does not appear to have been a single large sedimentary basin during Cretaceous time but was divided into smaller short-lived troughs separated by tectonically and volcanically active highs. The bulk of the sedimentary deposits in the province are composed of first- and second-cycle volcanic debris derived from these highs and from older volcanic terranes in the borderlands.

STRATIGRAPHY

Pre-Cretaceous Rocks

The pre-Cretaceous rocks that border the province are chiefly metasedimentary rocks of Paleozoic age and mafic volcanic and intrusive rocks of probable Late Triassic or Jurassic age. The metasedimentary rocks include pelitic schist, quartzite, and partially recrystallized limestone and dolomite. Scattered fossil collections from the carbonate rocks indicate that these are mainly Paleozoic in age, although in a few places they probably include rocks as young as Triassic and as old as Precambrian. The mafic volcanic and intrusive rocks which overlie and intrude the metasedimentary rocks comprise a typical ophiolite sequence of pillow basalt, diabase, gabbro, and serpentinite.

Cretaceous Rocks

Marine andesitic volcanic rocks

The lower part of the Cretaceous sequence in the Yukon-Koyukuk province is a thick assemblage of marine andesitic volcanic rocks that includes tuffs, breccias, and flows with local intercalations of volcanic graywacke and impure fossiliferous limestone. This volcanic assemblage is widely exposed along the "Hogatza trend," a broad structural high that extends across the province from Kotzebue Sound to the Koyukuk River valley. It also crops out on the lower Yukon River, south of the Kaltag fault, and it appears to underlie large parts of the Koyukuk Flats (Zietz and others, 1959) and Kobuk-Selawik Lowland (Patton and Miller, 1968). The total thickness of this volcanic assemblage is not known, as the complete sequence has not been found anywhere in the province. At least 5,000 feet is exposed along the Koyukuk River below Hughes, but the total thickness of the assemblage may be several times this.

The bulk of the volcanic rocks can be dated as earliest Cretaceous (Neocomian) on the basis of the widespread occurrence of Buchia and several K-Ar dates (Patton and Miller, 1966; Patton, 1967). Some volcaniclastic rocks included in this assemblage may be mid-Cretaceous, as they appear to interfinger with volcanic graywackes that contain Albian fossils.

Sedimentary rocks

Graywacke and mudstone--In the northern and western part of the province the andesitic volcanic rocks are overlain by marine graywacke and mudstone of late Early Cretaceous age. These graywacke and mudstone deposits comprise nearly all of the Cretaceous sedimentary sequence in the Kobuk and upper Koyukuk drainages and along the west side of the province from the Seward Peninsula south to the Yukon-Kuskokwim Coastal Lowland (fig. 1). Typically they form thick, monotonously uniform, rhythmically interbedded successions with characteristic turbidite features such as graded beds, small-scale crossbedding, and sole markings. Favorable reservoir beds are lacking owing to their poor sorting and "poured-in" nature. Rapid lateral variations in thickness and facies, absence of diagnostic horizon markers, and scarcity of fossils preclude detailed stratigraphic analyses and formal classification of these strata over most of the province. However, two grossly different facies can be mapped locally: 1) volcanic graywacke and mudstone composed chiefly of first- and second-cycle volcanic debris derived from volcanic highs within the province and from pre-Cretaceous volcanic rocks in the borderlands (Patton and Miller, 1966), and 2) calcareous graywacke and mudstone which, besides volcanic debris, contain as much as 50 percent detrital carbonate derived from Paleozoic limestone and dolomite terrane in the borderlands (Patton,

1967). Also included in this graywacke and mudstone assemblage is a locally mappable sequence of laumontitized tuffs and tuffaceous graywacke which is exposed in a narrow belt that extends from the latitude of the Seward Peninsula southwestward to Nunivak Island (Hoare and others, 1964). These strata appear to be at least in part nonmarine, and on Nunivak Island they contain abundant plant fossils.

The total thickness of these graywacke and mudstone deposits is estimated to be on the order of 10,000 feet along the lower Kobuk River and probably as much as 20,000 feet in the basin between Norton Sound and the Yukon River (Gates and others, 1968).

Scattered fossil collections suggest that the graywacke and mudstone assemblage is largely, if not entirely, of Albian age (Patton and Miller, 1966, 1968).

Shallow marine and nonmarine deposits--The graywacke and mudstone assemblage is overlain by and in part laterally gradational with shallow marine and nonmarine paralic deposits including sandstone, shale, conglomerate, and coal. These deposits, with an aggregate thickness of at least 10,000 feet, occur in a broad band along the eastern side of the province from the latitude of the Koyukuk Flats southward to the Yukon-Kuskokwim Coastal Lowland. They also crop out in a narrow belt along the northern and northeastern perimeter of the province (fig. 1). In places these rocks rest unconformably upon the Cretaceous andesitic volcanic rocks, and along the northern and eastern margin they lap onto the pre-Cretaceous metasedimentary and volcanic rocks.

In general, these paralic deposits are better sorted and contain a larger fraction of resistant rock and mineral detritus than the underlying

graywacke and mudstone. Washed, crossbedded, strandline sandstones, which are developed locally in the zone of interfingering marine and nonmarine beds, appear to be the only potential reservoir beds in the entire Cretaceous sedimentary sequence.

Abundant marine mollusks and well-preserved plant fossils date these paralic deposits as late Early (Albian) and early Late Cretaceous.

Cretaceous and Tertiary

Felsic volcanic rocks

Moderately deformed flows, tuffs, and hypabyssal intrusives, chiefly of felsic composition, are widely distributed in the eastern part of the province. These volcanic rocks, which have been dated by K-Ar methods as Late Cretaceous and early Tertiary, overlie and pervasively intrude the Cretaceous sedimentary and andesitic volcanic rocks. Their widespread presence in the sedimentary section appears to severely limit the possibility that oil will be found in the eastern part of the province.

Tertiary(?) and Quaternary Rocks

Basalt

Flat-lying flows of olivine basalt of Quaternary and probable late Tertiary age cover broad areas of the Cretaceous strata along the western side of the province from the Kobuk-Selawik Lowlands southward to Nunivak Island. These basalt flows were extruded over a terrain of moderate relief and locally are as much as 500 feet thick.

STRUCTURE

The structure of the Cretaceous rocks over most of the province is exceedingly complex. Tight to isoclinal folds with dips as steep as 90° are the rule. Small faults are observable in nearly every exposure, and

three sets of major faults trending north, northeast, and northwest have been mapped throughout the province (Bickel and Patton, 1957; Patton, 1967; Hoare and Condon, 1966). A major strike-slip fault, the Kaltag fault, with possibly as much as 40 to 80 miles of right-lateral offset, transects the province between Unalakleet and Tanana (Patton and Hoare, 1968).

Although most of the Cretaceous rocks in the province are complexly deformed, broad open folds have been mapped in three places: 1) west of the lower Koyukuk River in the Kateel River quadrangle (Patton, 1966), 2) in the Lockwood and Hogatza Hills of the west-central Hughes quadrangle (Patton and Miller, 1966), and 3) in the Waring Hills of the Selawik quadrangle (Patton and Miller, 1968). Even in these areas, however, the large folds are locally complicated by small-scale folds and faults.

PETROLEUM POSSIBILITIES

The reconnaissance mapping suggests that petroleum prospects are generally unfavorable over most of the Yukon-Koyukuk province, owing to structural complexity, scarcity of potential reservoir beds, and the widespread occurrence of volcanic and intrusive rocks. Possibilities for finding favorable sandstone reservoir rock seem to be confined to the sequence of interfingering marine and nonmarine paralic deposits in the upper part of the Cretaceous sedimentary section. These paralic deposits have been mapped over an area of approximately 13,000 square miles. However, in 5,000 square miles of this along the eastern margin of the province the petroleum possibilities of these paralic deposits are limited by pervasive Late Cretaceous and early Tertiary shallow intrusive and volcanic rocks. Thus, potential target areas for exploration of these paralic deposits are limited to only about 8,000 square miles. This

includes a belt roughly 20 miles wide and 300 miles long extending from the western edge of the Koyukuk Flats southward to the Yukon-Kuskokwim Lowland and a small area roughly 20 miles wide by 80 miles long on the middle reaches of the Kobuk River. Exploration of these target areas undoubtedly will be directed towards finding local occurrences of washed strandline sandstones in a favorable structural setting.

Lowland Areas

Nearly a third of the Yukon-Koyukuk province is made up of coastal and interior lowlands which are covered by a thick blanket of Quaternary silts. Payne (1955) and Miller and others (1959) suggested that these lowlands may represent Cenozoic structural basins underlain by only mildly deformed Tertiary strata. The following assessment is based upon scattered aeromagnetic profiles across the lowlands and recent reconnaissance bedrock mapping around the margins.

Kobuk-Selawik Lowland

On the basis of surface mapping and aeromagnetic surveys, it appears unlikely that any significant thickness of Cretaceous or Tertiary sedimentary rocks is present beneath the Quaternary surficial deposits in the eastern part of the Kobuk-Selawik Lowland. Intrusive and volcanic rocks crop out near the south edge of Selawik Lake, and aeromagnetic profiles along the north side show steep-gradient large-amplitude anomalies which suggest that igneous rocks occur at shallow depth (Andreasen, 1960; Dempsey and others, 1957c). Aeromagnetic profiles over the Kobuk River delta in the western part of the lowland are relatively smooth and free of marked magnetic anomalies (Miller and Anderson, 1969). This probably reflects the presence of a thick wedge of Quaternary fill beneath the delta. However, the possibility that the delta and adjoining

parts of Kotzebue Sound may also be underlain by Cretaceous and Tertiary sedimentary rocks cannot be ruled out. Recent marine geophysical investigations suggest that as much as 3 km of moderately deformed strata of Cenozoic and possibly Late Cretaceous age underlies large parts of the Chukchi Sea and Kotzebue Sound (Arthur Grantz and others, oral commun., 1970).

Yukon-Kuskokwim Coastal Lowland

Available data are insufficient for a meaningful appraisal of the petroleum possibilities of the Yukon-Kuskokwim Coastal Lowland. This vast area of nearly 30,000 square miles, sometimes referred to as the Bethel "basin" (Miller and others, 1959), is mantled by a thick veneer of Quaternary alluvium and basalt flows that all but completely masks the underlying bedrock. Scattered exposures of Cretaceous sedimentary rock have been found on Nunivak and Nelson Islands (Hoare and others, 1968) and near Cape Romanzof (Hoare and Condon, 1966, 1968). About 15,000 feet of gently deformed Cretaceous and possible Tertiary strata reportedly was penetrated in the Napatuk well near Bethel. These occurrences and the presence of Cretaceous strata along the Yukon River suggest that large parts of the lowland probably are underlain by Cretaceous strata. Tertiary strata, if present, presumably are confined to local basins or embayments.

Innoko Lowlands

No geophysical data are available for the Innoko Lowlands. However, the presence of both Cretaceous and Tertiary volcanic and intrusive rocks along the edges of this narrow north-trending flat makes it an unattractive target for exploration.

Koyukuk Flats

Airborne magnetic profiles across the Koyukuk Flats (Dempsey and others, 1957a, b; Zietz and others, 1959) show anomalies of large amplitude and steep gradient, indicating the presence of highly magnetic rocks at shallow depths. This is confirmed by surface mapping in and around the flats, which indicates that the Quaternary alluvial deposits are underlain chiefly by volcanic rocks. There is no evidence of a substantial thickness of Tertiary strata beneath the flats except along the Kaltag fault, where evidence of recent sinking (Patton and Hoare, 1968) and a gravity low (Barnes, 1969) suggest the presence of a narrow trench filled with Cenozoic deposits.

SELECTED REFERENCES

Andreasen, G. E., 1960, Total intensity aeromagnetic profiles of Kobuk River, Alaska: U.S. Geol. Survey open-file report.

Barnes, David F., 1969, Progress on a gravity map of Alaska: EOS (Am. Geophys. Union Trans.), v. 50, no. 10, p. 550-552.

Bickel, Robert S., and Patton, William W., Jr., 1957, Preliminary geologic map of the Nulato and Kateel Rivers area, Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-249.

Coonrad, W. L., 1957, Geologic reconnaissance of the Yukon-Kuskokwim delta region, Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-223.

Dempsey, W. J., Meuschke, J. L., and Andreasen, G. E., 1957a, Total intensity aeromagnetic profiles of Hogatza uplift, Alaska: U.S. Geol. Survey open-file report, June 10, 1957, 1 sheet.

_____1957b, Total intensity aeromagnetic profiles of Koyukuk, Alaska: U.S. Geol. Survey open-file report, June 10, 1957, 2 sheets.

Dempsey, W. J., Meuschke, J. L., and Andreasen, G. E., 1957c, Total intensity aeromagnetic profiles of west Hogatza, Alaska: U.S. Geol. Survey open-file report, June 10, 1957, 1 sheet.

_____1957d, Total intensity aeromagnetic profiles of Bethel Basin, Alaska: U.S. Geol. Survey open-file report, June 10, 1957, 3 sheets.

Gates, George O., Grantz, Arthur, and Patton, W. W., Jr., 1968, Geology and natural gas and oil resources of Alaska in Natural gases of North America: Am. Assoc. Petroleum Geologists Mem. No. 9, p. 3-48.

Gryc, George, Miller, D. J., and Payne, T. G., 1951, Alaska in Possible future petroleum provinces of North America: Am. Assoc. Petroleum Geologists Bull., v. 35, no. 2, p. 151-168.

Hoare, J. M., and Condon, W. H., 1966, Geologic map of the Kwiguk and Black quadrangles, western Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-496.

_____1968, Geologic map of the Hooper Bay quadrangle, Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-523.

_____1970, Geologic map of the Marshall quadrangle, western Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-668 (in press).

Hoare, J. M., Condon, W. H., and Patton, W. W., Jr., 1964, Occurrence and origin of laumontite in Cretaceous sedimentary rocks in western Alaska: U.S. Geol. Survey Prof. Paper 501-C, p. C74-C78.

Hoare, J. M., Condon, W. H., Cox, Allan, and Dalrymple, G. B., 1968, Geology, paleomagnetism, and potassium-argon ages of basalts from Nunivak Island, Alaska: Geol. Soc. America Mem. 116, p. 377-413.

Hoare, J. M., and Coonrad, W. L., 1959a, Geology of the Bethel quadrangle, Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-285.

_____1959b, Geology of the Russian Mission quadrangle, Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-292.

Hoare, J. M., and Coonrad, W. L., 1961, Geologic map of the Goodnews quadrangle, Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-339.

Miller, T. P., and Anderson, L. A., 1969, Airborne radioactivity and total intensity magnetic survey of the southern Kobuk-Selawik Lowland: U.S. Geol. Survey open-file report.

Miller, T. P., Patton, W. W., Jr., Lanphere, M. A., 1966, Preliminary report on a plutonic belt in west-central Alaska: U.S. Geol. Survey Prof. Paper 550-D, p. D158-D162.

Miller, D. J., Payne, T. G., and Gryc, George, 1959, Geology of possible petroleum provinces in Alaska: U.S. Geol. Survey Bull. 1094, 131 p.

Patton, W. W., Jr., 1966, Regional geology of the Kateel River quadrangle, Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-437.

_____1967, Regional geologic map of the Candle quadrangle, Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-492.

Patton, W. W., Jr., and Bickel, Robert S., 1956a, Geologic map and structure sections along part of the lower Yukon River, Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-197.

_____1956b, Geologic map and structure sections of the Shatolik River area, Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-226.

Patton, W. W., Jr., and Hoare, J. M., 1968, The Kaltag fault, west-central Alaska: U.S. Geol. Survey Prof. Paper 600-D, p. D147-D153.

Patton, W. W., Jr., and Miller, T. P., 1966, Regional geologic map of the Hughes quadrangle, Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-459.

_____1968, Regional geologic map of the Selawik and southeastern Baird Mountains quadrangles, Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-530.

Patton, W. W., Jr., and Miller, T. P., 1970, Preliminary geologic investigations in the Kanuti River region, Alaska: U.S. Geol. Survey Bull. 1312-J, p. J1-J10.

Patton, W. W., Jr., Miller, T. P., and Tailleur, I. L., 1968, Regional geologic map of the Shungnak and southern part of the Ambler River quadrangles, Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-554.

Payne, T. G., 1955, Mesozoic and Cenozoic tectonic elements of Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-84.

Zietz, Isidore, Patton, W. W., Jr., and Dempsey, W. J., 1959, Preliminary interpretation of total-intensity aeromagnetic profiles of the Koyukuk area, Alaska: U.S. Geol. Survey open-file report, Nov. 12, 1959, 7 p.

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