U. S. Department of the Interior
Bureau of Land Management

Alaska State Office
222 West 7th, #13
Anchorage, Alaska 99513

BLM-Alaska Open File Report 44
BLM/AK/AE/93/042+3071+985
July 1993

Innoko National Wildlife Refuge Oil and Gas Resource Assessment

Robert J. Bascle, Aden Seidlitz and James Borkoski

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Innoko National Wildlife Refuge
Oil and Gas Resource Assesement

Abstract

Most of the refuge has No potential for the occurrence of oil and gas resources because igneous and metamorphic rocks underlie most of the area. The area of the refuge that borders the Yukon River has a Low potential for the occurrence of oil and gas because of negative, but limited, evidence for the probable existence of either good source rock or good reservoir in the sedimentary rocks that underlie this area. Also, the rocks have a high degree of structural disruption.

I. Introduction

The Bureau of Land Management (BLM) is authorized through a Memorandum of Understanding with the U.S. Fish and Wildlife Service (FWS) to assess the oil and gas resource potential of the National Wildlife Refuge System in Alaska. Section 1008 of the Alaska National Interest Lands Conservation Act (ANILCA) requires the Secretary of the Interior to initiate an oil and gas leasing program on the federal lands of Alaska. However, ANILCA exempts "... those units of the National Wildlife Refuge System where the Secretary determines, after having considered the national interest in producing oil and gas from such lands, that the exploration for and development of oil and gas would be incompatible with the purpose for which such unit was established."

pBLM helped to fulfill that part of Section1008 that mandates:

"In such areas as the Secretary deems favorable for the discovery of oil or gas, he shall conduct a study, or studies, or collect and analyze information obtained by permittees authorized to conduct studies under this Section, of the oil and gas potential of such lands and those environmental characteristics and wildlife resources which would be affected by the exploration for and develompent of such oil and gas."

This report is intended to assist the FWS in deciding which lands within the Innoko National Wildlife Refuge should or should not be opened to oil and gas leasing and development by identifying those areas which may be favorable for the discovery of oil and gas according to the BLM classification criteria *(Appendix A)*. This analyisis relied on the published geologic reports for the area and the published descriptions of the tectonostratigraphic terranes that underlie the refuge and was originally submitted to the FWS in 1988 .

2. Location and Physiography

The Innoko National Wildlife Refuge (INWR), in west-central Alaska, flanks the eastern bank of the Yukon River *(Figure 1)*. Two major units form the refuge. The northern unit lies east and southeast of the Yukon River between the communities of Galena, near the northeastern corner of the unit, and Kaltag, near the southwestern corner. The southern unit extends from about 18 miles south of the northern unit to about six miles south of Grayling. It reaches eastward from the Yukon River to about Cripple Landing. The refuge also includes several islands in the Yukon River.

The boundary of the northern unit encloses about 751,000 acres. From the Yukon River, it stretches across the Kaiyuh Flats and climbs the northwestern slopes of the Kaiyuh Mountains. Water or wetlands cover more than 80 percent of the Kaiyuh Flats, a large floodplain of the Yukon River, with many lakes and sloughs. This area ranges in height from about 100 to about 400 feet above sea level. The rounded to flat summits of the northern Kaiyuh Mountains rise to more than 2,000 feet (U.S. Fish and Wildlife Service, 1987).

The boundary of the southern unit encloses about 3 million acres. It straddles the southern Kaiyuh Mountains and sprawls across the Innoko Flats almost to the northwestern slopes of the Kuskokwim Mountains. The Magitchlie Range rises just north of the northern boundary, near the Yukon River. A floodplain, up to about 12 miles wide, separates the north-trending Kaiyuh Mountains from the Yukon River. The Innoko Flats, a large, poorly-drained floodplain of the Innoko, Iditarod, Mud, Yetna, and Dishna rivers, fills the valley between the Kaiyuh Mountains and the Kuskokwim Mountains. This floodplain merges with the Yukon River floodplain south of the Kaiyuh Mountains. Several ranges of rounded, low-lying hills jut into the Innoko Flats. The flats range in height from about 70 to about 200 feet above sealevel. The mountains rise to over 1,300 feet above sealevel.

3. Geologic Exploration

Gold prospectors and a U.S. Geological Survey (USGS) geologist first explored the area in the vicinity of the INWR in the late 1890's. Prospectors first entered the area in 1898. They didn't find any gold until 1906, when Thomas Gane and his compatriots found gold on what is now Ganes Creek, Innoko Mining District.

Spurr, a USGS geologist, traveled down the Yukon past the present site of Ruby in 1896. He inspected crystalline limestones that outcrop along the southern bank of the river. In 1898, he explored the Kuskokwim River. Several USGS geologists, including Collier, Maddren, Anderson, Eakin, Harrington, and Martin, and a Smithsonian Institution geologist, Gilmore, visited the general vicinity by 1920 (Mertie and Harrington, 1924). Mertie and Harrington prepared reports on the area in the 1920s and 1930s (Mertie and Harrington, 1924; Mertie, 1937).

The area received scant attention in the geologic literature until the 1950s. Since the 1950s, interest in this area has increased. The oil industry explored large parts of the area from 1954-1961. They drilled an exploratory oil well, the Nulato No. 1, near

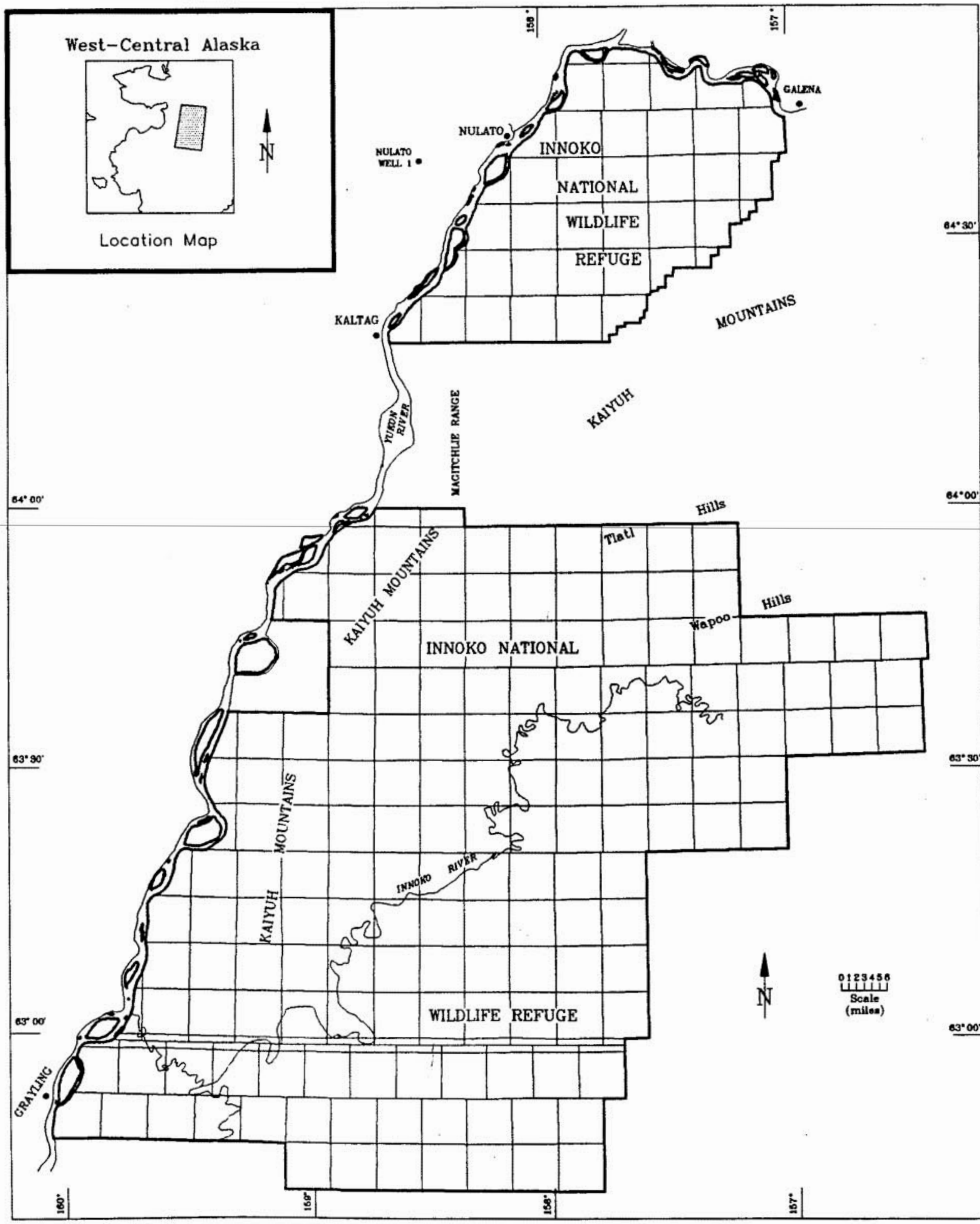


Figure 1. Location map for Innoko National Wildlife Refuge

Nulato in 1960-1961. An unconfirmed report of an oil seep in the vicinity led to the drilling of this well (Patton, 1971).

The acceptance of the theories of plate tectonics and tectonostratigraphic terranes (defined below) has contributed to an increase in interest. Alaska, considered a good example of tectonostratigraphic terranes, has attracted many researchers in the past three decades.

The only operating oil or gas fields for onshore Alaska are on the North Slope and in the Cook Inlet-Kenai Peninsula area. Historically, the Katalla Field, near the mouth of the Copper River produced the first commercial oil in Alaska. It has long since ceased production.

These oil fields lie far away from the Innoko National Wildlife Refuge and have no bearing on the oil and gas potential of the refuge.

4. Geology

Tectonostratigraphic Terranes

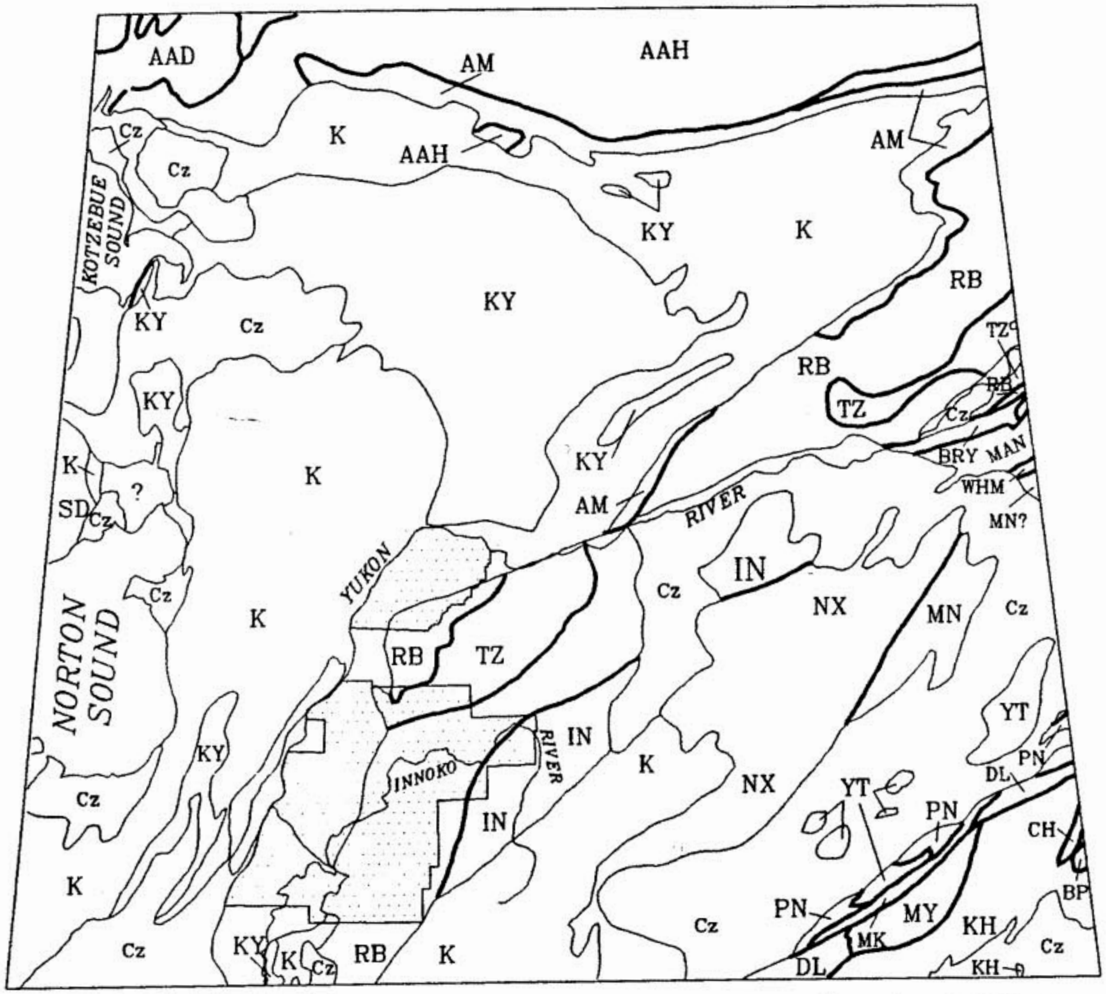
Tectonostratigraphic terranes might best describe the geology of this part of western Alaska. A tectonostratigraphic terrane is a fault-bounded block having a tectonic and geologic history which differs from surrounding rocks. The INWR encompasses parts of four, and possibly five, terranes: the Yukon-Koyukuk terrane (province), the Ruby terrane, the Angayucham terrane, the Innoko terrane, and, possibly, the Tozitna terrane (*Figure 2*). Researchers do not uniformly accept the delineations of and relationships among the various terranes, so some disagreements exist.

Only the Yukon-Koyukuk terrane (province or basin) appears to have any potential for oil and gas resources in the INWR. The other terranes will only be described briefly.

Yukon-Koyukuk Terrane

The Yukon-Koyukuk terrane, or Yukon-Koyukuk basin, is a wedge-shaped basin open to the southwest. It lies between the Brooks Range, Seward Peninsula, and the Ruby geanticline (Ruby Terrane). A "U-shaped" outcrop belt of volcanic rocks divides the terrane into two subbasins: an outer, remnant-forearc basin to the north and east of the belt of volcanic rocks (the Koyukuk basin), and an inner, remnant-backarc basin to the south and southwest of the belt of volcanic rocks (the Yukon basin). The volcanic belt arcs through the terrane from Kotzebue Sound to the Yukon River. A part of the belt appears to lie to the south of the main outcrop of volcanic rocks.

The "U-shaped" outcrop belt consists of a thick Lower Cretaceous assemblage of marine andesitic volcanic rocks that include tuffs, breccias, and flows with local intercalations of volcanic graywackes and impure fossiliferous limestone (Patton, 1971). Similar rocks unconformably overlie pre-Cretaceous volcanic and plutonic rocks which crop out to the south of the main volcanic sequence about midway between Norton Sound and the Yukon River. This outcrop lies between the Chiroskey and Anvik faults. The pre-Cretaceous rocks include altered basalts of uncertain age, but younger than Middle Jurassic, and diorite and tonalite of the Middle and Late Jurassic (Patton and Moll, 1984). The western margin of the Koyukuk subbasin, likewise, consists of Lower Createaceous andesitic rocks resting



LEGEND

Innoko National Wildlife Refuge

Galena

Terranes

AAC – Arctic Alaska Subterrane
AAD – Delong Mountains Subterrane
AAH – Hammond Subterrane
* AM – Angayucham Terrane
BP – Broad Pass Terrane
BRY – Baldry Terrane
CH – Chulitna Terrane
DL – Dillinger Terrane
* IN – Innoko Terrane
KH – Kahiltna Terrane
* KY – Koyukuk Terrane
MAN – Manley Terrane
MK – McKinley Terrane
MN – Minchumina Terrane
MY – Mystic Terrane
NX – Nixon Fork Terrane
PN – Pingston Terrane
* RB – Ruby Terrane
SD – Seward Terrane
* TZ – Tozitna Terrane
WHM – White Mountains Terrane
YT – Yukon–Tanana Terrane

Overlying Sedimentary Deposits

Cz – Cenozoic Deposits
* K – Cretaceous deposits

* Discussed in the report text. The Koyukuk Terrane and the Cretaceous deposits around it are discussed as the Yukon–Koyukuk Terrane.

Figure 2. Tectonostratigraphic terrane map of west–central Alaska (after Jones et al., 1987).

on older pillow-basalts. The andesitic rocks consist of pyroclastic and epiclastic strata deposited in subaerial to shallow submarine environments (Box, Carlson, and Patton, 1984). The K-Ar age of the basal island-arc sequence ranges from 173 to 100 million years. A suite of alkalic plutons, 113-100 million years old, intrudes Lower Cretaceous (Neocomian) andesites in the western part of the terrane (Harris, Stone, and Turner, Stone, 1987).

Middle Lower Cretaceous K-feldspar-bearing tuffs, deposited in deeper water (a sub-wave-base environment) succeed the shallow-water facies in the Koyukuk Basin (Patton, 1971; Box, Carlson, and Patton, 1984). Upper Lower Cretaceous, medium-grained turbidites conformably onlap the tuffs. The composition of these turbidites (graywackes and mudstones) shows derivation from the ophiolite rocks of the Angayucham terrane and the schistose rocks of the Brooks orogen (Box, Carlson, and Patton, 1984).

Middle Cretaceous (Albian-Cenomanian) hemipelagic shales (basin plain?) and sandstones indicative of a mid-fan (channel?) environment overlies the Lowe Cretaceous sediments. These middle Cretaceous sediments onlap the marine volcanic rocks (Box, Patton, and Carlson, 1985).

Calc-alkaline plutons, with K-Ar ages of 89-79 milion years, intrude the Albian (late Early Cretaceous) sediments and the Neocomian (early Early Cretaceous) andesites in the eastern Yukon-Koyukuk Terrane. Also in the eastern part of the terrane, the turbidite deposits grade upward into nonmarine, fluvial-deltaic deposits which contain Late Cretaceous plant and invertebrate fossils. A sequence of Late Cretaceous molasse, shed from the Brooks Range and adjacent borderland, crops out along the northern margin of the terrane.

In the Yukon subbasin, a lower unit of graywacke and mudstone overlies the andesitic volcanic assemblage and underlies an upper unit of shallow-marine and fluvio-deltaic deposits of sandstone and shale. The graywacke-mudstone unit crops out along the Norton Sound coast and contains no fossils. Correlation with similar rocks elsewhere in the Yukon-Koyukuk terrane suggests a late early Creaceous (Albian) age. The succeeding shallow-water sands and shales contain abundant marine fossils of late Early and early Late Cretaceous (Albian-Cenomanian) age (Patton and Moll, 1984). These shallow-water sands and shales occur mainly around the edge of the terrane.

Felsic volcanics (Harris, Stone, and Turner, 1987) mark the end of the final phase of the deposition in the Yukon-Koyukuk terrane. These rocks consist of rhyolite, trachyte, latite, andesite, and minor dacite and basalt. The K-Ar ages for these rocks fall into two groups: 56-49 and 44-43 million years (Early Eocene to lower Mid-Eocene and late Mid-Eocene, respectively).

Ruby Terrane

The Ruby terrane contains some of the oldest rocks in Alaska. It consists mostly of a complex suite of metamorphic rocks of Precambrian to late Paleozoic age (Miller and Buddington, 1987 . The metamorphic rocks include phyllite, quartzite, a greenschist to amphibolite facies pelitic schist, quartzofeldspathic gneiss, marble, and amphibolite (Smith and Puchner, 1985). Granites of mid-Cretaceous age (115-100 Ma) intrude the Ruby terrane (Miller, 1985).

Allochthonous sheets of Mississippian to Jurassic oceanic crustal rocks (Angayucham terrane) structurally overlie the Ruby terrane (Dillon, et. al., 1985). Isotopic and gravity data indicate that the Ruby terrane does not underlie the Yukon-Koyukuk terrane (Patton and Box, 1985).

Precambrian to Paleozoic metamorphic rocks form a broad, southwest trending belt from the Galena-Ruby area, on the Kaltag Fault, southwestward to Goodnews Bay. North of the Kaltag Fault, they form a discreet belt called the Kokrines-Hodzana Highlands (Gemuts, Puchner, and Steffel, 1983). Ruby terrane rocks crop out in the Kaiyuh Mountains, Tlatl Hills, and some of the other hills in the vicinity of the INWR.

Angayucham Terrane

The Angayucham terrane is a structurally and stratigraphically complex assemblage of oceanic rocks. The rocks consist of gabbro, diabase, pillow basalts, tuff, chert, graywacke, argillite, and minor limestone. The sedimentary rocks range in age from Mississippian to Jurassic. Separate thrust sheets of plutonic ultramafic rocks occur throughout the terrane (Jones et al., 1984).

The Angayucham terrane crops out discontinuously for about 900 km along the northern and southeastern margins of the Yukon-Koyukuk terrane (Loney and Himmelberg, 1985). Gravity and magnetic highs, coincident with the northern and southeastern margins of the Yukon-Koyukuk terrane, form a "V" open to the southwest. A model assuming dense, magnetic sources that dip 30-70 degrees toward the Yukon-Koyukuk terrane best fits the data (Cady, 1986). Cady (1986) assigns the northern arm to the Angayucham terrane and the southeastern arm to the Kanuti terrane on the basis of geology and geophysics. The Angayucham structurally overlies the Ruby terrane on the southeast and the Arctic Alaska terrane on the north (Silberling and Jones, 1984).

Only the southeastern arm of the terrane reaches into the INWR. There it occurs as a reversely stacked, dismembered ophiolite assemblage thrust to the southeast across the metamorphic complex (Ruby terrane) from a root zone at the margin of the Yukon-Koyukuk terrane (Patton, et. al., 1984).

Innoko Terrane

An assemblage of folded and disrupted chert, argillite, minor graywacke, limestone blocks, and volcanogenic sandstone make up the Innoko Terrane. Cherts date from the Late Devonian to Late Triassic while limestones date mainly to the Carboniferous. The sedimentary rocks have a similarity to the sedimentary rocks of the Angayucham Terrane without the large volume of pillow basalt, gabbro, and diabase (Silberling and Jones, 1984). Three gross lithologic units make up this structurally complex terrane. The lower unit consists of varicolored bedded chert with scattered, thin, lenticular bodies of limestone. The middle unit consists mostly of tuff, volcanic conglomerate, breccia, and basalt. An angular unconformity separates the upper unit from the lower and middle units. The upper unit consists of a thick sequence of tuff, volcanic sandstone, and volcanic conglomerate (Patton, 1978).

Tozitna Terrane

The Tozitna terrane consists of a structurally complex assemblage of gabbro, pillow basalt, massive basalt and diabase, argillite, tuff, chert, graywacke, minor conglomerate, and limestone. Comminuted prismatic bivalve shells make up the Permian(?) limestones. Radiolarian cherts range from Mississippian to Triassic age. Sparse radiometric ages (K/Ar) from gabbros are late Triassic, but Paleozoic basaltic rocks are probably present. This terrane includes the Rampart Group of east-central Alaska (Jones et al., 1984).

5. Structure

The Yukon-Koyukuk terrane is a broad, asymmetric, "V-shaped", depression open to the southwest (Harris, Stone, and Turner, 1987). Along its northern and southeastern margins a narrow, highly-tectonized belt of Mesozoic oceanic rocks (Angayucham terrane) overthrusts the Paleozoic metamorphic borderland (Cady, 1986). This oceanic crust dips toward the Yukon-Koyukuk terrane and may form the basement of the basin. Terrigenous strata overlap the oceanic crust and metamorphic rocks along the margin (Patton and Moll, 1982).

The Yukon-Koyukuk terrane has tightly folded and highly faulted strata. Folds trend northeastward along the southeastern margin and east-west along the northern margin. The Early and Middle Cretaceous rocks are intensely folded on a scale that ranges from inches to miles (Lyle et al, 1982; Harris, Stone, and Turner, 1987), and numerous intrusive bodies cut the strata (Miller, Payne, and Gryc, 1959). The latest Cretaceous or earliest Tertiary volcanic rocks are broadly warped and dip, generally, less than 40°. Late Tertiary or Quaternary basalt flows are essentially undeformed (Patton and Moll, 1984). Few, if any, anticlinal structures remain unbroken by pervasive north and northeast trending faults (Gates, Grantz, and Patton, 1968).

A broad structural high, the "Hogatza trend," extends across the terrane from Kotzebue Sound to the valley of the Koyukuk River. It exposes a thick assemblage of marine andesitic volcanic rocks. This assemblage appears to underlie large parts of the Koyukuk Flats and the Kobuk-Selawik lowland (Patton, 1971).

A major strike-slip fault, the Kaltag Fault, cuts across the Yukon-Koyukuk terrane along an east-northeast trend. It shows right-lateral displacement (i.e., the rocks on one side of the fault have moved to the right relative to the rocks on the other side) of 100 to 130 kilometers (62 to 81 miles). Most of this movement occurred after deposition of the Cretaceous rocks (Lyle et. al., 1982; Patton and Moll, 1984).

6. Tectonic Development

As with the tectonostratigraphic terrane and structure discussions, we will concentrate on the tectonic development of the Yukon-Koyukuk terrane. We will consider the associated terranes only to the extent necessary for discussion of the Yukon-Koyukuk terrane.

The Ruby terrane may have formed as a rifted-away portion of the North American Continent at the end of the Paleozoic. This would have formed the Yukon-Koyukuk basin as a marginal sea or mini-ocean basin which existed from the late Paleozoic to the Early Cretaceous (Patton, 1976).

Formation of the Ruby terrane as a rifted fragment would mean that extensional tectonics affected this area in the late Paleozoic. The change from extensional tectonics to compressive tectonics, as would be necessary for the subsequent development of the Yukon-Koyukuk Terrane, is not discussed in the literature. Alternatively, the Ruby Terrane may have been an original promontory, or peninsula, of the North American continent. Regardless, the subsequent tectonic development remains the same.

Oceanic rocks (i.e., the rocks of the Angayucham terrane) overthrusted the margins of the Yukon-Koyukuk terrane (i.e., onto the rocks of the Ruby terrane) during the latest Jurassic (Tithonian) and Early Cretaceous (Berriasian) time (Patton and Box, 1985). This clearly implies that the tectonic regime had changed from extensional (if it was once extensional) to compressional by this time. An island arc system, with its attendant arc volcanism, developed synchronously with this collision of the oceanic rocks with the irregular margin of the North American continent (Patton and Box, 1985; Cady, 1986).

Continued collision of the island arc into a continental reentrant developed the "U-shape" of the volcanic trend in the Yukon-Koyukuk Terrane (Box and Patton, 1985). During the Berriasian to Valanginian (Early Cretaceous), mostly clastic volcanic rocks collected in shallow marine to subaerial environments in the Koyukuk subbasin (to the northeast of the island arc system)(Box and Patton, 1986).

During the Hauterivian (middle Early Cretaceous) the area experienced marked subsidence accompanied by a change to highly potassic pyroclastic volcanism (Box and Patton, 1986). By the Barremian (possibly Aptian) the pyroclastic tuffs interbedded with turbidites derived from the uplifted Brookian metamorphic belt. The Brookian orogeny apparently originated from the attempted subduction of the North American margin beneath the intraoceanic island arc (Box and Patton, 1986). Significant volcanism ceased by the Albian (late Early Cretaceous) and the intervening trough filled with sediments derived from the Brooks Range. Terranes which accreted from the southeast in Late Cretaceous time further tightened the "U-shape" of the volcanic trend (Cady, 1986).

In the Yukon subbasin (to the south and southwest of the volcanic arc system), marine graywacke and mudstone compose nearly all of the Cretaceous sedimentary sequence along the west side of the terrane from the Seward Peninsula to the Yukon-Kuskokwim lowland. Sandstones, shales, conglomerates, and coal record deposition in shallow-marine and nonmarine environments around the perimeters of the terrane. These shallow marine and nonmarine sediments interfinger with the marine graywackes and mudstones and, in places, overlie the andesitic volcanic rocks of the island arc system. These sediments derived from the metamorphic borderlands which uplifted when of the island arc system collided with the continent (Patton, 1971).

A major episode of calc-alkaline volcanism during the Late Cretaceous and early Tertiary (70 to 60 million years ago) affected a broad area from the Bering Sea Shelf eastward to the Alaska Range and northward to the Arctic Circle. Widespread contemporaneous hypabyssal (minor) intrusive rocks of similar composition overlaps four tectonostratigraphic terranes: the Nixon Fork, Innoko-Rampart, Yukon-Koyukuk, and Brooks Range-St. Lawrence Island (the names of the terrane given here reflect some of the disagreement mentioned above). This overlap establishes conclusively that these terranes were sutured together by the end of the Late Cretaceous. Subduction along the Pacific margin during the Late Cretaceous and early the Tertiary may have caused this calc-alkaline volcanism and contemporaneous plutonism (Moll and Patton, 1982b).

Tertiary volcanics mark the end of the final phase of terrigenous sedimentation in the Yukon-Koyukuk terrane. The 56 to 49 million year old, mostly felsic volcanics tilt from about 20 degrees to about 50 degrees and record the final deformation of the Yukon-Koyukuk terrane. The 44- to 43-million-year-old group of undeformed basalts indicate no further tectonic tilting of the Terrane (Harris, Stone, and Turner, 1987).

The 100 to 130 kilometers of right-lateral offset of the Kaltag fault record post-Cretaceous strike slip deformation of the Yukon-Koyukuk terrane. Evidence suggests that this deformation continues.

Reservoir Rocks

The late Early and early Late Cretaceous shallow marine and nonmarine rocks around the edge of the Yukon-Koyukuk terrane offer the best possibility of having reservoir-quality rocks. These units have better sorting and contain a larger fraction of resistant rock and mineral detritus than do the underlying graywackes and mudstones (Patton, 1971). The impermeable graywackes and mudstones (Gates, Grantz, and Patton, 1968) have little probability of having reservoir-quality rocks. These shallow marine and nonmarine rocks lie within the boundaries of the INWR along the Yukon River. The well drilled just to the west of the refuge near Nulato, drilled to a depth of 12,000 feet, apparently encountered no reservoir rocks (Patton, 1971).

7. Hydrocarbon Indicators and Geochemistry

An unverified oil seep near Nulato (Gates, Grantz, and Patton, 1968) apparently provided one of the incentives for drilling the Nulato well. The well, however, apparently encountered no oil shows (Patton, 1971). Harris et. al., 1985, reported that vitrinite reflectance values from two, mid-Late Cretaceous sedimentary sections plotted in the oil window of a time-temperature kinetic relationship.

Geophysics

Gravity and magnetic highs correspond with the arms of the "V" formed by the Angayucham terrane and with the "U" formed by the island arc assemblage within the Yukon-Koyukuk terrane. The highs associated with the Angayucham terrane are asymmetric with steeper gradients to the outside. These highs can be modeled by assuming dense, magnetic sources that dip 30° to 70° inward beneath the Yukon-Koyukuk Terrane. The steep gradients coincide with boundaries determined by surface geology and strontium isotope data between oceanic terranes in the Yukon-Koyukuk terrane and nearby continental terranes. Isostatic constraints and gravity modelling preclude a model in which oceanic terranes are thrust over continental crust in the interior of the Yukon-Koyukuk terrane. Acceptable models include thickened oceanic crust or oceanic crust thrust over attenuated continental crust (Cady, 1985; Cady, 1986).

Old continental crust of the Brooks Range and the Ruby terrane produce gravity lows. Also, the middle Cretaceous clastic rocks which fill the subbasins of the Yukon-Koyukuk Terrane produce gravity lows (Cady, 1986).

The gravity highs indicate that dense rock lies near the surface and the gravity lows indicate that less dense rock lies near the surface. The magnetic highs indicate the presence of magnetic rock near the surface.

Aeromagnetic data indicate that the basin, north of the Kaltag Fault, may have as much as 25,000 feet of basin fill (Gates, Grantz, and Patton, 1968).

Areas of Hydrocarbon Potential

The parts of refuge underlain by the metamorphic and oceanic rocks of the Ruby, Angayucham, Innoko, and Tozitna terranes have No hydrocarbon occurrence potential because of the igneous and metamorphic nature of the rocks *(Figure 3)*. This is an O/D classification according to BLM's Mineral Potential Classification System *(Appendix A)*. Only that area that overlies the shallow marine and nonmarine sediments along the edge of the Yukon-Koyukuk Terrane has a Low potential for the occurrence of hydrocarbons. This is an L/A classification. This area lies along the Yukon River and under much of the northern unit of the INWR and under the western portion of the southern unit of the INWR.

8. Typical Oil and Gas Development Scenario

We classify the INWR, in its entirety, as having No potential for economic deposits of oil or gas, or both. Therefore, the scenario presented below is unlikely to occur, but, should a small deposit of gas be discovered, this is most likely what one might see.

For any chance of development, the deposit must be located near a potential market. Disturbance would be minimal: one or two gas wells, separator facility, road from the field to the market, and a small-diameter pipeline to transport the gas. It is unlikely one would see any office modules or buildings in the field. An estimate of the direct acreage disturbed would range from 10 to 20 acres and would require approximately 120,00 cubic yards of gravel (assuming the gravel pad and two-mile road would be at least five feet thick to protect the permafrost environment).

A larger gas deposit or an oil deposit in INWR is very unlikely, thus these types of scenarios are not discussed.

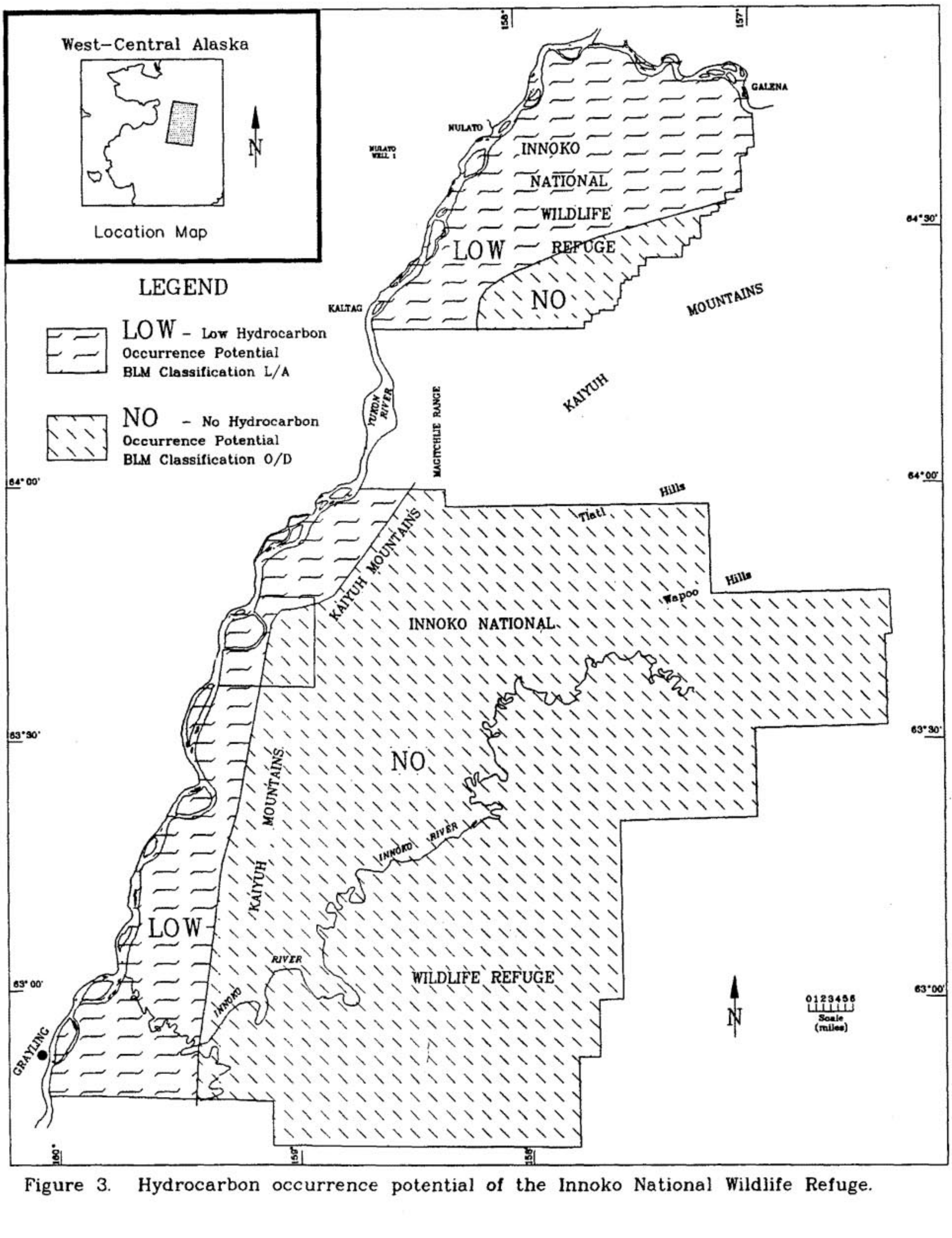


Figure 3. Hydrocarbon occurrence potential of the Innoko National Wildlife Refuge.

9. Economics

The whole of the Innoko NWR (3.75 million acres) has been rated as having No economic potential for the development of oil or gas resources at least through the next quarter of a century.

Approximately 74 percent of the refuge was determined to have no geologic potential for the occurrence of oil or gas. The balance of the refuge, approximately 0.98 million acres, has been determined to have only a low hydrocarbon occurrence potential. Even this possibility is very uncertain, as available data is insufficient to base a strong case and, as such, the BLM categorized "level of certainty" is quite low (see L/A in Appendix A).

Much of the area was explored between 1954 and 1961 by the oil industry but no wells have been drilled within the refuge boundaries. One exploratory well, the Nulato, was drilled to a depth of approximately 12,000 feet but encountered no reservoir rock formations. Industry's interest in the area at the present time is considered to be low in relationship to other areas which hold more promise of success. Another negative factor in terms of exploration/development of the Innoko NWR is its location. This refuge lies in the west-central portion of the State and is distant from current production sites on the North Slope and in the Kenai Peninsula (275 to 450 miles).

Due to the location of the refuge and the lack of infrastructure, costs of exploration/development would be extremely high. Since the area holds so little promise, it is very doubtful that industry would be willing to incur the anticipated high costs of exploration/development for some time.

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Appendix A
3031 Energy and Mineral Resource Assessment

Mineral Potential Classification System *

I. Level of Potential

O. The geologic environment, the inferred geologic processes, and the lack of mineral occurrences do not indicate potential for accumulation of mineral resources.

L. The geologic environment and the inferred geologic processes indicate low potential for accumulation of mineral resources.

M. The geologic environment, the inferred geologic processes, and the reported mineral occurrences of valid geochemical/geophysical anomaly indicate moderate potential for accumulation of mineral resources.

H. The geologic environment, the inferred geologic processes, the reported mineral occurrences and/or valid geochemical/geophysical anomaly, and the known mines or deposits indicate high potential for accumulation of mineral resources. The "known mines and deposits" do not have to be within the area that is being classified, but have to be within the same type of geologic environment.

ND. Mineral(s) potential not determined due to lack of useful data. This notation does not require a level-of-certainty qualifier.

II. Level of Certainty

A. The available data are insufficient and/or cannot be considered as direct or indirect evidence to support or refute the possible existence of mineral resources within the respective area.

B. The available data provide indirect evidence to support or refute the possible existence of mineral resources.

C. The available data provide direct evidence but are quantitatively minimal to support or refute the possible existence of mineral resources.

D. The available data provide abundant direct and indirect evidence to support or refute the possible existence of mineral resources.

For the determination of No Potential use O/D. This class shall be seldom used, and when used it should be for a specific commodity only. For example, if the available data show that the surface and subsurface types of rock in the respective area is batholithic (igneous intrusive), one can conclude, with reasonable certainty, that the area does not have potential for coal.

* As used in this classification, potential refers to potential for the presence (occurrence) of a concentration of one or more energy and/or mineral resources. It does not refer to or imply potential for development and/or extraction of the mineral resource(s). It does not imply that the potential concentration is or may be economic, that is, could be extracted profitably.

Consideration of the Potential for Development and the Economic Potential

Whenever known, the quality, quantity, current, and projected development potential or economic potential should be part of the mineral resource assessment. Although this is not necessary or required for most BLM actions, it is often useful to the decision maker. Assessments of economic potential should not be attempted for actions requiring low levels of detail, or when data are scant.

Development potential means whether or not an occurrence or potential occurrence is likely to be explored or developed within a specified timespan under specific geologic and nongeologic assumptions and conditions. Economic potential means whether or not an occurrence or a potential occurrence is exploitable under current or foreseeable economic conditions. The time period applicable to the economic or development potential assessment should be specified in the assessment report (e.g., the occurrence is likely to be exploited in the next 25 years). Conditions that could change the economic potential, such as access, world energy prices, or changing technology, shall be an important part of every economic potential assessment. Determining the economic or development potential of either an actual or an undiscovered mineral occurrence is a matter of professional judgment based on an analysis of geologic and nongeologic factors. The rationale for that judgment shall be part of the mineral Assessment Report, when the economic potential is assessed. The rationale may include data on the current marketing exploitability, distance from roads, anticipated capital costs, etc. In other words, if the economic or development potential is assessed, the rationale for the conclusions regarding that potential must be thoroughly documented.

Calculating the quality and quantity of an occurrence, where the quality and quantity are not known from existing data, is only done for actions requiring a high level of detail. These calculations involve methods appropriate to the type of action and are described in the pertinent Bureau Manual (e.g., appraisal, validity, etc.).