PETROLEUM GEOLOGY
OF THE
NOWITNA NATIONAL WILDLIFE REFUGE

by

Arthur C. Banet, Jr.
Jim Borkoski
Aden Seidlitz

Table of Contents

Page

Executive Summary

The Nowitna National Wilflife Refuge is located in the central part of the State, along and south of the Yukon River. This area is remote, having no vehicular access via roads and is largely dependent upon river and air transportation. The land consists of a central swampy lowland area with many lakes surrounded by low, rolling hills. The lowlands cover part of the 2,500 square mile Lower Tanana basin. Field geological investigations, Bouger Gravity maps, and aeromagnetic data suggest that lithologies exist that are favorable to the generation and preservation of natural gas rather than oil and that they are inferred to exist within the subsurface of the Nowitna Refuge. Approximately 800 square miles are estimated to have moderate potential for the discovery of natural gas.

Plates

Figures

Page

Tables

PETROLEUM GEOLOGY OF THE NOWITNA WILDLIFE REFUGE

Introduction

The Nowitna Wildlife Refuge (NWR) is one of the 16 National Wildlife Refuges created in 1980 under the Alaska National Interest Lands Conservation Act (ANILCA) legislation. Although it is one of the smaller refuges, it covers approximately 2,050,000 acres. It is located in approximately the center of the State (figure 1). The northern boundary of the refuge is the Yukon River, including the islands within the river. The outer boundaries are mostly township and section lines (unsurveyed); Tps. 3 S., to 18 S., Rs. 17 E., to 29 E., inclusive, Kateel Meridian, and Tps. 6 S., to 4 N., Rs. 26 and 27 W., Fairbanks Meridian (plate 1). Most of the area is within the Nowitna River drainage.

The village of Ruby is the nearest settlement and is immediately west and downstream of the refuge. Tanana is some 25 miles upriver. Plate 1 shows these villages and several abandoned villages and mining settlements. Access to this area is predominantly by boat and air travel during the summer months, or by snowmachine and dog sled over the frozen ground during the winter. There are no roads or permanent trails across the refuge.

Previous Work

Following the discovery of gold in this area in the early 1900s, Eakin (1918) did the initial reconnaissance geology and topographic survey of this region. Eardly (1938) mapped and synthesized much of the geology of the surficial deposition. Cass (1959) mapped the bedrock geology of the Ruby Quadrangle. This includes most of the refuge; some 93 percent of the area which is described under the Kateel Meridian. Chapman and Patton (1978) mapped the northwest portion of this quadrangle. The easternmost part of the

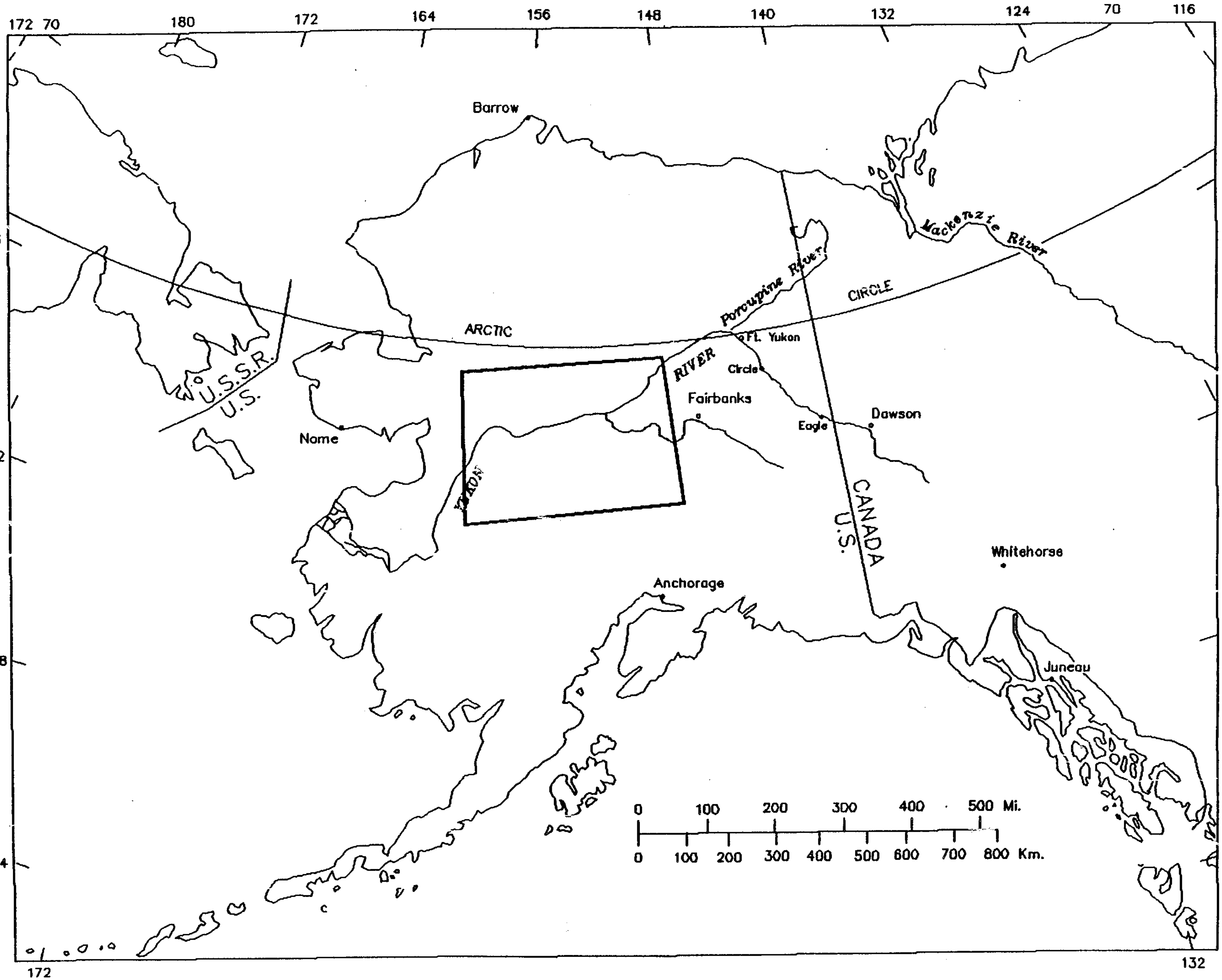


Figure 1. Index map showing Central Alaska

refuge was mapped by Chapman (1975). Several regional studies and compilations include this area; Patton (1973), coal studies by Barnes (1977), Meritt and Hawley (1986), and regional geophysical compilations by Barnes (1977) and Godson (1984). Precious metal mining still takes place around the periphery of the refuge.

Physiography

The physiography of the Nowitna Wildlife Refuge consists mostly of low rounded hills, areally extensives predominantly flat lying terraces, and wide modern flood plains along the drainages. This is typical to most of the Alaskan interior. Vegetated northeast trending dunes cover the central and northeast part of the refuge. The hills where bedrock is exposed are mostly in the south-southwest part of the refuge. They are generally less than 2,300 feet in elevation and 700 to 1,500 feet higher than the surrounding terrace areas. Vegetation and colluvium are common on the hillsides. Ridgelines of these hills trend northeasterly.

The flat lying terraces, which are predominantly found on the south side of the Yukon River in this area, are mostly areally extensive unconsolidated silt deposits that overlie bedrock and washed gravels from ancestral eastward drainages in this area (Eardley, 1938). Both the silts and gravels thicken north, from the bedrock exposures in the hills towards the Yukon River. The gravels are poorly exposed, but probably are stream deposited. Eakin (1918) reports approximately 500 feet of thinly interbedded, light colored silt, clay, and silt size (0.00016 to 0.0025 inches in diameter) quartz and mica in bluffs along the lower Chititana River. At outcrop, the silts show some remnant planar and cross stratification and fossil suites suggest deposition in fresh, quiet water environments such as lakes.

Lithology and Stratigraphy

Geologic mapping in the Nowitna area is still of a regional and reconnaissance nature (Eakin, 1918; Cass, 1959; Patton, 1973, 1975, 1978;

Chapman, 1975; Chapman and Patton, 1978). Outcrops are badly weathered, commonly vegetated, widespread, and usually have been severely deformed by tectonism. Stratigraphic correlations are limited, as strikingly different rock suites appear to be juxtaposed across faults or from one outcrop area to another. Jones and others (1981), Churkin and others (1982), Silberling and Jones (1984), and Howell (1985) suggest that these relationships are indicative of amalgamated geologic terranes rather than being vaguely related portions of a single geologic domain or province. Jones and others (1981) define terranes as lithostratigraphic or tectonostratigraphic entities of regional extent uniquely different from contiguous rock units.

Plate 2 shows four distinct tectonostratigraphic terranes in or immediately adjacent to the Nowitna Refuge. The names of these terranes are from Silberling and Jones (1981) to facilitate comparisons with mapped terranes of other areas and previous literature. The extensive Nowitna lowland, which is largely marsh and lakes, is mostly underlain by unconsolidated or poorly consolidated recent or Pleistocene sediments. In addition, Cretaceous age sediments of the Yukon Koyukuk basin crop out northwest of the refuge across the Yukon River (plate 2).

Miller, Payne and Gryc (1959) show a 2,500-square-mile Lower Tanana Cenozoic basin (their plate 2) beneath the Nowitna lowlands and extending to some 25 miles up the Tanana River. This elliptical shaped basin is based on the outcrops of Tertiary rocks in the area. Eardly (1938) reported approximately 600 feet of Tertiary section, including a 20-foot seam of lignite, overlain by and in fault contact with unconsolidated Pleistocene silt, sand, and loam at the "Pallisades" outcrop along the Yukon River in the northwest part of the refuge (figure 2).

The Tertiary rocks at the "Pallisades" outcrop consists of mostly friable tan and gray, fine-to-coarsely grained sandstone and minor amounts of siltstone. White rounded quartzite and chert pebbles commonly occur as

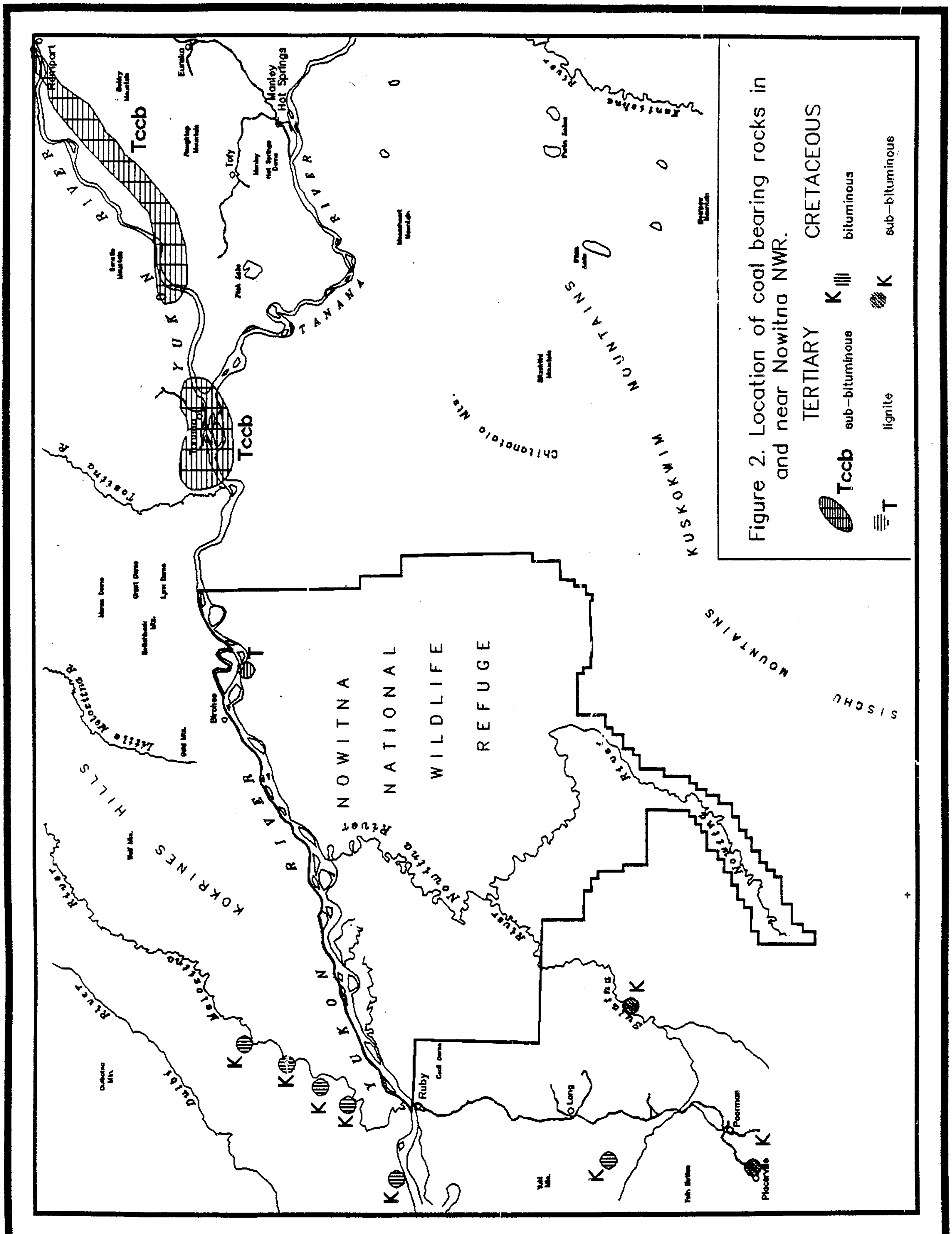
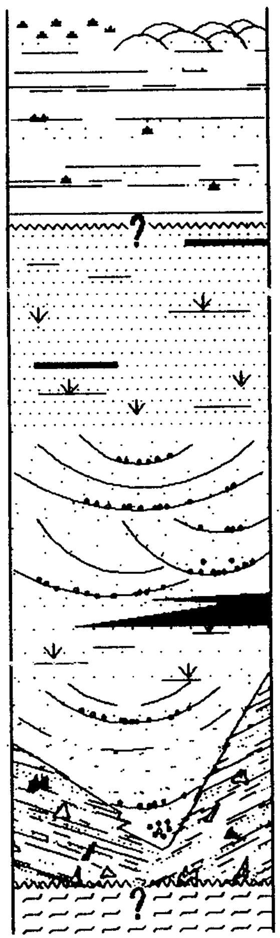


Figure 2. Location of coal bearing rocks in and near Nowitna NWR.

channel lag in large scale trough cross beds. Some units of pea-gravel sized clasts are up to three feet thick. These sands are mostly well sorted, quartzose and, overall, fine upwards (figure 3). Depositionally, they represent fluvial and upper flood plain environments. The silts are tan to brown and soft. Both the sand and silt units commonly have lignitic plant remains and partially fossillized wood fragments along bedding planes. Brown iron oxide concretions and plant casts of branches are common.

The next closest Tertiary rocks crop out at Tanana (figure 2). At this location, the rocks record chaotic landslide type deposition. These exposures consist of well indurated, agglomerated rock fragments in a silt-to-very coarse sand-sized matrix. The rock fragments are mostly one to eight inches in diameter, subangular to subrounded, and consist of various clasts of schist, quartzite, chert, greenstone, and limestone (figure 3). There are also minor amounts of poorly sorted and poorly graded channel sandstones with pebbly lag deposits. Brown staining, interstitial iron oxide cement is common. Secondary quartz, quartz replacement on slickensides surfaces, and white vein quartz show that these rocks have undergone considerable burial, a severe diagenetic history, and subsequent uplift. Reservoir properties of these rocks were initially poor and now are nonexistent. Similar lithologies at the basal part of the Tertiary section probably exist around the periphery of the entire basin, but do not reflect the reservoir properties of the upsection nonmarine lithologies.

The Tertiary sediments in the refuge are overlain by a thick succession of unconsolidated silts and sands with minor deposits of washed and sorted gravels of Pleistocene age. Chapman (1975) divides these unconsolidated sediments into seven units. Most noticeable in this area are the sands and silts of the east-northeast trending dunes found in the central and eastern parts of the refuge, the terraces in the highlands, and the flat bedded Pleistocene lacustrine silts, sands, and clays seen in exposures along the rivers draining the refuge.



Unconsolidated , unsorted silts , sands and gravels. Predominantly lacustrine deposits underlie the surficial swamps, bogs , terraces and aeolian dunes.
Fossils, including large Pleistocene mammals are locally common.

Poorly consolidated sands and silts with locally abundant lignitic material.

Poorly consolidated sands to coarse sands; large scale cross cutting trough cross bedded channel sands.
Rounded pebbles are common as channel lag and partially coalified plant material and lignite are locally common.

Agglomerated bedrock clasts in a mostly unsorted matrix, clasts are subangular to angular and matrix is mostly unsorted coarse to very coarse sands with minor amountl of bedded coarse units. Probably restricted to the periphery of the basin.

Figure 3. Stratigraphy extrapolated into Lower Tanana basin, underlying the Nowitna Wildlife Refuge.

The extent within the basin of prospective lithologies, similar to those rocks which crop out at the "Pallisades," is uncertain. However, the Bouger Gravity map (plate 3) shows that approximately 800 square miles of the area is within the -30 mgal closed contour. This area of the north and northeast part of refuge and beyond, is roughly coincident with Lower Tanana basin limits suggested by Miller, Payne, and Gryc (1959) from Tertiary outcrops. The aeromagnetic map of the area (plate 4) indicates that the basin suggested by the Bouger Gravity and outcrop is not intruded by magnetic plutons or underlain by extensive shallow mafic rocks.

Across the Yukon River and immediately northwest of the Nowitna Refuge, Cretaceous rocks of the Yukon-Koyukuk basin crop out. The basal map unit is andesitic flows interbedded with fine grained tuffaceous sandstones, siltstones, and shales which crop out along the river (plate 2). Upsection units consist of an overall regressive sequence of deep water marine to fluvial pebble conglomerates, sandstones, siltstones, and shales (Nielsen and Patton, 1984). Most of these units have a large component of volcanic and tuffaceous material. These sediments are mostly the products of arc trench sedimentation. Thus, they are rich in volcanic lithic fragments. This serves to destroy porosity and primary rock fabrics due to poor initial sorting of grains, clasts, and rock fragments. It also serves to promote precipitation of authigenic cements from ion rich interstitial fluids from both physical and chemical interactions (Dickinson, 1982, and Housnecht, 1987). Loss of porosity in these rocks is documented from the Nulato No. 1 well which penetrated some 12,015 feet of this section 90 miles to the west. Reservoir properties of these rocks are very poor, and hydrocarbon source potential is very poor and is limited to gas. Also, these rocks would probably not serve as gas sources to adjacent rocks such as the Tertiary sediments of the Nowitna Refuge.

Contiguous Terranes

The hills that surround the Nowitna Refuge lowlands were originally mapped as poorly defined assemblages of possibly lower Paleozoic greenstone, chert, schist and slate with minor limestone (Eakin, 1918), and as schist, crystalline quartz, greenschist and meta-igneous rocks (Cass, 1959). These rocks are severely folded and faulted to such an extent that the internal stratigraphic relationships of the units are unclear with dates from cherts ranging in age from Late Devonian to Late Triassic and fossil assemblages in limestones as Mississippian. Silberling and Jones (1984) have assigned the volcanogenic clastics, chert, argillite, tuff, and limestone of the central part of the refuge as the Innoko terrane (plate 2). Although there is no data on reservoir or source rock characteristics of these rocks, field descriptions do not suggest the existence of favorable conditions for the generation and preservation of oil or gas.

The hills west of the refuge are more closely related to the rocks that crop out north of the refuge. These are designated the Ruby Terrane (plate 2). They are, chemically, less basic than the Innoko rocks and consist of mica schist, phyllite, greenschist, marble, and quartzite with minor amphibolite and calc schist. Cretaceous granitic plutons have intruded the Ruby Terrane rocks and have caused considerable regional metamorphism (Silberling and Jones, 1984), especially north of the Yukon River. Consequently, there are no favorable indications for the existence of oil or gas from these rocks near the refuge.

The southern part of the refuge is part of the Nixon Fork Terrane (plate 2), which is very similar to, and may be remnant of the North American Terrane. Patton and others (1980) describe the well stratified Lower Paleozoic reefal carbonate rocks and fossilliferous Permian-Triassic and Cretaceous sediments which overlie the pre-Cambrian basement in the hills along the southern boundary of the refuge. Notably, clasts of pelitic schist, quartzite, and meta-volcanic rocks from the basement are locally found in the

Permian section. Patton (1980) described a Triassic sequence of calcareous sandstone, limestone, conglomerate, chert, and fossils of the Monotis genera from the Kuskokwim Mountains south of the Refuge. Elsewhere in Alaska, units of similar age and lithology are rich in organic petroleum source material and are demonstrated oil source rocks (Shublik Formation, North Slope), or are closely associated with oil seeps or stained rocks (east-central Alaska and the Alaska Peninsula). However, this lithology is not yet demonstrated to extend into the refuge, nor is there any geochemical data describing the source rock potential of this unit in this area. Also, none of the units have been tested to determine reservoir quality. Thus, the area of the Nixon Fork Terrane is shown as low potential until data become available to quantatively assess the oil and gas potential.

The Angayucham Terrane is a relatively thin sliver sandwiched between the Cretaceous Yukon-Koyukuk basin sediments and the metamorphic and igneous rocks of the Ruby Terrane, on the north side of the river. The Angayucham rocks are a deep water assemblage of pillow basalts, diabase, tuff, and radiolarian cherts (Jones and others, 1981). Most of these units are severely tectonized and altered to greenstone. The Angayucham rocks in this area are a sliver of much larger terrane to the north. It has no units with reservoir or source potential and contributes nothing to the potential of the Nowitna Refuge.

Structure and Tectonics

The Nowitna Refuge is located along and south of the Kaltag Fault Zone (plate 2). This is an extensive right lateral strike slip fault system that has offset much of interior Alaska by some 40 to 80 miles (Patton and Hoare, 1968; McWhae, 1986). Episodic movement has emplaced and amalgamated the terranes in this area and has offset the Yukon-Koyukuk basin. Local extension of the crust has also created the Cenezoic Lower Tanana Basin beneath the lowland of this refuge.

Most of the exposures of rocks from the Angayucham, Innoko, Nixon Fork, and Ruby Terranes show severe deformation, probably in addition to and predating regional movement along the Kaltag Fault Zone. The parallel northeast trending folds in the Cretaceous Yukon-Koyukuk sediment may represent enechelon second order compressions to the strike slip movement along the Kaltag Fault System. Similar style, although possibly later phase faults, also probably offset the Tertiary rocks. Indeed, the Tertiary rocks at the "Pallisades" outcrop in the northeast part of the refuge are in fault contact with unconsolidated Pleistocene sediments. The exposure is limited, and throw on the fault cannot be determined. Overall uplift at the Tertiary section in this locale has brought sediments to the surface which have been buried deeply enough for catagenesis to transform the organic plant material to lignite rank coal. The size of the area considered to be within the basin, i.e., within the -30 mgal Bouger Gravity contour, is large enough to accommodate structures similar in size to those seen in the Cretaceous Yukon-Koyukuk sediments northwest of the refuge.

Geophysics

Available geophysical data from this area consists of a regional Bouger Gravity map (Barnes, 1977) and a regional compilation of Aeromagnetic data (Godson, 1984). Neither survey indicates or suggests more than the presence of a sedimentary basin without magnetic extrusive or plutonic rocks similar to those which surround the area. Since the lithologies of the Innoko Terrane rocks are considerably more dense than those of the Tertiary rocks, and the Bouger Gravity map shows no penetration over them, I suggest that the Innoko Terrane is probably relatively thin towards the north and is thrust over the Tertiary rocks in the southern part of the basin (plates 2 and 3). However, there is no common depth point (CDP) seismic data in the area or in the entire region to indicate this or to prove/disprove the existence of inferred structures.

Geochemistry

Geochemical information is mostly limited to qualitative lithological descriptions and speculations. Lignite in the Tertiary rocks shows that organic plant material exists in the section and is at least in the initial stage of thermal maturity for generating gas (figure 4) at the Pallisades location. Also, the nonmarine depositional environment is mostly favorable for generating gas upon reaching thermal maturity during catagenesis. Since there is no geothermal gradient data, the entire area within the -30 mgal Bouger Gravity contour (plates 3 and 5) is suggested as prospective for gas.

A possible oil source rock exists in the Nixon Fork Terrane. The Triassic sediments are lithologically similar to demonstrated oil source rocks elsewhere in the State, but have not yet been quantatively evaluated for organic richness, type, or thermal maturity. Their existence in the refuge area is also speculative. Thus, they are not considered to contribute to the potential of the refuge.

Historical Geology

The terranes surrounding the refuge represent mostly distinct and unique geologic histories. However, internal stratigraphic relationships are not well established owing to intensely tectonized and complex geologic histories. The Nixon Fork Terrane records mostly Lower Paleozoic clastics and carbonates deposited upon pre-Cambrian metamorphic basement. The similarity between coeval rocks and fossils suggests that this may be a severed and displaced part of the North American Terrane. The Innoko Terrane rocks are internally disrupted and mildly metamorphosed sediments ranging in age from Late Devonian through Late Triassic. The Ruby rocks are largely metamorphosed and intruded by Cretaceous plutons to the extent that the stratigraphic succession is unclear. The mafic rocks and Late Mississippian to Jurassic sediments of the Angayucham Terrane suggests the partial obduction of a Late Paleozoic spreading center. These terranes were brought together by Late Cretaceous subduction events recorded in the Yukon-Koyukuk rocks.

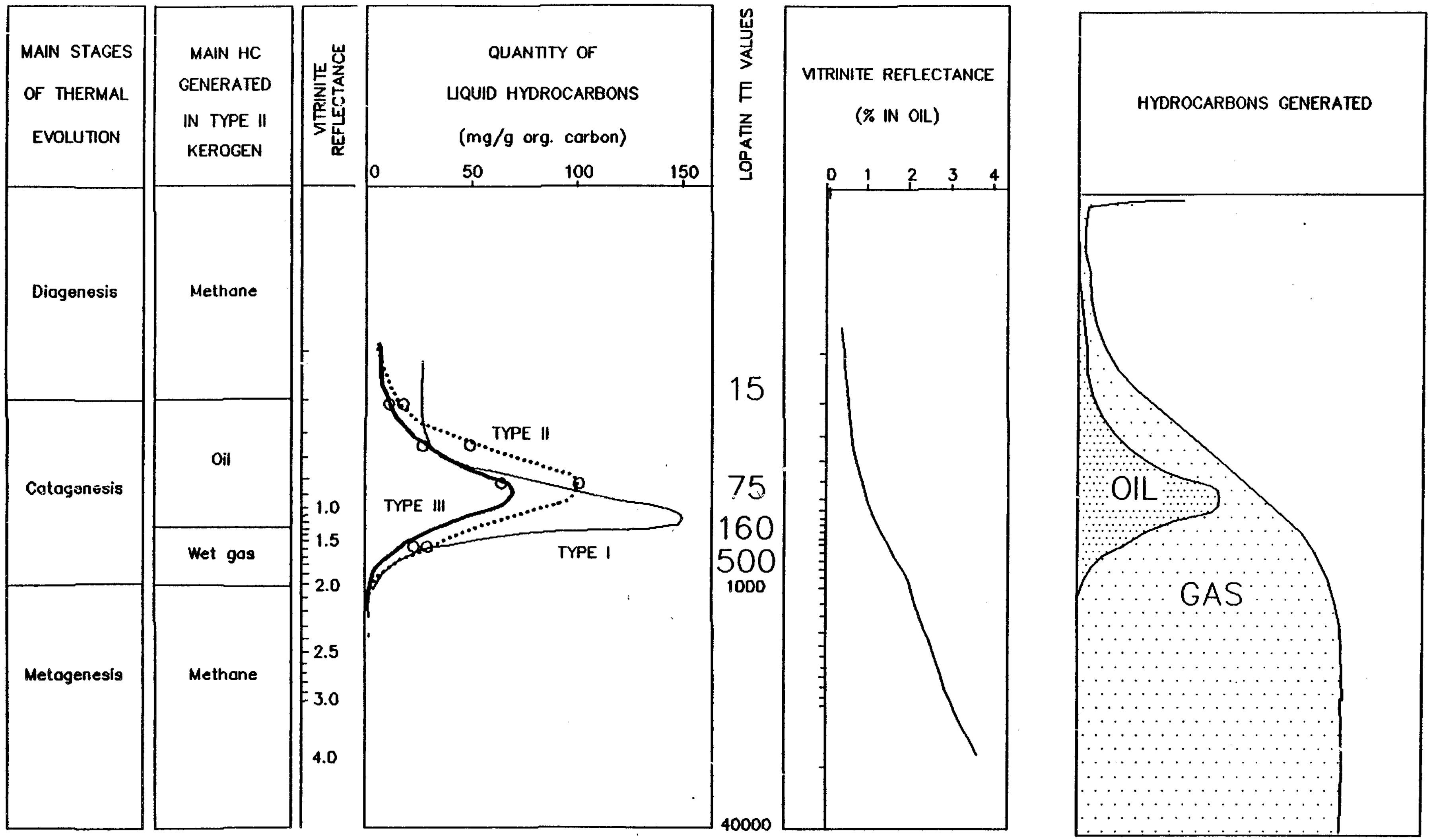


Figure 4. Major stages of thermal maturity, the major indicators of thermal maturity and hydrocarbons generated.

This amalgamation of terranes now described in Central Alaska began as subduction tectonics. After the last of the oceanic crust was consumed, movement was transformed into strike slip movements. Predominantly right lateral movement probably began during late Eocene (McWhae, 1986) and proceeded to culminate in lateral offsets estimated to range from 40 to 80 miles (Patton and Hoare, 1966). The Lower Tanana basin developed as one of several basins along the Kaltag Fault system. Exposures of Tertiary rocks in Central Alaska suggests that at least some of the basin consists of chaotic landslide deposits overlain by fresh water fluvial-lacustrine rocks. Coal is a common in these Tertiary rocks and coal of lignite ranks crops out in the northwestern part of the refuge.

Fossil bearing fluvial, lacustrine, and aeolian periglacial unconsolidated sediments overlie most of the older rocks in the basin. The predominant upstream drainage patterns and abrupt changes in the direction of flow of major streams draining these sediments, such as the bend in the Nowitna River, record that drainages were previously eastward. For rivers upstream of Ruby, Eardley (1938) speculated that the drainage of the ancestral Yukon River became westward with the failure of glacial dams near the end of the Pleistocene. Offsets in the terrane levels and stream mouths show that there has been recent, but prehistorical movement along the Kaltag Fault Zone.

Description of Oil and Gas Resources

Direct evidence and inferences show that the Nowitna Refuge has areas of both medium and low potential for oil and gas discovery (plate 5). The area of moderate potential is based on the favorable reservoir characteristics of Tertiary rocks exposed within the refuge and the inferred extent of similar rocks within the Lower Tanana basin underlying the refuge (plate 3). These rocks are probably gas prone owing to their fluvial-lacustrine depositional environments. Kerogens from these environments are type III and tend to generate gas during catagenesis. Outcrops show that at least some, and probably all, of the Tertiary rocks within the basin are in the gas generating, or gas preservation, phase of catagenesis (figure 3). Traps may be both structural or stratigraphic in nature.

Except for where a suggested thin, fault emplaced veneer of Innoko Terrane rocks overlies the basin, the contiguous terranes are considered to have low potential for oil and gas discovery (plates 3 and 5). Direct evidence from field descriptions and hand specimens from these terranes shows that the rocks originally had low or no potential, or are chemically and physically altered to such an extent that the probability of preservation of hydrocarbons in these rocks is very low.

Only extensive geophysical studies, such as CDP seismic programs will delineate the exact extent of the Lower Tanana basin and indicate whatever structures or stratigraphic hydrocarbon traps exist. And, only a detailed organic geochemical survey of the organic richness, type of organic material, and thermal maturity of rocks in this area will demonstrate the oil and gas generating and preservation history of the rocks in this area. The present state of knowledge indicates that there is a basin, that hydrocarbon traps probably exist, and that sediments having indigenous gas prone kerogens would be in these traps. Thus, the northeast to central part of the Nowitna Wildlife Refuge is considered to have moderate potential for gas and the rest of the area, low potential.

NOWITNA WILDLIFE REFUGE (NWR)

Production Scenario

As mentioned in the geological assessment, the potential for discovering economical quantities of crude oil is low throughout the refuge (plate 5). However, the assessment gave the northcentral area of the refuge a moderate potential of finding natural gas reserves. Due to the location of this refuge and the estimated "most likely" gas reserves, the scenario presented assumes the market for this gas will be a local village or villages near the developed field. Should a large oil or gas field be discovered in this area, a pipeline could feasibly be built in an easterly direction to connect with the Trans-Alaska Pipeline System or the proposed Trans-Alaska Gas System. Also, the infrastructure needed to produce a major field this size would be more complex than the scenario described here.

The following scenario was develcped under these assumptions: The three- to six-inch production pipeline would be buried, there would not be a road connecting the field to existing road insfrastructure, all equipment, facilities, and supplies needed to develop and produce the gas would be transported from existing road systems to the field via the Yukon River, field personnel would be transported to and from the field by the river or by small aircraft, and domestic water would be taken from local sources.

In the event of an economic discovery in the NWR, development and production activities would begin on a year-round basis. Proposed plans for the production and transportation facilities are developed during the economic study of the discovery and submitted to local, State, and Federal agencies for approval. After completing the required review process, the plans are either approved or denied pending further information, studies, and/or modifications. Once approved, construction of permanent pads, air support facilities, roads, and a docking facility could begin. The first activity is to establish a temporary camp for the construction workers. As the pad and road infrastructure nears completion, the necessary wells could be drilled, the pipelines buried, and the needed production facilities and camp modules transported to the field and assembled. The modules would be designed to last the life of the field. Considering the likelihood of gas production and the potential market(s), one would expect this hypothetical field to produce 30 to 50 years. If an economical oil field is discovered, production would be expected to last 15 to 30 years.

For illustrative purposes, figure 5 shows the location of the facilities needed to produce our hypothetical prospect. Table 1 summarizes the acreage disturbed and gravel requirements for each facility, and table 2 is a summary of total acres disturbed and gravel required to develop this prospect. Drilling/production pads used in this scenario are designed to produce approximately 3,000 acres. Depending upon actual reservoir characteristics, more pads may be required to adequately deplete the resources. Once the gas is depleted from the prospect, the wells would be plugged, the facilities removed, and the disturbed surface reclaimed per Federal and State regulations.

Production Facilities

As shown, the facilities needed for the production of oil and gas are the central production facility, drilling/production pads, airstrip, pipelines, docking facility, and roads.

Central Production Facility (CPF)

The CPF is the headquarters and primary operations center for the production activities of the field. Buildings on this pad would enclose the production equipment, housing needs, and office space. Areal extent of this

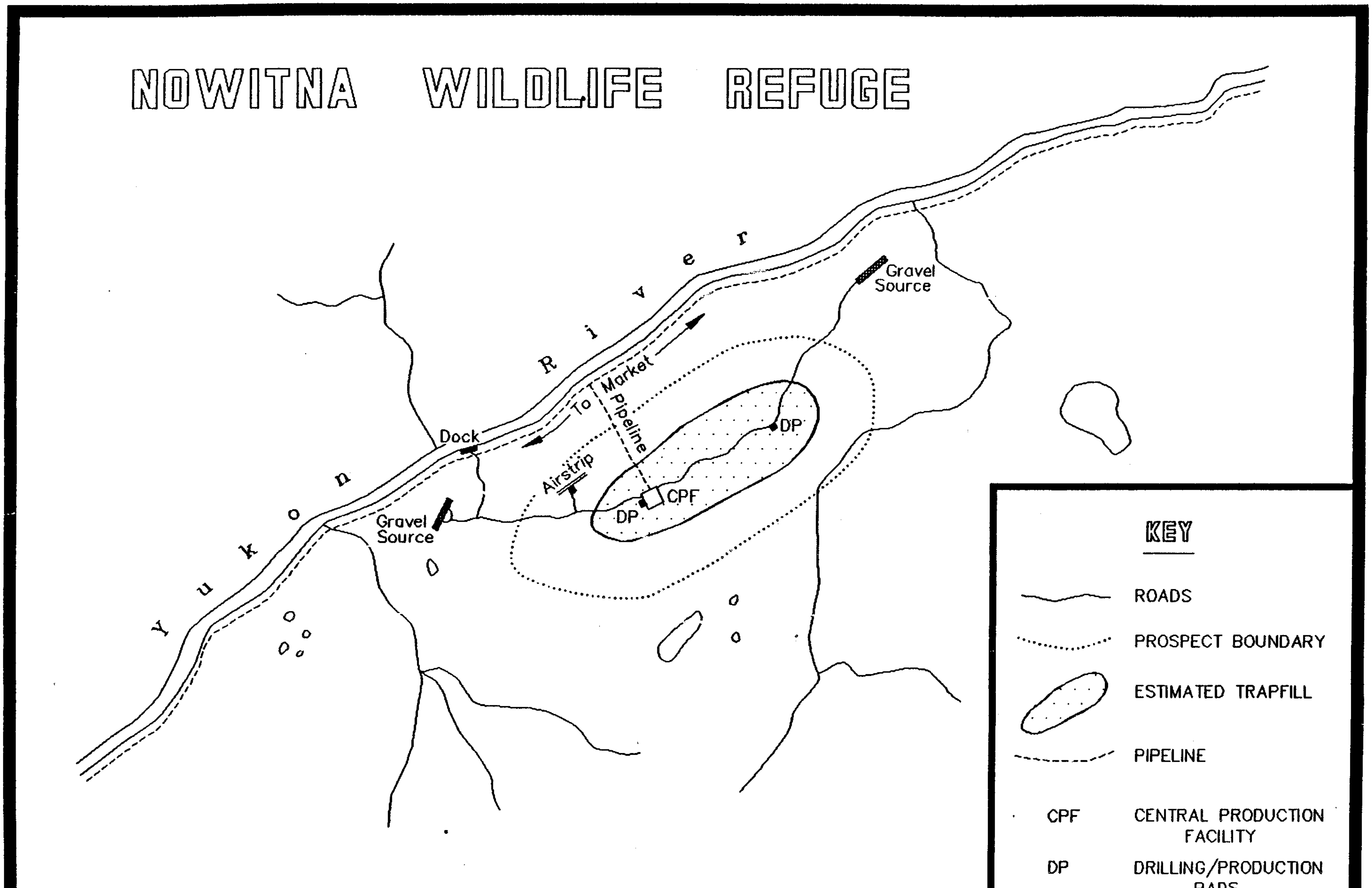


Figure 5.
Hypothetical Development Scenario

Table 1

Production Facilities

NWR

Facility	Acres Disturbed (each)	Cubic Yards of Gravel to Construct (each)
Central Production Facility Pad	40	325,000
Drilling/Production Pads	10	80,000
Airstrip and Facilities	8-10	65,000-80,000
Roads	4 acres/mile	35,000 yd^3/mile
Docking Facility	5	40,000

Table 2

TOTAL ACRES DISTURBED AND TOTAL GRAVEL REQUIREMENT FOR THE DEVELOPMENT OF THE NWR HYPOTHETICAL PROSPECT

Facility	Acres Disturbed	Cubic Yards of Gravel to Construct
Central Production Facility Pad (1)	40	325,000
Drilling/Production Pads (2)	20	160,000
Airstrip and Facilities (1)	9	73,000
Roads (12.0 miles)	48	420,000
Docking Facility (1)	5	40,000
TOTALS:	122	1,018,000

pad is approximately 40 acres. To protect permafrost from thermal degradation, it is estimated this pad will need to be at least five feet thick and, in addition, may require other insulating medium. Before construction began, detailed studies of the area would be performed to determine the most effective and economical construction design to protect the permafrost and the environment. Assuming a five-foot thickness and a 40-acre pad, approximately 325,000 cubic yards of gravel would be required.

A housing module would include sleeping and eating quarters, food storage area, and recreational and sanitation facilities. The module would be designed to accommodate 5 to 10 workers. The office module and shop would provide the necessary support services to develop and produce the field.

The production module would house a separator unit, compressor unit, and a gas cooling unit. Produced gas would be dehydrated, compressed, cooled, and sent down the production pipeline. Any produced water would be disposed down an injection well.

Water for domestic use would be obtained from rivers, local lakes, or water-filled pits (abandoned gravel source areas). Insulated tanks would store a sufficient amount of potable water for human consumption. Sewage treatment facilities and the incinerator would eliminate most of the human waste and trash. Items which could not be burned would be transported to an approved disposal site.

Fuel storage would hold diesel and other refined petroleum products necessary for operating the equipment of the CPF. The area would be diked to contain any spills which may occur. Electricity would be provided by a natural gas powered generation plant.

Drilling/Production Pads

A drilling rig and necessary equipment and supplies for drilling the wells would be placed on the drilling/production pad. As wells are completed, wellheads and pipelines would be put in place. The size of these pads are dependent upon the number of wells drilled and the distance between wellheads. The presented scenario shows two pads of approximately 10 acres each supporting 10-12 wells. All pads would be at least five feet thick and would require approximately 80,000 cubic yards of gravel per pad.

Depending upon the proposed depth and subsurface conditions, production wells will take 10-60 days to drill and complete. Production from each well is piped to a main line from the production pad to the CPF.

Production wells are directionally drilled from the pads to various bottom hole locations within the hydrocarbon reservoir. The procedure allows maximum depletion of the reservoir and minimizes the surface acreage disturbed. Spent drilling fluids would be injected into the subsurface and the solids, if environmentally sound, would be capped in the reserve pits. If the pits cannot be secured, the material would be transported to an approved disposal site.

Airstrip, Roads, Pipelines, and Docking Facility

The airstrip would be permanent and maintained year-round for the lifetime of the project. It is assumed the facility would be designed for small aircraft transporting personnel to and from the field. Minimum length of the airstrip would be 2,600 feet and minimum width would be 50 feet. Three acres of surface would be covered by the airstrip itself and another 5-7 acres are required for the taxiway, apron, and support facilities. Approximately 73,000 cubic yards of gravel would be required to construct this facility.

Roads will connect all of the above facilities. They will be built with a crown width of 35 feet and would be approximately five feet thick. Each mile of road would cover four acres of surface and require 35,000 cubic yards of gravel. Total mileage varies between projects, depending on the size and surface features of the prospects.

Gathering lines would run from each production pad to the CPF. These lines would most likely be buried along the most direct route between these facilities. Diameter of the pipe, for this hypothetical prospect, would be two or three inches. Any produced water would be injected down a disposal well which would most likely be drilled on the CPF pad.

The main production pipeline leaving the field would probably be three to six inches in diameter. The route of the pipeline to market will depend on circumstances at the time production begins. This scenario assumes a village downriver and a village upriver would be interested in purchasing natural gas for their local needs.

The docking facility would include an unloading ramp and a five-acre storage pad. This pad would be used to store the equipment needed to unload the supplies off of the barges. A storage module may be located on this pad to protect the equipment and supplies. Estimated gravel requirements for this facility would be 40,000 cubic yards.

Economic Potential

Background

The Nowitna Refuge is located approximately 150 miles west of Fairbanks in the Central Yukon River Valley (figures 1 and 2). The refuge was created in 1980 upon passage of the Alaska National Interest Lands Conservation Act (ANILCA) and encompasses 2,051,000 acres (3,225 square miles) of Federal, selected, and conveyed lands. The refuge is accessible by boat along the Yukon and Nowitna rivers and by float plane. There are no roads or all-weather trails on the refuge.

Exploratory History

Presently, oil and gas leasing is prohibited on the refuge due to its wildlife status. Subject to site-specific compatibility with refuge purposes, oil and gas exploration inclusive of seismic activities may be allowed.

To date, drilling for oil and gas has not occurred within the boundaries of the refuge. The findings from one well which was drilled 90 miles to the west of the refuge (Nowitna No. 1) indicated that the reservoir properties of the rock formations penetrated were very poor. In 1982, special use permits were issued to AMOCO and Doyon Limited, a Native corporation to do geologic mapping as well as hand and pan concentrate sampling. The following year, EXXON was issued a permit to do geologic mapping and shallow core sampling. As late as 1985, Union Oil made inquiries to the Fish and Wildlife Service regarding a special use permit, but this inquiry was not followed-up with a formal application. The results of completed sampling efforts is not known at this time, but comments received from oil companies do not indicate a strong interest in the area.

Geologic Potential

The geologic petroleum potential[1/] of the Nowitna refuge has been evaluated based on available geological and geophysical information. Evidence evaluated indicates that the refuge has both medium and low geologic potential for gas discovery and low potential for oil discovery (plate 5). The area of moderate geologic potential is located in the north-central portion of the refuge and extends to, and beyond, the northeastern boundary. The area determined to have moderate potential is based on the favorable reservoir characteristics and inferred gas prone kerogens of Tertiary rocks exposed within the refuge and the inferred extent of similar rocks within the Lower Tanana basin underlying the refuge (plate 3).

Development Potential

The development or economic potential of an area considers not only the geologic environment concerning the existence of mineral resources, but also the nongeologic environment.

The nongeologic environment includes such considerations as market availability, the existing infrastructure in the subject area, price projections, costs of production and marketing, anticipated rate of return, and also alternative investment opportunities.

The Nowitna Refuge has been determined to be an area of "low" economic development potential for oil and gas resources. As previously indicated, no drilling has occurred on the refuge and an exploration well 90 miles west of the refuge was unsuccessful. Favorable reservoir characteristics of Tertiary

1/ Geologic petroleum potential refers only to the probability of the presence (occurrence) of a concentration of that mineral resource. It neither refers to or implies potential for extraction or that the concentration of the resource, if any, is economic or could be extracted profitably.

rocks within the basin has been previously noted, but these rocks are probably gas prone. The information available regarding the existence of oil and gas resources on the Nowitna Refuge is presently very limited and, to date, industry has not shown much interest in the area. Three permits for exploratory work on the refuge were issued in the past, but the results of these permitted activities are not known.

In conjunction with the above facts, the physical remoteness of the area, lack of infrastructure inclusive of the nonexistence of roads, would result in industry incurring high capital costs to explore and develop this area. The closest existing production to this refuge is in the Kenai Peninsula, 250 miles south of the refuge or in the Prudhoe Bay field approximately 375 miles to the north. It is expected that industry, in ranking this area against other investment opportunities, would be strongly inclined to focus their interest on areas showing greater promise.

Current technology exists that would allow exploration and development of potential hydrocarbon resources from this refuge, should commercial quantities be discovered; so the interest in opening this area to exploration is dictated by the resource potential and economic viability of oil and gas development in the area.

Price Projections

Current petroleum price projection compiled from a variety of sources[2/] are significantly lower than previous forecasts completed earlier in the 1980s (appendix A, table 1). The range of oil prices projected in these current forecasts vary from $18 to $42 per barrel by the year 2000 (constant 1984/85 dollars). With such a wide spread in forecasts, it is difficult to assess

2/ U.S. Department of Energy, 1985; Data Resources Incorporated, 1986; Chevron Corporation, 1986.

future impacts of this variable of future exploration activities. It was of interest to note that both a private research firm and a major oil company forecast a crude oil price of $35/barrel, whereas the most optimistic level of $42/barrel was a forecast of the U.S. Department of Energy (DOE) and was dependent on high economic growth. Assuming that high economic growth is not achieved, the DOE mid-range forecast of $36.75 is less than $2/barrel higher than those of the private sector. This level ($36.75/barrel by the year 2000) is approximately $5/barrel, or 12 percent, less than the average annual refiner's cost of imported crude in 1981/82 (constant 1984 dollars). This scenario does reflect an optimistic picture as compared to the current pricing structure.

Other forecasts from the same sources indicate an upward trend in petroleum demand, but conversely project a decline in domestic production which is indicative of a decrease in domestic exploration activities.

One last petroleum price projection that should be considered is the scenario presented by Arlon Tussing, a Seattle based energy economist. Mr. Tussing, in late 1980, against all conventional price projections, correctly forecast that international oil prices would soon collapse. In January 1984, prior to the concern of most energy forecasters, he stated that we were headed for a 10-year cycle of falling prices, and he projected that oil would soon drop within the range of $12 to $20 per barrel. To date, this forecast has been quite accurate.

Mr. Tussing's latest forecast is even more foreboding, as he expects oil prices in constant dollars to remain within a range of $10 to $20 a barrel through the rest of the century. Beyond this timeframe, he expects energy prices to decline even further.

The basis for this scenario is "fuel switching." Mr. Tussing states that "many" of the industrial users are now equipped to use alternate fuels such as oil, gas, or coal, depending on the prevailing price. He believes that the exceptional high prices during the six-year period between 1979 and 1985 were possible only because heavy industrial users were not at that time equipped to switch fuels and were heavily dependent on oil as a bulk fuel. This stemmed from the fact that exceptionally low oil prices prevailed in the 1950s and 1960s, and this trend was expected to continue ad-infinitum. He points out that for a century, between 1878 and 1978, crude oil prices never exceeded $15/barrel in 1986 dollars, and the average wellhead price during this 100-year period was between $8 and $9/barrel. Mr. Tussing believes that as long as technological progress is self-sustaining, the long-term price trend for oil can only be downward.

The wide divergence in oil price projections just presented are indicative of the future uncertainty which exists in the national petroleum industry. As we have seen, though, most mainline economists are forecasting an upward trend in long-term bulk oil prices. Although this is considered a promising sign for the industry as a whole, this is foreshadowed by forecasts of a long-term decline in U.S. production. This decline was brought on by a general cutback in drilling and production activities by U.S. petroleum companies triggered by an excess world supply and resultant low product prices. Future expansionary efforts by the petroleum industry would be anticipated to take place in areas where, hopefully, capital costs can be held down, or, in lieu of this, in areas of great promise.

Overview

In 1985, Alaska contributed nearly 20 percent of domestic petroleum production (United States Department of Energy, Energy Information Administration, 1986). In comparison, Alaska is a relatively minor producer of natural gas, with production of approximately 300 billion cubic feet per year in 1985 (United States Department of Energy, Energy Information Administration, 1986a). However, Alaska is an exporter of natural gas in the form of liquified natural gas (LNG), which is primarily shipped to Japan.

Fundamental changes in the petroleum industry since the early 1970s will certainly be a force in shaping the industries' future. This period brought two major crude oil price shocks, rapid expansion in petroleum demand and heavy reliance of foreign sources of supply to meet domestic needs. Similarly, the consumer experienced shortages in natural gas supply which resulted in a new era of gas price regulation (see appendix A for a detailed discussion of these changes). The rapid growth of the energy sector in the late 1970s and early 1980s resulted in the highest petroleum prices ever experienced by the industry. This set the stage for a period of energy conservation efforts, followed by declining demand and excess world productive capacity with falling petroleum prices. By the middle of 1986, crude oil prices had dropped to levels at or below prices received in 1973, before the Arab oil embargo. Natural gas price increases stimulated drilling and production in the early 1980s, which has resulted in domestic surplus capacity (gas bubble) and depressed prices. The present unstable nature of the oil and gas industry has resulted in a great deal of restructuring within the industry and expectations for the future are very uncertain.

Most recent long-term price forecasts project an upward trend that will be realized in the 1990s and possibly beyond (see appendix A for specific prices and trends). Domestic petroleum demand is expected to rise slightly above the 1985 level of 15.7 million barrels per day to a range from 15.9 to 18.1 million barrels per day by the year 2000. Natural gas demand could also increase from 17.4 trillion cubic feet per year in 1985 to a possible range from 17.1 to 20.4 trillion cubic feet per year in the year 2000. In contrast, domestic production of petroleum and natural gas is projected to decline below 1985 levels by the year 2000 (see appendix A for a more detailed discussion of historic and future petroleum and natural gas demand and supply relationships). Therefore, the United States' dependency on foreign sources of hydrocarbon supplies is expected to increase above current levels. Based on these projections, there is a considerable gap between domestic consumption and production that can only be filled nationally by exploring new areas and developing any commercial discoveries that are made.

In summary, if the Nowitna Refuge were opened to oil and gas exploration and development, some benefits would accrue to the local economy through the expenditure of explorational dollars, with some small-scale benefits to the State. economic benefits would, of course, be dependent on industries' interest in the area and investing the necessary capital for development. Presently, and at least through the turn of the century, it is expected that industry will not have significant interest in the area and, as such, would be more inclined to expend their exploration dollars in areas of greater promise. Any long-term benefits that would accrue would, of course, be dependent on locating commercial quantities of oil and gas that could be recovered from a favorable economic viewpoint.

BIBLIOGRAPHY

Barnes, David F., 1977, Bouger Gravity map of Alaska: U.S. Geological Survey G.P. 918.

Barnes, Farrell F., 1977, Coal resources of Alaska: U.S. Geological Survey Bulletin 1242 B.

Box, Stephen E., Patton, William W. Jr., and Carlson, Christine, 1985, Early Cretaceous evolution of the northeastern Yukon-Koyukuk basin, west central Alaska: in Howell, D. G., ed., Tectonostratigraphic terranes of the Circum-Pacific region: Houston, Texas, Circum-Pacific Council for Energy.

Chapman, Robert M., 1975, Geology of western half of Kantishina River quadrangle: U.S. Geological Survey Circular 722.

Chapman, R. M., Yeend, W., 1975, Geological reconnaissance of the east one-half of Kantishina River quadrangle and adjacent areas: U.S. Geological Survey Circular 722.

Chapman, Robert M., and Patton William W. Jr., 1978, Preliminary summary of the geology in the northwest part of the Ruby quadrangle: U.S. Geological Survey Circular 772-B.

Dutro, J. T., and Patton, W. W. Jr., 1981, Lower Paleozoic platform carbonate sequence in the Medfra quadrangle, in USGS in Alaska: U.S. Geological Survey Circular 823B.

Eakin, Henry M., 1918, The Casna-Nowitna region: U.S. Geological Survey Bulletin 667.

Eardley, A. S., 1938, Unconsolidated sediments and topographic features of the Lower Yukon Valley (Alaska): Geological Society of America Bulletin, vol. 49, p. 303-341.

Godson, Richard H., 1984, Composite magnetic anomaly map of the United States, part B. Alaska and Hawaii: U.S. Geological Survey Map GP 954B.

Grantz, Arthur, Kirschner, C. E., 1975, Tectonic framework of petroliferous rocks in Alaska: U.S. Geological Survey Open-File Report 75-149.

McWhae, J. R., 1986, Tectonic history of northern Alaska and Spitsbergen regionsl since Early Cretaceous: American Association of Petroleum Geologists Bulletin, vol. 70, No. 4, p. 420-450.

Meritt, R. D., and Hawley, C. C., 1986, Map of Alaska's coal resources: Alaska Department of Natural Resources, Division of Geological and Geophysical Services Special Report No. 37.

Miller, Don J., Payne, Thomas G., Gryc, George, 1959, Geology of possible petroleum provinces in Alaska: U.S. Geological Survey Bulletin 1094.

Nielsen, Tor H., and Patton, William W. Jr., 1984, Cretaceous fluvial to deep-marine deposits of the central Yukon-Koyukuk basin, Alaska, in U.S. Geological Survey Accomplishments in Alaska, 1982, Reed, K. M., and Bartsch-Winkler, S., ed., U.S. Geological Circular.

Patton, W. W. Jr., 1971, Petroleum possibilities of the Yukon-Koyukuk province, Alaska: American Association of Petroleum Geologists Memoir No. 15.

Patton, William W. Jr., 1973, Reconnaissance geology of the nothern Yukon-Koyukuk province: U.S. Geological Survey Professional Papper 774-A.

Patton, William W., 1975, New information on Kaltag Fault: U.S. Geological Survey Circular 722.

Patton, W. W. Jr., 1976, Newly discovered Upper Triassic and Lower Cretaceous in the northern Kuskokwim Mountains: U.S. Geological Survey Circular 733.

Patton, William W. Jr., 1978 Juxtaposed continental and oceanic-island arc terranes in the Medfra quadrangle, west central Alaska: U.S. Geological Survey Circular 772-B.

Patton, William W. Jr., and Hoare, Joseph M., 1968, The Kaltag Fault, west-central Alaska: U.S. Geological Survey Professional Paper 600 D.

Appendix A - Oil and Gas Demand and Supply Relationships

The importance of potential oil and gas resources from this refuge is dependent on the hydrocarbon potential of the area, national need for additional sources of oil and gas, and the economics of exploring and producing any hydrocarbons that might be discovered. This Appendix provides a detailed review of the factors that have contributed to the present domestic oil and gas situation and possible future demand for oil and gas, which is directly linked to the national need for oil and gas resources from the refuge.

Domestic Energy Trends

The domestic energy situation, as it relates to oil and gas consumption and production, has changed dramatically since the early 1970s. In 1970, petroleum and natural gas supplied 44 and 33 percent (United States Department of Energy, Energy Information Administration, 1984), respectively, of the total energy consumed in the United States (figure 1). By 1977, petroleum accounted for nearly 49 percent of domestic energy consumption, and natural gas consumption had declined to approximately 26 percent of total energy demands. The relative contribution of both petroleum and natural gas declined through 1985, when petroleum supplied nearly 42 percent, and natural gas contributed approximately 25 percent of total energy demand. Figure 1 shows the contribution of each major primary energy source to total national energy demand in 1970, 1980, and 1985. Coal, nuclear, and geothermal energy were the primary forms of energy to increase their market share of total energy consumption during this time period, at the expense of petroleum and natural gas resources.

Total domestic energy consumption peaked at 78.9 quadrillion (QUAD) British thermal units (BTU) in 1979 and subsequently declined to 73.8 QUADS in 1985 (United States Department of Energy, Energy Information Administration, 1986). Over the 15-year period from 1970 to 1985, total primary energy consumption increased 11 percent, from 66.4 QUADS to 73.8 QUADS; however, the rapid increase in energy consumption and escalation in the cost of energy (the cost of energy more than doubled, from 1.35 constant 1972 dollar per million BTU in 1970 to 2.90 in 1981) during this time period resulted in a dramatic change in national energy consumption patterns. Total energy consumed per constant 1972 dollar of Gross National Product (GNP) ranged from 56,500 to 61,000 BTUs per 1972 dollar of GNP from 1960 through 1976 (United States Department of Energy, Energy Information Administration, 1985a). A decline in the intensity of energy utilization was realized in 1977, when total energy consumption dropped to 55,700 BTUs per dollar of GNP, and this downward trend continued through 1985, when energy consumption was reduced to 42,900 BTUs per 1972 dollar of GNP (United States Department of Energy, Energy Information Administration, 1986). The decline in energy consumption was led by the reduction in the intensity of petroleum and natural gas utilization. In 1985, only 68 percent as much petroleum and natural gas were consumed per dollar of GNP than in 1977, as compared to 77 percent for total energy consumption. The reduction in intensity of energy utilization was indicative of a national conservation effort which any be attributed to many factors, including:

FIGURE 1

PRIMARY ENERGY CONSUMPTION BY SOURCE

FIGURE 1A
1970
Total = 66.4 Quadrillion Btu

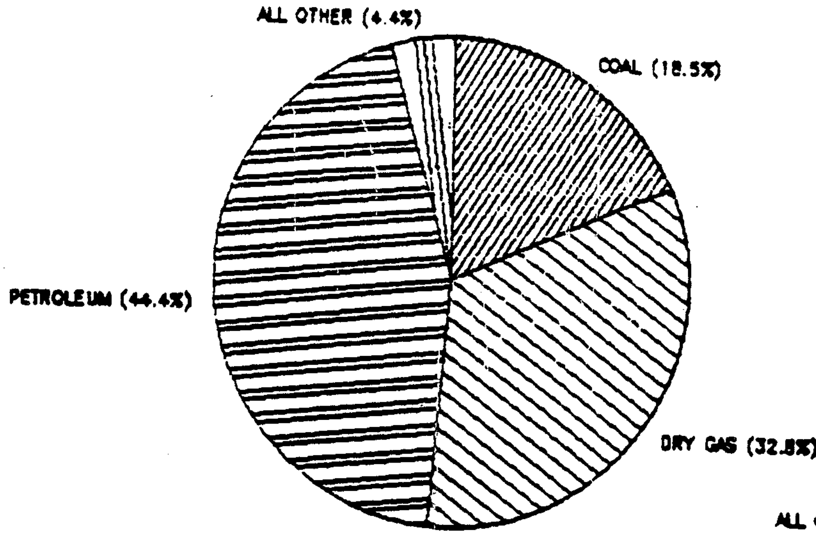


FIGURE 1B
1980
Total = 76.0 Quadrillion Btu

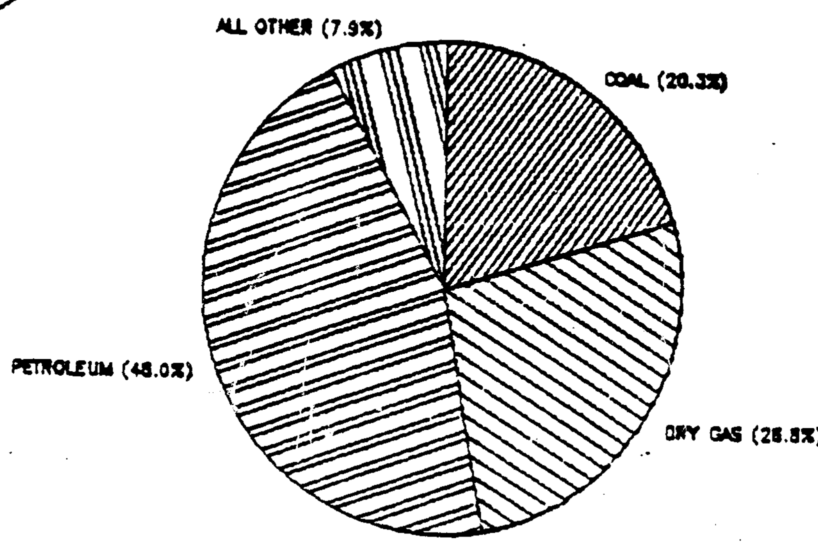
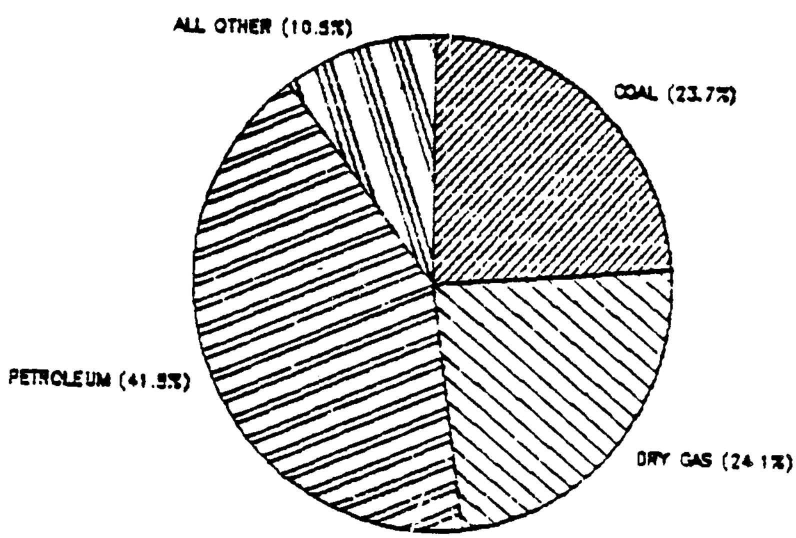


FIGURE 1C
1985
Total = 73.8 Quadrillion Btu



increased real energy prices, the increased service orientation of the economy, and changes in the mix of product production (United States Department of Energy, Energy Information Administration, 1985a).

Historical Oil and Gas Demand, Supply, and Price Relationships

The relationship between price and domestic petroleum supply and demand is shown in figures 2 and 3. Import prices utilized for petroleum in figure 3 are represented by the national average refiner's acquisition cost of imported crude oil, and wellhead prices are presented on the basis of the national average from all producing wells. Domestic crude oil prices were not completely decontrolled until January 1981 and, therefore, domestic wellhead prices do not follow import prices during the 1970s. Petroleum product demand rose throughout the early 1970s, until it peaked at 18.8 million barrels per day (MBPD) in 1978 (United States Department of Energy, Energy Information Administration, 1986a). Crude oil price increases began with the Arab oil embargo in 1973, and a second major price run-up was triggered in 1978 by the Iranian revolution and subsequent oil stock building in anticipation of world oil shortages. Real import prices peaked at $44.00 per barrel (1985 dollars) in 1980.

Domestic petroleum product demand began a downward slide in 1979 which continued through 1983. The Organization of Petroleum Exporting Countries (OPEC) members sought to maintain the higher prices, that resulted from oil price shocks of the 1970s, by production restraints. However, oil prices have steadily declined since 1981 as a result of slow economic growth with subsequent declining petroleum demand and excess world productive capacity (United States Department of Energy, Energy Information Administration, 1986b). Domestic oil prices in the second quarter of 1986 had declined to the lower teens in nominal terms, which is comparable to 1974 prices in real dollars. Figures 2 and 3 show that petroleum demand is sensitive to price and is characterized by long lags and high elasticities.

Domestic petroleum production has been much more stable than petroleum product demand. Figure 2 shows that Alaskan production, primarily from the North Slope, contributes a significant portion of domestic supply. In 1985, Alaska accounted for more than 20 percent of the national crude oil production (United States Department of Energy, Energy Information Administration, 1986a). Price increases of the 1970s provided incentive for exploration and production from higher cost areas such as Alaska. Foreign imports have been required to fill the gap between domestic supply and demand. Crude oil and petroleum product imports peaked in 1977, when net imports accounted for more than 46 percent of domestic petroleum consumption. Net petroleum import levels declined to 27 percent of product demand in 1985, but the United States still remains highly dependent of foreign petroleum supply sources.

FIGURE 2

NATIONAL PETROLEUM DEMAND

AND SUPPLY 1970 – 1985

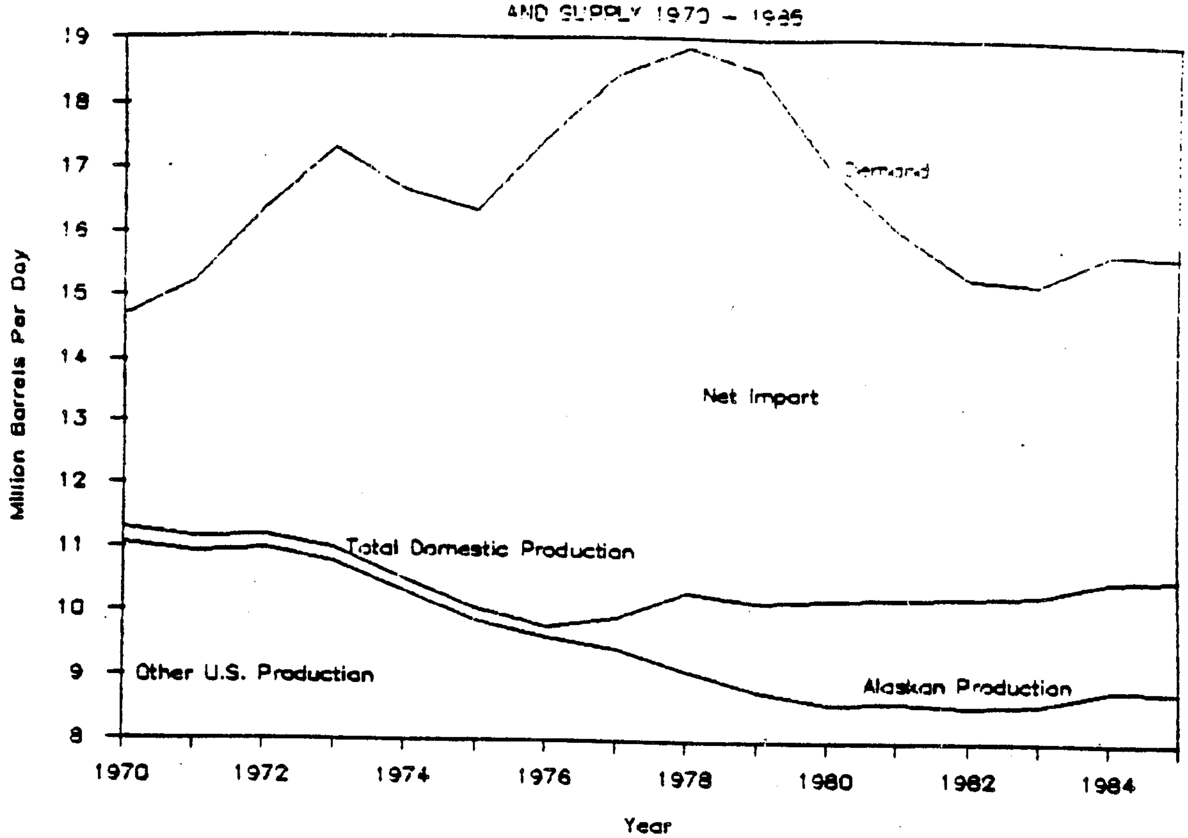
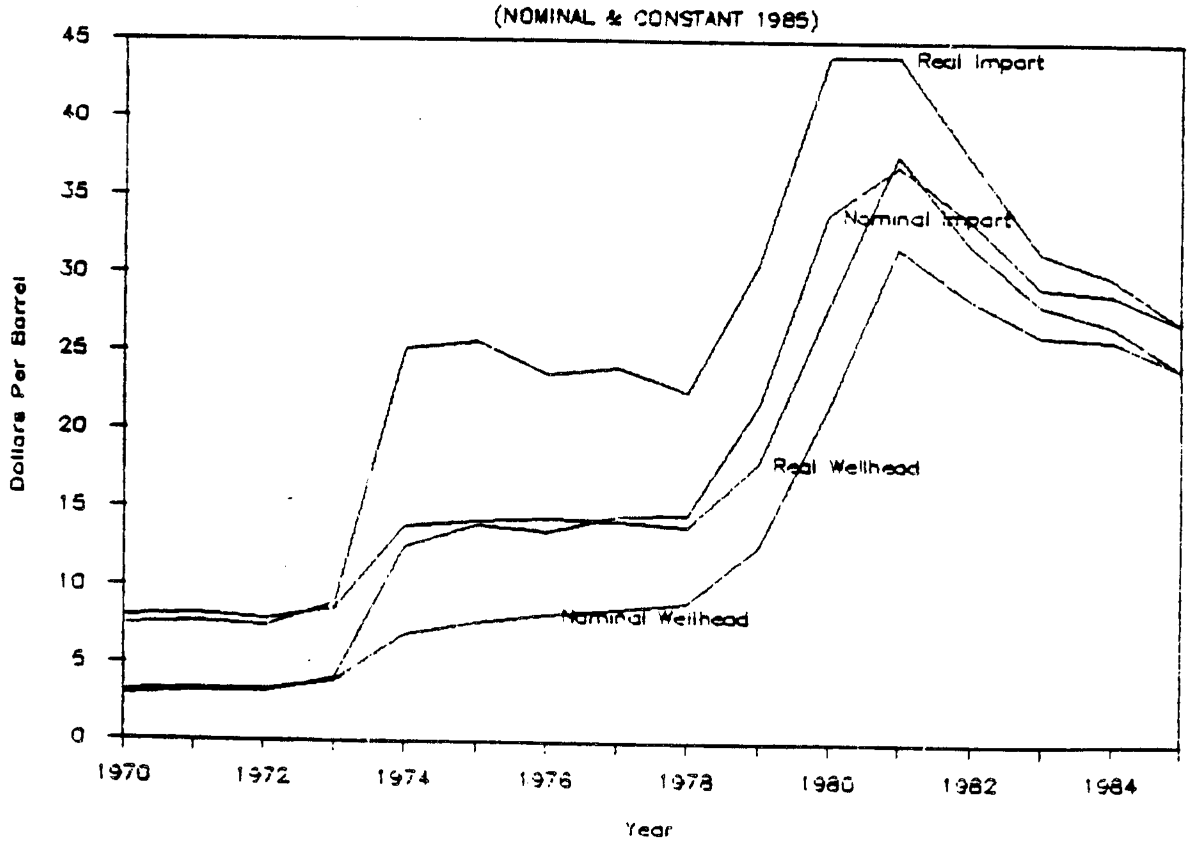


FIGURE 3

CRUDE OIL PRICES

(NOMINAL & CONSTANT 1985)



tory of natural gas production and consumption in the Un
ifferent from petroleum, and it has a direct bearing on g
emand, and supply relationships in the 1970s and 1980s (
atural gas went from a little used waste by-product of oi
in the 1930s to a source of energy that supplied nearly
consumption in 1970 (figure 1). By 1970, gas was being
s at prices well below those of competing petroleum prod
tes Department of Energy, Energy Information Administrat
ces paid to gas producers by interstate pipeline compani
levels through regulation by the Federal Power Commissi
increased demand and reduced incentives for producers t
new gas reserves. Regulated prices allowed intrastate
n companies and distributors to bid natural gas supplies
carriers (Tussing and Barlow, 1984). The 1970s has been
ply shortages in the midwest and northern states. Import
eased in a pattern similar to oil prices, but domestic p
der regulation. The Natural Gas Policy Act was passed i
ed wellhead prices to increase and it deregulated certai
of gas. Price increases provided incentives to explore
of gas. Natural gas consumption started a sharp declin
the influence of higher gas prices, a weak economy, warm
1981, falling oil prices (United States Department of En
rmation Administration, 1984). This trend continued thr
ception of a small increase in gas demand realized in 19
ibuted to the strong economic growth in the national econ

orts of natural gas are primarily received through pipel
Mexico, although there are some liquified natural gas (L
a. Net imports generally ranged near five percent from
ka is a relatively small producer of natural gas, ranging
ly 100 to 325 billion cubic feet per year from 1970 to 19
rtment of Energy, Energy Information Administration, 1985
however, a net exporter of natural gas in the form of LNG
o Japan. Huge gas reserves have been identified on the A
, but this resource has not been commercially produced d
nsportation infrastructure.

and Gas Demand, Supply, and Price Relationships

he review of historic petroleum and natural gas price, dem
sationships, it is apparent that there have been fundamenta
stroleum price deregulation and energy conservation efforts
nnery market since the early 1970s that will likely affect
pand natural gas production and consumption. At the presen
tal troleum market is directly linked to the world petrol
bnd pply. The situation is characterized by excess produ
cn t world market, a strong desire by exporting nations t

The history of natural gas production and consumption in the United States is quite different from petroleum, and it has a direct bearing on gas pricing policies, demand, and supply relationships in the 1970s and 1980s (figures 4 and 5). Natural gas went from a little used waste by-product of oil production in the 1930s to a source of energy that supplied nearly 33 percent of national consumption in 1970 (figure 1). By 1970, gas was being delivered to consumers at prices well below those of competing petroleum products (United States Department of Energy, Energy Information Administration, 1984). Prices paid to gas producers by interstate pipeline companies were held at low levels through regulation by the Federal Power Commission, which resulted in increased demand and reduced incentives for producers to explore and develop new gas reserves. Regulated prices allowed intrastate transmission companies and distributors to bid natural gas supplies away from interstate carriers (Tussing and Barlow, 1984). The 1970s has been noted for the gas supply shortages in the midwest and northern states. Imported gas prices increased in a pattern similar to oil prices, but domestic prices remained under regulation. The Natural Gas Policy Act was passed in 1978, which allowed wellhead prices to increase and it deregulated certain categories of gas. Price increases provided incentives to explore and develop new sources of gas. Natural gas consumption started a sharp decline after 1980 under the influence of higher gas prices, a weak economy, warm winters, and, since 1981, falling oil prices (United States Department of Energy, Energy Information Administration, 1984). This trend continued through 1985, with the exception of a small increase in gas demand realized in 1981, which may be attributed to the strong economic growth in the national economy in that year.

Net imports of natural gas are primarily received through pipelines from Canada and Mexico, although there are some liquified natural gas (LNG) imports from Algeria. Net imports generally ranged near five percent from 1970 to 1985. Alaska is a relatively small producer of natural gas, ranging from approximately 100 to 325 billion cubic feet per year from 1970 to 1985 (United States Department of Energy, Energy Information Administration, 1985b).. Alaska is, however, a net exporter of natural gas in the form of LNG, which is delivered to Japan. Huge gas reserves have been identified on the Alaskan North Slope, but this resource has not been commercially produced due to a lack of transportation infrastructure.

Future Oil and Gas Demand, Supply, and Price Relationships

From the review of historic petroleum and natural gas price, demand, and supply relationships, it is apparent that there have been fundamental changes, such as petroleum price deregulation and energy conservation efforts in the national energy market since the early 1970s that will likely affect future petroleum and natural gas production and consumption. At the present time, the national petroleum market is directly linked to the world petroleum market by price and supply. The situation is characterized by excess productive capacity in the world market, a strong desire by exporting nations to sell

FIGURE 4
NATIONAL NATURAL GAS DEMAND

AND SUPPLY 1970 – 1985

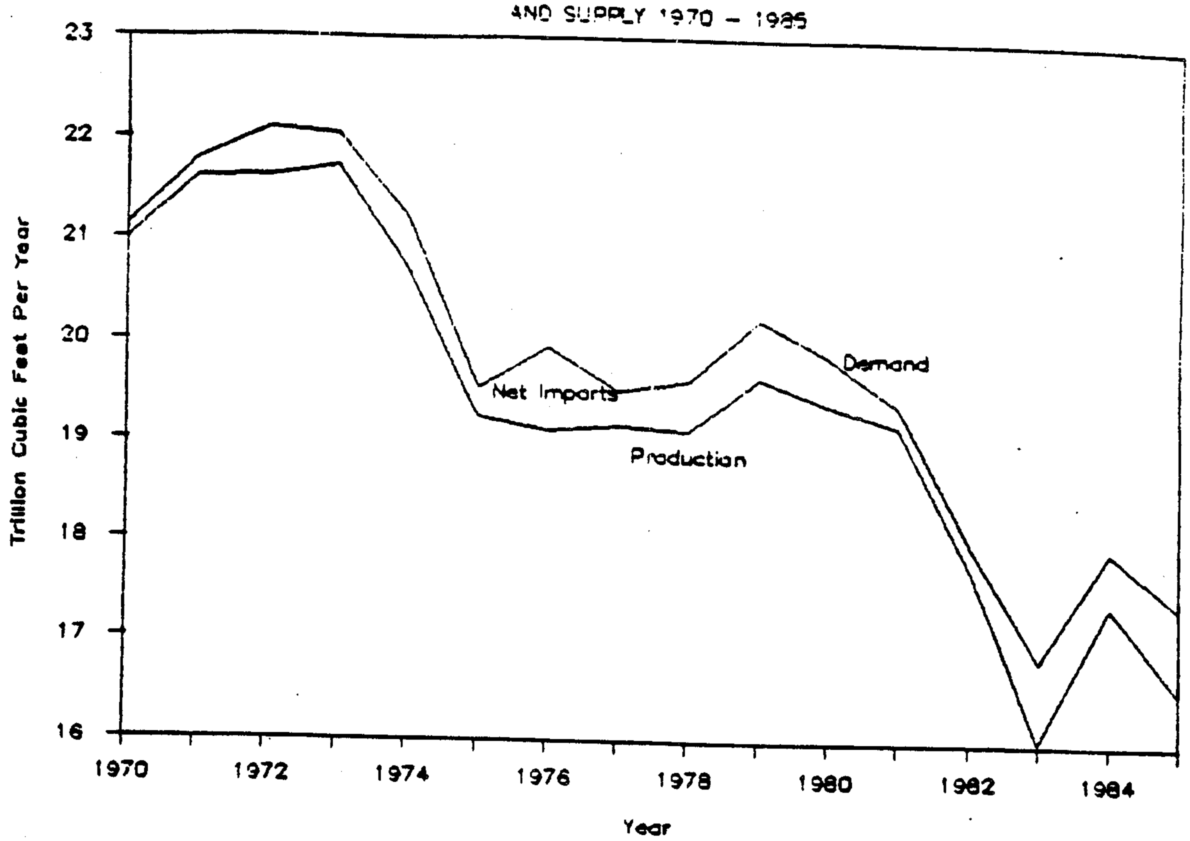
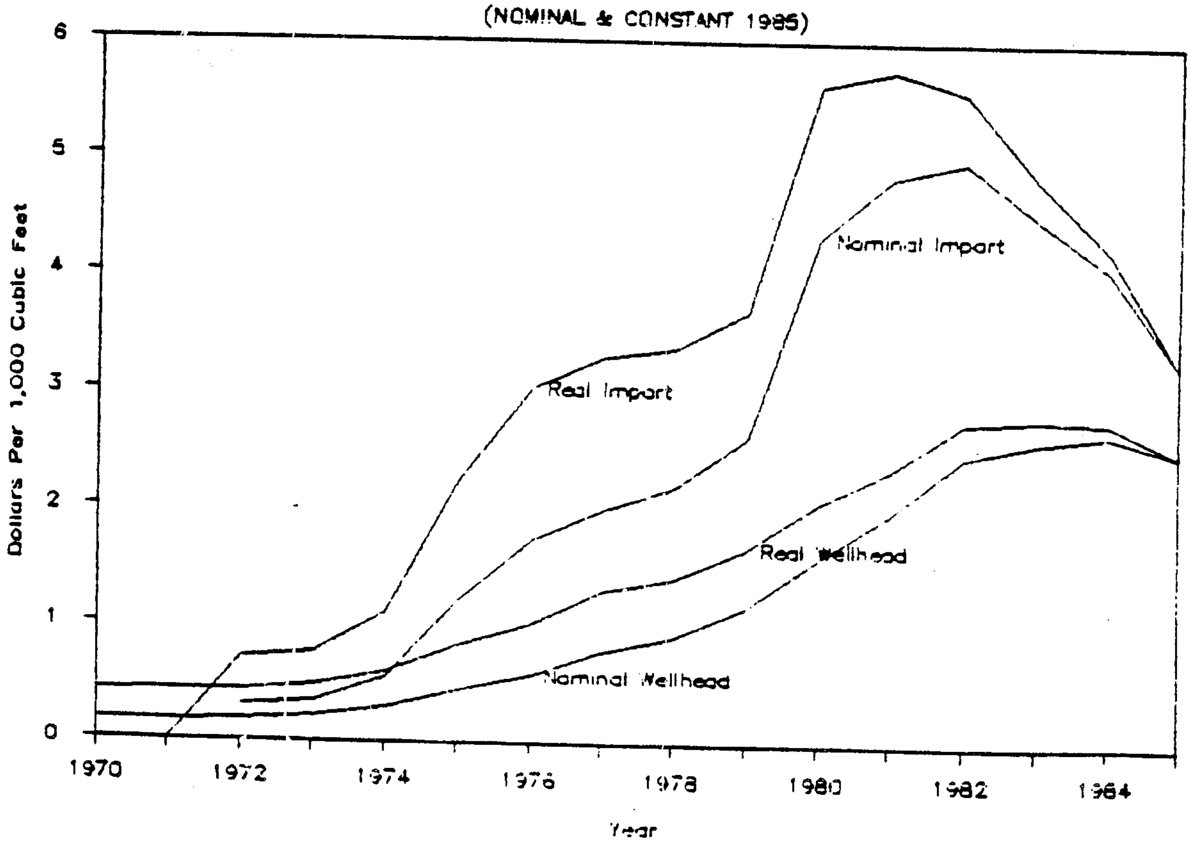


FIGURE 5
NATURAL GAS PRICES

(NOMINAL & CONSTANT 1985)



petroleum to meet financial obligations, a time of relatively slow economic growth, and declining petroleum prices. The domestic natural gas industry is currently working off surplus reserves added during the early 1980s, but depressed prices have resulted in a sharp reduction in drilling which could have serious implications for future domestic gas production.

Implications of the petroleum price slide during the first half of 1986 are not yet fully discernable. Middle eastern nations have been unable to reach accord in setting and adherence to self-imposed oil production quotas. In the past, Saudi Arabia has taken the position as swing producer for OPEC, and thereby reduced production to maintain quota levels. However, Saudi Arabia changed policies in 1986 to concentrate on achieving a "fair market share" of the international petroleum market with little concern for output quotas. The strategy behind this policy was not disclosed, but speculation as to the potential motivation and results of this action includes:

1. Saudi Arabia is making a show of strength to discipline OPEC members that have cheated on production quotas and prices with hopes of bringing member and possibly non-member nations together as a unified market group;

2. Saudi Arabia sought to increase revenue, but underestimated the effects additional production would have on price;

3. Saudi Arabia is flooding the world oil market in an effort to eliminate producers with higher costs of production and thereby reduce competition;

4. Saudi Arabia is acting to reduce prices and stimulate growth in petroleum demand to reverse conservation efforts initiated in the late 1970s and 1980s.

In any event, a tremendous amount of uncertainty exists in the national petroleum industry, which has resulted in major financial restructuring. The most evident signs of restructuring are major employment reductions and reduced capital expenditures for exploration and drilling.

The interest in mineral exploration and possible development in this refuge is driven by the future national demand for oil and gas, the cost and availability of domestic supplies, and the hydrocarbon potential of the area. The rate of future economic growth and hydrocarbon prices will be the major determinants of petroleum and natural gas demand. Future domestic production is dependent on resource availability and market prices. However, political forces are having an increasingly important effect on world oil prices, which will ultimately dictate future market conditions. The instability in the world oil market results in tremendous uncertainty in predicting future hydrocarbon prices and market conditions. Table 1 presents three recent crude oil and natural gas price forecasts by the United States Department of Energy, a private research firm, and a major oil company. The prices shown in these forecasts are significantly lower than previous forecasts completed earlier in

TABLE 1

PETROLEUM AND NATURAL GAS PRICE FORECASTS[1]

Reference	Crude Oil ($/Barrel)			Natural Gas ($/MCF)		
	1990	2000	2010	1990	2000	2010
U.S. Department of Energy, 1985[2]						
Low Economic Growth	20.27	31.31	47.42	2.64	4.13	6.02
Reference Case	22.89	36.75	56.77	2.76	4.80	7.68
High Economic Growth	25.02	42.17	67.12	2.88	5.42	9.14
Data Resources Incorporated, 1986[2]	16.91	34.32	49.99	1.69	3.80	5.76
Chevron Corporation, 1986[3]						
Low Case	12.00	18.00	N/A	Rise to parity with fuel oil prices		
High Case	27.50	35.00	N/A			

1/ Some of the price estimates presented in this table were interpreted from graphic displays and/or extrapolated from data series, so the reported prices may vary slightly from the actual values.

2/ Reported on the basis of constant 1984 dollars.

3/ Reported on the basis of constant 1985 dollars.

the 1980s. The range of oil prices projected in these forecasts is $18.00 to $42.00 (constant 1984 and 1985 dollars) per barrel in the year 2000. The high price range is approximately equivalent to the average annual refiner's acquisition cost of imported crude received in 1981 and 1982 (constant 1984 dollars). The range of prices projected for the year 2010 is $47.00 to $67.00 per barrel. These prices would be substantially above the peak levels paid in the early 1980s. Natural gas prices are projected to range between $4.10 and $5.50 per thousand cubic feet (MCF) in the year 2000, and $6.00 to $9.10 per MCF in the year 2010. The magnitude of projected natural gas price increases is similar to forecast changes in world oil prices.

Projections of future domestic petroleum and natural gas demand and supply conditions is presented in table 2. All three forecasts projected an upward trend in petroleum demand above current levels. Petroleum consumption is projected to range from 15.9 to 18.1 MBPD in the year 2000, and possibly increase to 19.4 MBPD by the year 2010. In comparison, domestic petroleum production is projected to decline to levels ranging from 6.1 to 8.9 MBPD by the year 2010. Domestic natural gas demand is projected to increase to a level ranging from 17.1 to 20.4 TCF per year by the year 2000 and then decline to a level of 16.7 to 18.3 per year by 2010. Domestic gas production is projected to follow a similar trend with domestic oil production and decline to levels ranging from 13.9 to 15.0 TCF by the year 2010.

Conclusion

National hydrocarbon markets have undergone substantial changes since the early 1970s. Energy conservation trends initiated by real price increases of the 1970s are expected to continue through the end of this decade and possibly beyond. However, future economic growth is expected to result in some increased demand for petroleum and natural gas, while domestic production of these finite resources is projected to decline. As a result, the United States will become increasingly dependent on foreign hydrocarbon sources to meet national requirements. New areas will need to be explored and any economically viable resources that are discovered will need to be brought into production in order to meet domestic needs. The potential contribution of this refuge to national oil and gas production is dependent on its resource potential and the potential cost at which any discovered hydrocarbon resources could be extracted and marketed within the constraints of future oil and gas prices.

TABLE 2

FUTURE DOMESTIC PETROLEUM AND NATURAL GAS
DEMAND AND SUPPLY RELATIONSHIPS[1]
(See Table 1 for Price Forecasts)

Reference	Demand 1990	Demand 2000	Demand 2010	Supply 1990	Supply 2000	Supply 2010
	Petroleum (Millions of Barrels Per Day)					
U.S. Department of Energy, 1985						
Low Economic Growth	16.1	15.9	15.5	9.8	9.0	7.8
Reference Case	16.7	16.6	16.5	10.0	9.4	8.3
High Economic Growth	16.8	17.0	17.3	10.0	9.7	8.9
Data Resources Incorporated, 1986	16.9	18.1	19.4	9.5	7.3	6.1
Chevron Corporation, 1986	16.0	16.8	N/A	9.2	7.0	N/A
	Natural Gas (Trillion Cubic Feet Per Year)					
Department of Energy, 1985						
Low Economic Growth	18.6	18.8	17.2	17.4	16.1	14.7
Reference Case	19.1	19.7	17.4	17.6	16.3	15.0
High Economic Growth	19.5	20.4	18.3	17.9	16.6	14.7
Data Resources Incorporated, 1986	18.9	18.1	16.7	16.7	15.3	13.9
Chevron Corporation, 1986	17.3	17.1	N/A	N/A	N/A	N/A

1/ Some of the numeric estimates presented in this table were interpreted from graphic displays and/or extrapolated from data series, so the reported prices may vary slightly from the actual values.

REFERENCES

Chevron Corporation, 1986, World energy outlook. Economics Department, Chevron Corporation, San Francisco, California, June 1986.

Data Resources Incorporated, 1986, Energy review executive summary. Spring 1986.

Tussing, Arlan, R., and Connie C. Barlow, 1984, The natural gas industry, evolution structure and economics. Ballinger Publishing Company, Cambridge, Massachusetts.

United States Department of Energy, 1985, National energy policy plan projections to 2010. Office of Policy, Planning and Analysis, United States Department of Energy, December 1985.

United States Department of Energy, Energy Information Administration, 1984, Annual energy outlook 1983 with projections to 1995. DOE/EIA-0383 (83), May 1984.

United States Department of Energy, Energy Information Administration, 1985, Annual energy review 1984. DOE/EIA-0384(84), April 1985.

United States Department of Energy, Energy Information Administration, 1985a, Enery conservation indicators 1984 annual report. DOE/EIA-0441(84). December 1985.

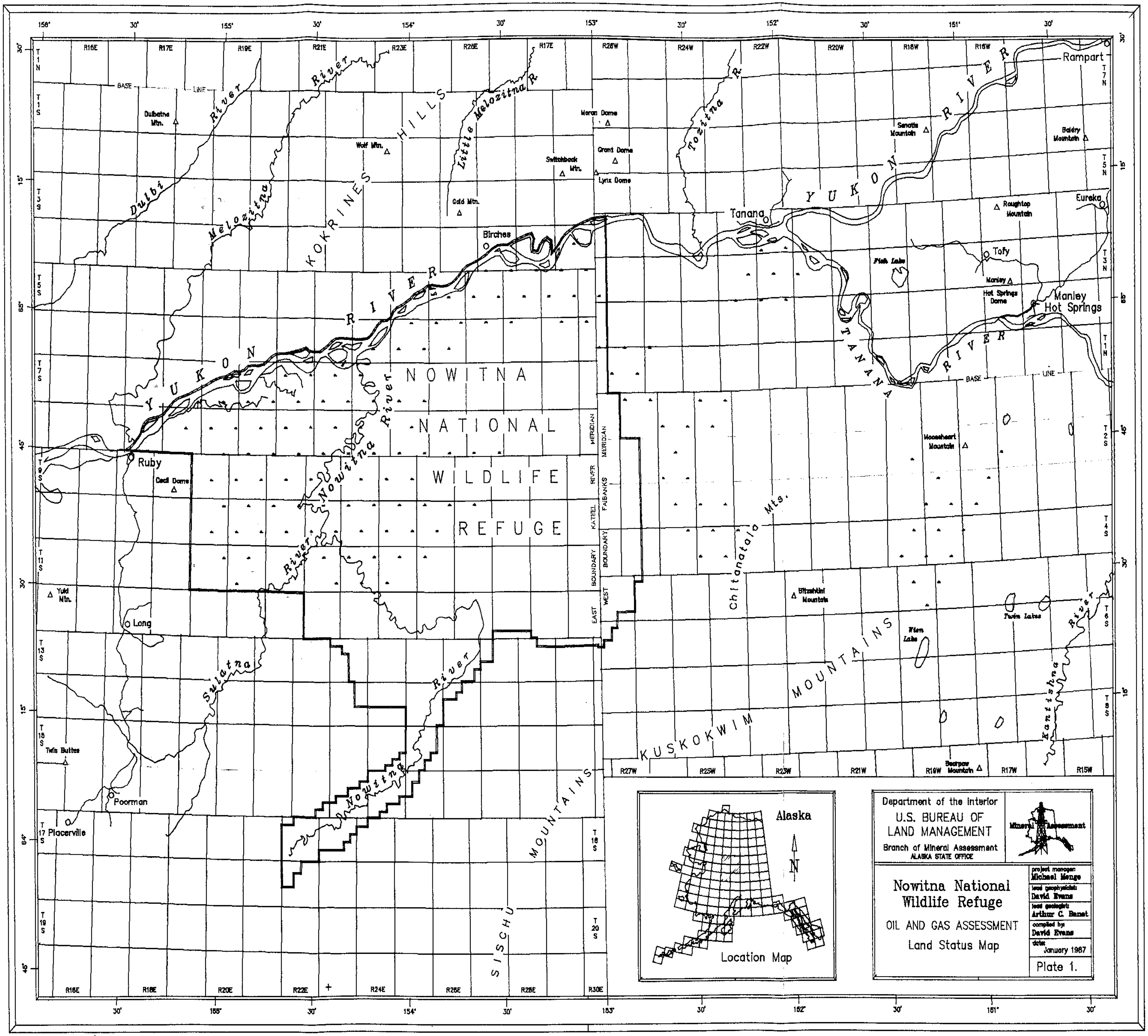
United States Department of Energy, Energy Information Administration, 1985b, Natural gas annual DOE/EIA-0131(84), December 1984.

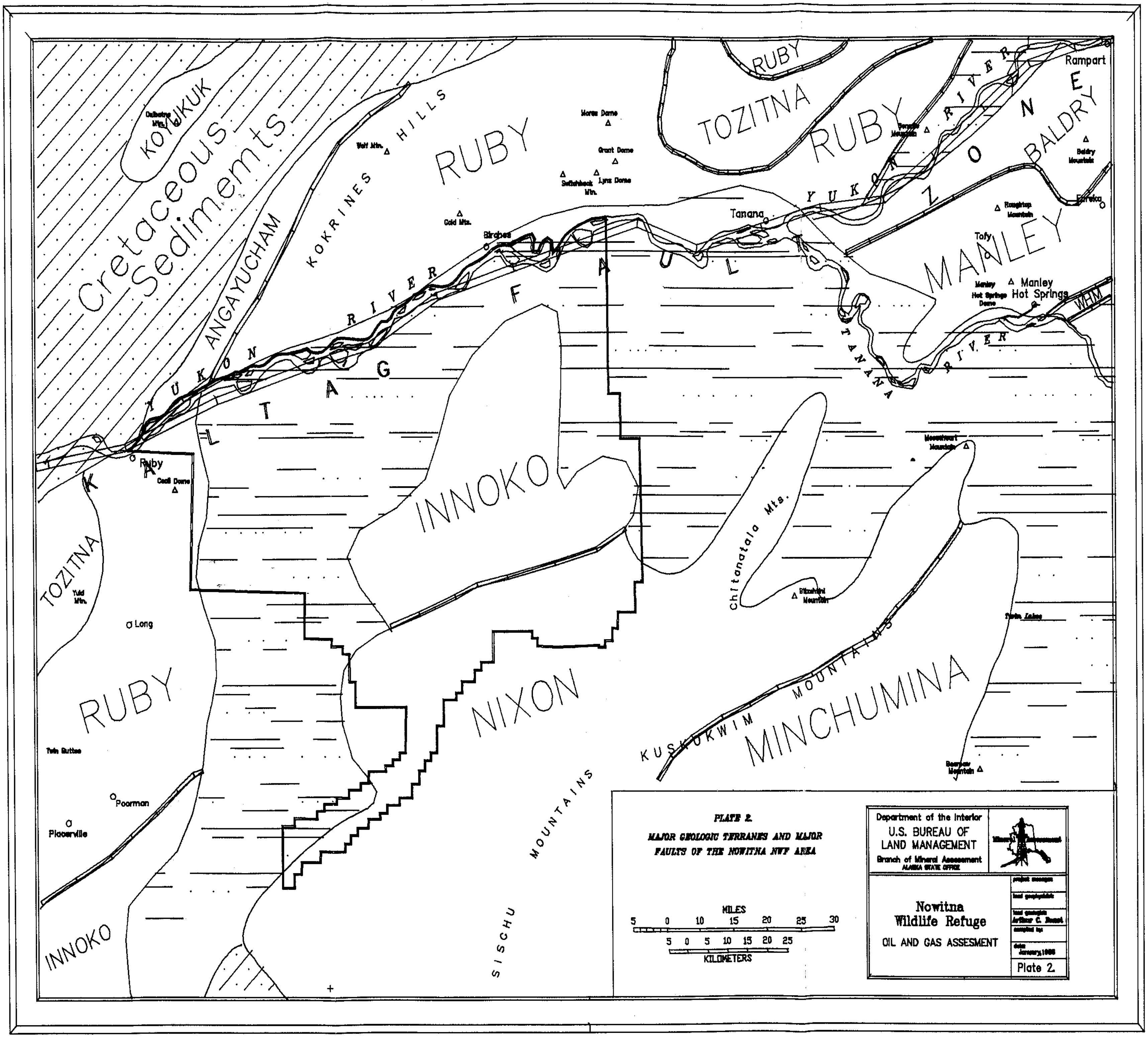
United States Department of Energy, Energy Information Administration, 1986, Monthly energy review DOE/EIA-0035(85/12), March 1986.

United States Department of Energy, Energy Information Administration, 1986a, Petroleum supply monthly. DOE/EIA-0109(86/01), March 1986.

United States Department of Energy, Energy Information Administration, 1986b, International energy outlook 1985, with projections to 19951 DOE/EIA-0484(85), March 1986.

United States Department of Energy, Energy Information Administration, 1986c, Natural gas monthly. DOE/EIA-0130(86/01), March 1986.


Department of the Interior
U.S. BUREAU OF LAND MANAGEMENT
Branch of Mineral Assessment
ALASKA STATE OFFICE
Mineral Assessment
Nowitna National Wildlife Refuge
OIL AND GAS ASSESSMENT
Land Status Map
project manager: Michael Menge
lead geophysicist: David Evans
lead geologist: Arthur C. Banet
compiled by: David Evans
date: January 1987
Plate 1.
Alaska
N
Location Map
NOWITNA NATIONAL WILDLIFE REFUGE
YUKON RIVER
TANANA RIVER
Nowitna River
KOKRINES HILLS
KUSKOKWIM MOUNTAINS
SISCHU MOUNTAINS
Chitanatala Mts.
Little Melozitna R.
Melozitna
Dulbi River
Tozitna R.
Sulatna
Kantishna River
Rampart
Eureka
Tofty
Manley Hot Springs
Tanana
Birches
Ruby
Long
Poorman
Placerville
Fish Lake
Wien Lake
Twin Lakes
BASE LINE
WEST BOUNDARY KATEEL RIVER MERIDIAN
EAST BOUNDARY FAIRBANKS MERIDIAN



Cretaceous Sedimemts
KOYUKUK
ANGAYUCHAM
KOKRINES HILLS
RUBY
TOZITNA
BALDRY
MANLEY
YUKON RIVER
TANANA RIVER
KALTAG FAULT
INNOKO
NIXON
MINCHUMINA
KUSKOKWIM MOUNTAINS
SISCHU MOUNTAINS
Chitanatala Mts.
Rampart
Eureka
Tofty
Tanana
Manley Hot Springs
Birches
Ruby
Long
Poorman
Placerville
Twin Buttes
Wolf Mtn.
Gold Mtn.
Morse Dome
Grant Dome
Lynx Dome
Switchback Mtn.
Twin Lakes
PLATE 2.
MAJOR GEOLOGIC TERRANES AND MAJOR FAULTS OF THE NOWITNA NWF AREA
MILES
5 0 10 15 20 25 30
5 0 5 10 15 20 25
KILOMETERS
Department of the Interior
U.S. BUREAU OF LAND MANAGEMENT
Branch of Mineral Assessment
ALASKA STATE OFFICE
Nowitna Wildlife Refuge
OIL AND GAS ASSESMENT
Plate 2.

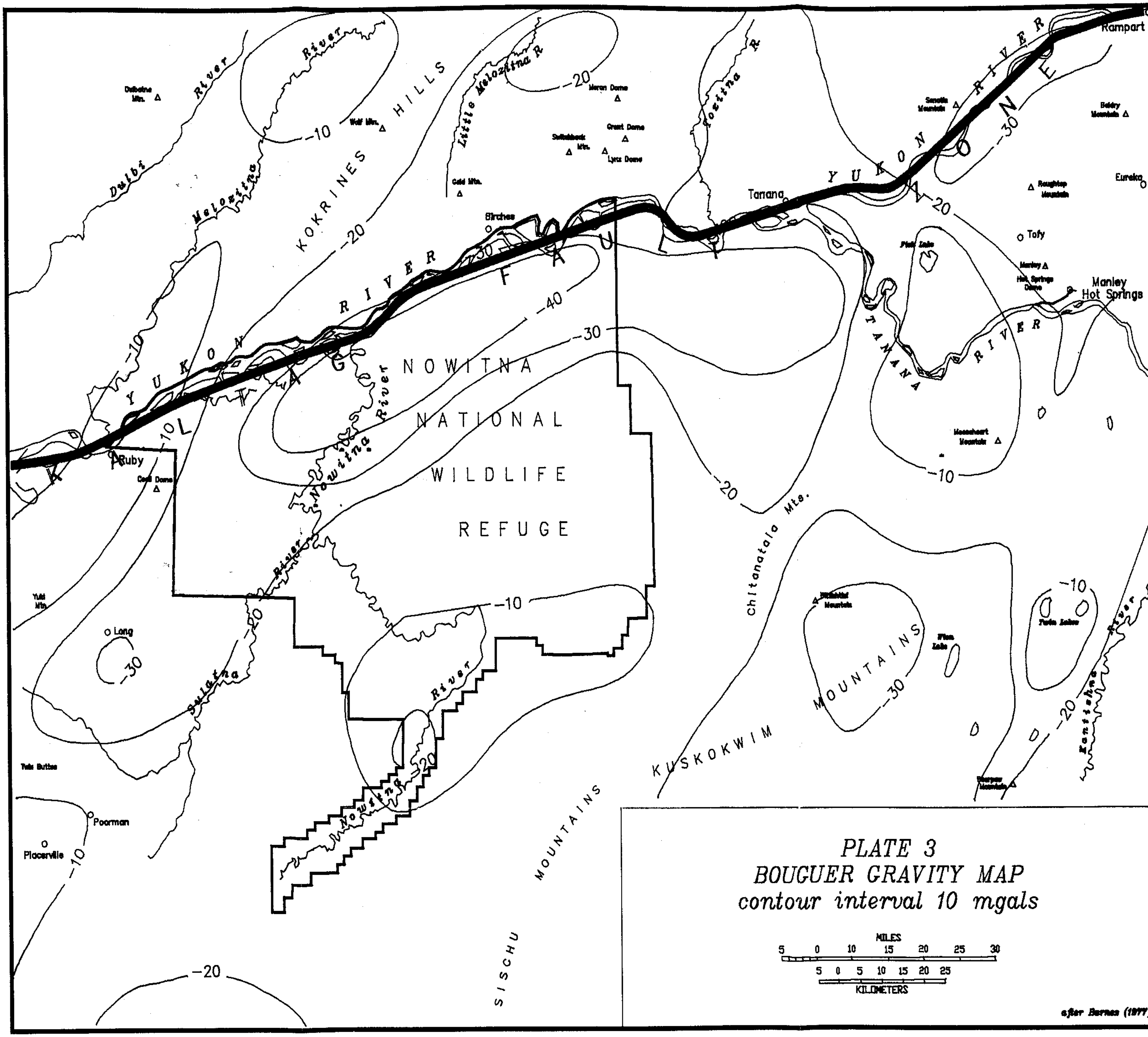


PLATE 3
BOUGUER GRAVITY MAP
contour interval 10 mgals

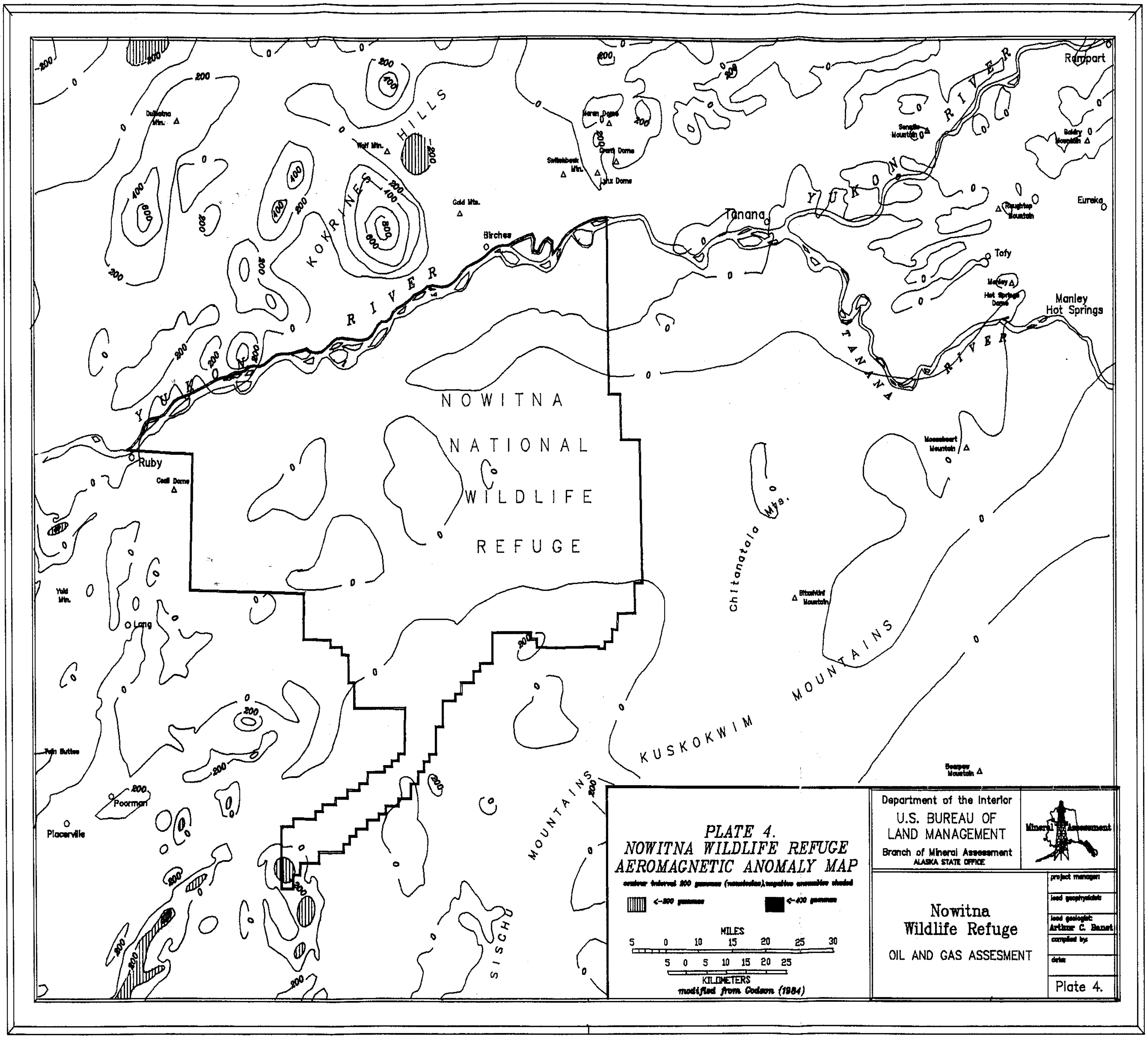
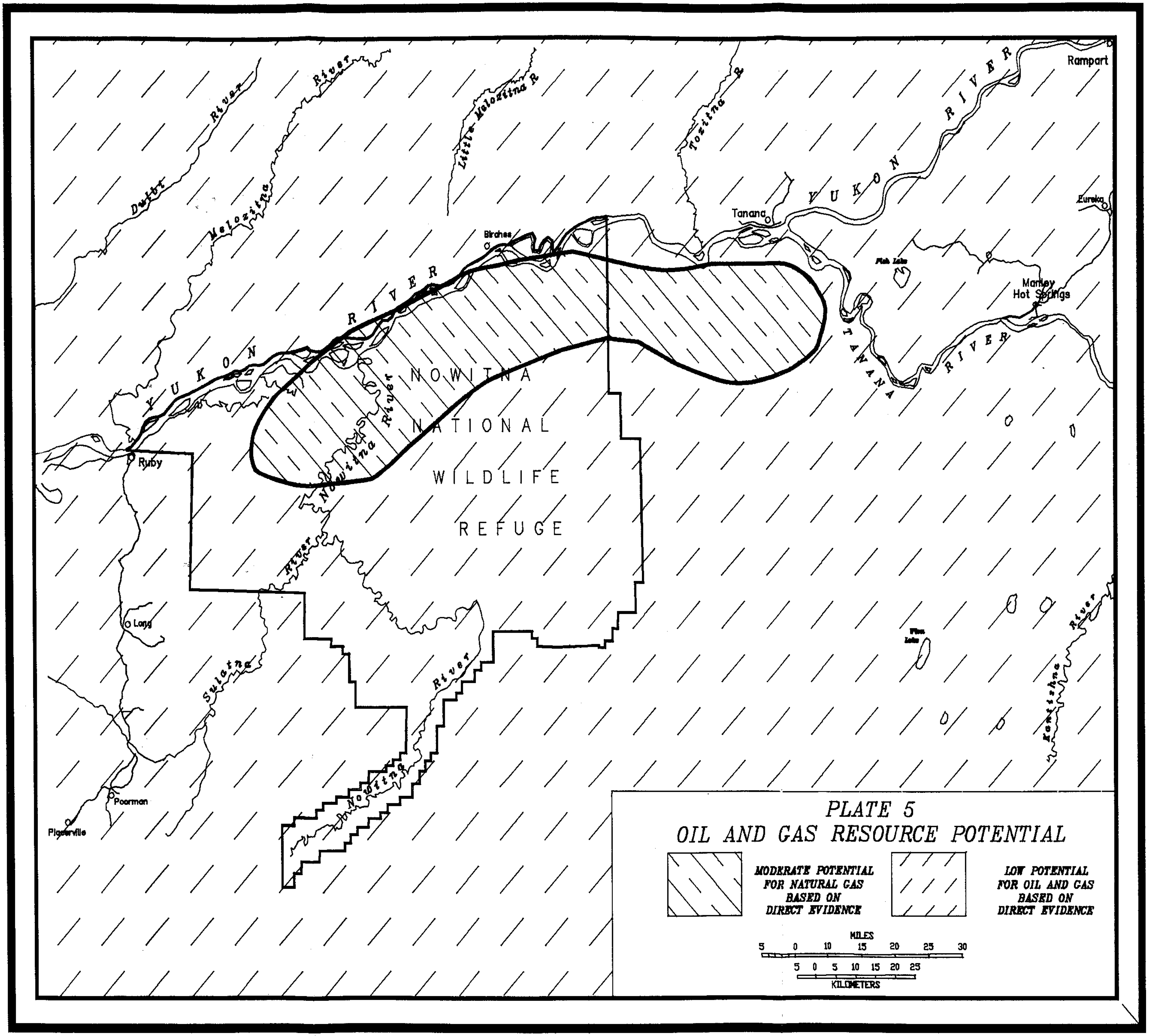


PLATE 4.
NOWITNA WILDLIFE REFUGE
AEROMAGNETIC ANOMALY MAP
MILES
KILOMETERS
modified from Godson (1984)
Department of the Interior
U.S. BUREAU OF LAND MANAGEMENT
Branch of Mineral Assessment
ALASKA STATE OFFICE
Nowitna Wildlife Refuge
OIL AND GAS ASSESMENT
project manager
lead geophysicist
lead geologist: Arthur C. Banet
compiled by
date
Plate 4.
NOWITNA NATIONAL WILDLIFE REFUGE
YUKON RIVER
TANANA RIVER
KOKRINES HILLS
KUSKOKWIM MOUNTAINS
Chitanatala Mts.
SISCHU MOUNTAINS
Rampart
Eureka
Manley Hot Springs
Tanana
Tofty
Birches
Ruby
Long
Poorman
Placerville


Rampart
Eureka
Manley Hot Springs
Fish Lake
Tanana
YUKON RIVER
TANANA RIVER
Tozitna R
Little Melozitna R
Birches
Melozitna
Dulbi River
River
Ruby
NOWITNA NATIONAL WILDLIFE REFUGE
Nowitna River
River
Long
Sulatna
Poorman
Placerville
Kantishna River
PLATE 5
OIL AND GAS RESOURCE POTENTIAL
MODERATE POTENTIAL FOR NATURAL GAS BASED ON DIRECT EVIDENCE
LOW POTENTIAL FOR OIL AND GAS BASED ON DIRECT EVIDENCE
MILES
5 0 10 15 20 25 30
5 0 5 10 15 20 25
KILOMETERS