DOE/ET/13350-T2

CHARACTERIZATION AND EVALUATION OF WASHABILITY OF ALASKAN COALS

Final Technical Report for Phase II

Contractor--University of Alaska

October 1980

Contract No. U.S.D.O.E. ET-78-G-01-8969
(formerly U.S.B.M. G0166212)

U.S. DEPARTMENT OF ENERGY
Assistant Secretary for Fossil Energy
Office of Coal Mining

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CHARACTERIZATION AND EVALUATION OF WASHABILITY OF ALASKAN COALS

Selected Seams from Northern Alaska, Broad pass, Little Tonzona, Tramway Bar, Beluga, Yentna, Kenai and Nenana Coal Fields

FINAL TECHNICAL REPORT FOR PHASE II

July 1, 1977, to February 29, 1979

This report represents work on a program that was originated by the Interior Department's Bureau of Mines and was transferred to the Department of Energy on October 1, 1977.

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U.S. DEPARTMENT OF ENERGY
Assistant Secretary for Fossil Energy
Office of Coal Mining
Pittsburgh Mining Technology Center
Pittsburgh, PA

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ABSTRACT

This report is a result of the second part of a continuing study to obtain washability data for Alaskan coals to supplement the efforts of the U.S. Department of Energy in their ongoing studies on washability of U.S. coals. Alaska, with its large coal resources, could supply the nation with environmentally acceptable low ash low sulfur coals.

Washability characteristics were determined for eleven coal samples, from the Northern Alaska, Broad Pass, Little Tonzona, Tramway Bar, Beluga, Yentna, Kenai and Nenana coal fields. The raw coals were crushed to 1-1/2 inches, 3/8 inch and 14 mesh top sizes and float-sink separations were made at 1.30, 1.40, and 1.60 specific gravities.

The results showed that the subbituminous "B" coals from Northern Alaska coal field can be washed to give an ultra clean product containing less than 3.5 percent ash at yields of 91 percent or better. The other sample from the Northern Alaskan coal field was very high in ash which could be reduced significantly, however, the yield would be very low. Subbituminous "C" coal from the Broad Pass coal field showed improvements in the 1.40 specific gravity product after crushing to 3/8 inch top size and gave a product with 10.6 percent ash at a 78.7 percent yield.

The subbituminous "C" rank sample of Little Tonzona coal bed gave an 8.9 percent ash product with 83.4 percent recovery for coal crushed to 1-1/2 inches top size. The sulfur in this coal is high 1.55, and with very little pyritic sulfur; therefore, washing will not improve the sulfur content.

The high volatile subbituminous coal from Tramway Bar coal field was high in ash. Washing the 1-1/2 inches top size coal at 1.60 specific gravity would provide a product with 11.5 percent ash and 0.27 percent sulfur with a calorific value of 11,523 Btu/lb.

The lower 30 feet of the Waterfall Bed from the Beluga coal field gave a float 1.40 specific gravity product with 7.2 percent ash, 0.20 percent sulfur and 11,222 Btu/lb at 92.7 percent yield.

Lignite from Yentna coal field has less than 5 percent ash in the raw coal and very little sulfur, less than 0.15 percent. Washing would not significantly improve the quality of this coal.

The subbituminous "C" coal crushed to 3/8 inch top size from Cabin Bed, Kenai coal field, near Homer can be washed at 1.40 specific gravity to give a product with 8.3 percent ash, 0.48 percent sulfur, and 11,189 Btu/lb with a 90.8 percent recovery.

Subbituminous "C" No. 4 bed coal, Nenana coal field, now being mined could provide a product with 9.6 percent ash and 10,854 Btu/lb at a 96.8 percent yield when crushed to 1-1/2 inches top size and cleaned at 1.40 specific gravity.

ACKNOWLEDGMENTS

The study was conducted under the sponsorship of the U.S. Department of Energy, however, several organizations furnished financial and helicopter support to obtain

ILLUSTRATIONS

TABLES

samples of beds in remote locations. The Alaska Field Operations Center of the U.S. Bureau of Mines provided funds for sampling the Wainwright and Meade River coal beds. The Alaska Division of Geological and Geophysical Surveys was responsible for the sampling and transportation of Little Tonzona coal from the field by air. They also furnished helicopter support and camping facilities for the first author for sampling the coal bed at Locality 2 in the Yentna field. Beluga Coal Corporation, a subsidiary of Placer Amex, sampled the Waterfall bed in the Beluga field and air lifted the two 55 gallon drums of the sample. We have received excellent cooperation from Usibelli Coal Mine for sampling No. 3 bed in the Lower Lignite Creek area. Sampling and transportation of samples from the Sagwon Bluffs was done while working on a project funded by the U.S. Bureau of Mines on the study of the mineral resources of the pipeline corridor. Cooperation of all these organizations is gratefully acknowledged.

Numerous individuals have helped in collecting the following samples. The bulk of sample sites were located in remote areas. The following are the individuals that were actually involved in sampling the beds.

UA-109 Northern Alaska Field - P. D. Rao, Allen Ahlalook

UA-110 Northern Alaska Field - P. D. Rao, Edmond Simmons

UA-114 Northern Alaska Field - Paul Metz, Mark Robinson

UA-111 Broad Pass Field - P. D. Rao, E. N. Wolff, and Cleland Conwell

UA-112 Little Tonzona Coal Field - Cleland Conwell, Bonita Maynard

UA-117 Tramway Bar Field - P. D. Rao, Paul Metz

UA-113 Beluga Field - Benno Patsch

UA-115 Yentna Field - P. D. Rao

UA-116 Yentna Field - P. D. Rao

UA-118 Kenai Field - P. D. Rao, Robert Hoedel

UA-119 Nenana Field - P. D. Rao, Ravishankar Rao

Laboratory investigations were assisted by Victor Ross and John Hendrick, students in mining engineering, and Robert Fisk and Jane Smith, students in geology.

Thanks are due to Dr. Earl H. Beistline, Dean, School of Mineral Industry, University of Alaska, Fairbanks, for his interest and encouragement in coal investigations.

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INTRODUCTION

This is a continuing investigation of the washability of Alaskan coals. Part I of the study included nine samples from Nenana, Jarvis Creek, and Matanuska fields

(1).[1] The current study includes 11 samples from widely separated areas from Wainwright in the north to Homer on the Kenai Peninsula in the south.

Alaska has very extensive coal deposits (figure 1). Barnes (2)(3) estimates identified coal resources at 130 billion tons. Recent estimates based on oil well drill logs in Cook Inlet (4) and the North Slope (5)(6) could place the coal resources of Alaska at several trillion tons, exceeding the resources of the rest of the nation. Alaska is in an enviable position of being able to supply the energy needs of this state as well as the nation.

Alaska can supply coal to lessen the nation's reliance on imported oil and reduce the balance of payments deficit by exporting Alaskan coals to other Pacific belt nations and to the west coast of the United States. This coal would come from the Nenana and Matanuska fields, accessible to the Alaska Railroad, or from the Beluga field, accessible to a deep water port.

There are three major undesirable substances in coal: sulfur, moisture, and ash. Alaskan coals are found in non-marine formations and this accounts for the low or no pyritic sulfur content and consequently very low total sulfur. Although moisture is the most undesirable of the constituents in Alaska's subbituminous coals, it is not being addressed at the present time. The extent to which ash and sulfur can be reduced depends to a large extent on the form of occurrence and is readily evaluated by standard washability tests. These involve crushing and float-sink separation of coals in organic liquids at varying densities, followed by chemical analysis and evaluation of the densimetric fractions.

COAL FIELDS SAMPLED

Eleven raw coal channel samples were collected for this phase of the study. In operating mines, samples were obtained from freshly exposed beds; elsewhere, fresh surfaces were exposed on outcrops of weathered coal. Six-hundred-pound samples were transported to the laboratory in heavy duty plastic bags in gunny sacks. The samples were obtained from the Northern Alaska, Nenana, Broad Pass, Little Tonzona, Yentna and Kenai coal fields and the Tramway Bar area.

Northern Alaska Coal Field

The great bulk of Alaska's coal resources lie in the Northern Alaska coal field, north of the Brooks Range. Coal bearing cretaceous rocks are known or inferred to underlie about 58,000 square miles (2)(3). Figure 2 is generalized facies diagram by Chapman and Sable (7). They find that the coal beds in the Utukok-Corwin region, particularly those of potential economic significance, are confined almost entirely to the Corwin formation. The cretaceous rocks include sandstone, conglomerate, siltstone, shale, and coal. Although these rocks are mostly of marine origin, non-marine coal bearing rocks predominate in some areas and intertongue with the marine rocks. Based on outcrops along river banks, Barnes (8) subdivided the field into six districts.

1. Corwin Bluff - Cape Beaufort district

2. Kukpowruk River district

[1]Underlined numbers in parentheses refer to items in the list of references at the end of this report.

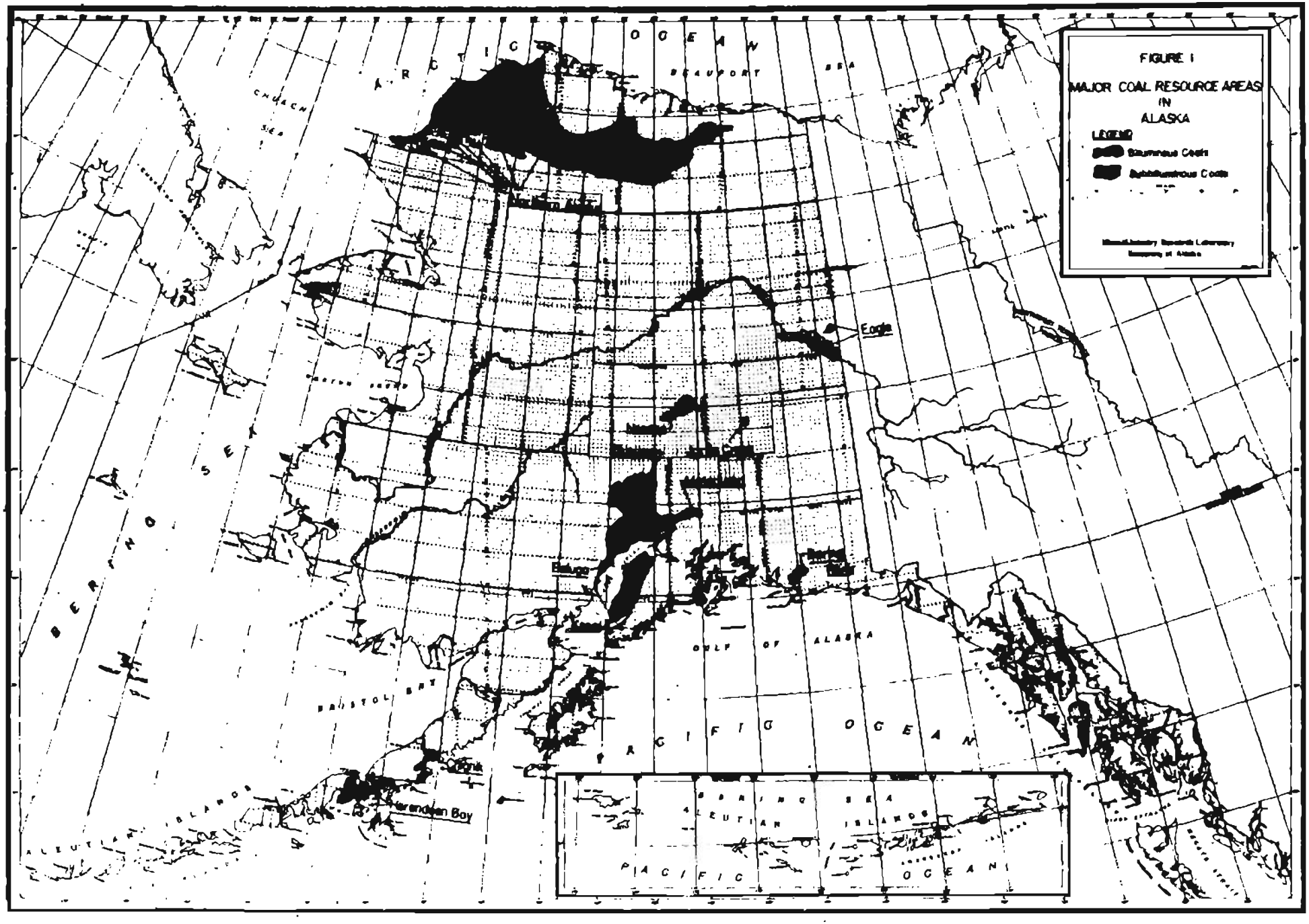
FIGURE 1
MAJOR COAL RESOURCE AREAS
IN
ALASKA
LEGEND
Bituminous Coals
Subbituminous Coals
ARCTIC OCEAN
BEAUFORT SEA
CHUKCHI SEA
BERING SEA
BRISTOL BAY
GULF OF ALASKA
PACIFIC OCEAN
Eagle
Beluga
Nenana
Herendeen Bay
ALEUTIAN ISLANDS
BERING SEA
ALEUTIAN ISLANDS
PACIFIC OCEAN

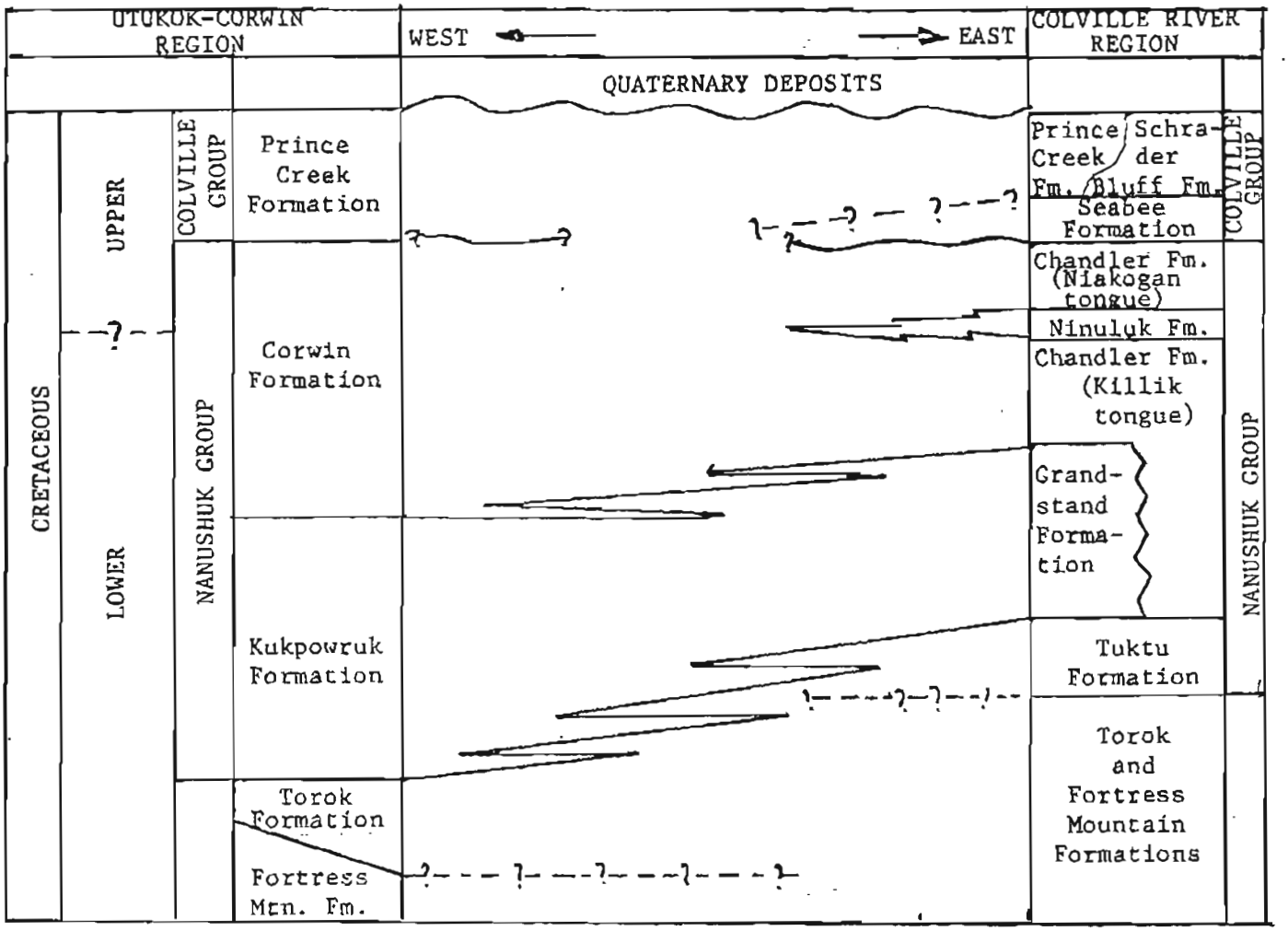

Figure 2: Generalized stratigraphic correlations of Cretaceous rocks of Northern Alaska Field. Wavy lines represent unconformities. Chapman and Sable (1960, p.70).

3. Kokolik - Utukok River district

4. Kuk-Kugrua Rivers district

5. Meade - Ikpikpuk Rivers district

6. Colville River district

Coal seams were sampled from Kuk and Meade River districts.

A sample from an uncorrelated coalbed (UA-109) was obtained from an outcrop on the east bank of the Kuk River, about 14 air miles from Wainwright (figure 3). The bed is five feet thick and the bottom of the seam is approximately four feet above the river level. The stratigraphic position of this bed has not been definitely established, but according to Barnes (2)(3), it is believed to be in rocks correlative with the Chandler formation (figure 2). Coal outcrops have been described and, in fact, some have been mined for a distance of 10 miles along the Kuk River. There are two uncorrelated coal beds exposed at the outcrops with approximately 10 feet of coal. The individual beds range in thickness from two to six feet and 10 to 50 feet overburden outcrop along the Kuk River (9). Barnes (2)(3) estimates indicated resources for the Kuk River (Wainwright) district at 62.6 million tons and inferred resources at 1,395 million tons.

A sample of the No. 2 coal bed (UA-110) was collected in the Meade River area. Coal outcrops along the west bank of the Meade River near the village of Atkasook (figure 4). Coal has been mined during the 1940's and early 1950's in an open trench and underground for shipment to Barrow. The U.S. Bureau of Mines has done extensive drilling in this region and delineated the coal bearing areas for mining purposes (10). Four coal seams have been identified in this locality. The No. 1 bed is 34 inches thick, the No. 2 bed is five to six feet and the No. 3 and No. 4 beds are approximately 12 inches and the beds are separated by one to two feet of clay.

A sample of Uncorrelated coal bed (UA-114) was collected from an outcrop in the Sagwon bluff area. Rocks in the Sagavanirktok quadrangle (11) are part of a thick sequence of submarine volcanic and nonmarine carbonate rocks of Mississippian through Tertiary age. Coal has been reported in Ignek formation of Cretaceous age and Sagavanirktok formation of Tertiary age. The sampled coal outcrop (UA-114) was from the bluffs on the Sagavanirktok River (12) adjacent to the Trans Alaska Pipeline (figure 5). The sampling location has not been mapped in detail and the age of the formation that the coal occurs has not been determined (cretaceous to tertiary).

Broad Pass Coal Field

Broad Pass coal field is located near Broad Pass station, 166 miles south of the Alaska Railroad and Parks Highway. The field may be divided into two basins. The Costello Creek Basin (13) is on the west side of the railroad and covers about seven square miles. Coal occurs in tertiary sequences of sandstone and claystones. There are three mineable coal beds in this basin, i.e. Dunkle bed (5 feet thick) Lower Billie bed (3.4 feet thick) and Upper Billie bed (3.9 feet thick). Coal was mined from this basin until the early 1950's. Analysis of shipped coal samples reported by Wahrhaftig indicated the coal to be of subbituminous rank. No sample was collected here at this time, but interest in these coals requires future collection of samples.

Coal Creek Basin is located on the east side of the Alaska Railroad and lies in an area three miles long and one mile wide (14). About 1-1/2 square miles are known to be underlain by coal bearing rocks.

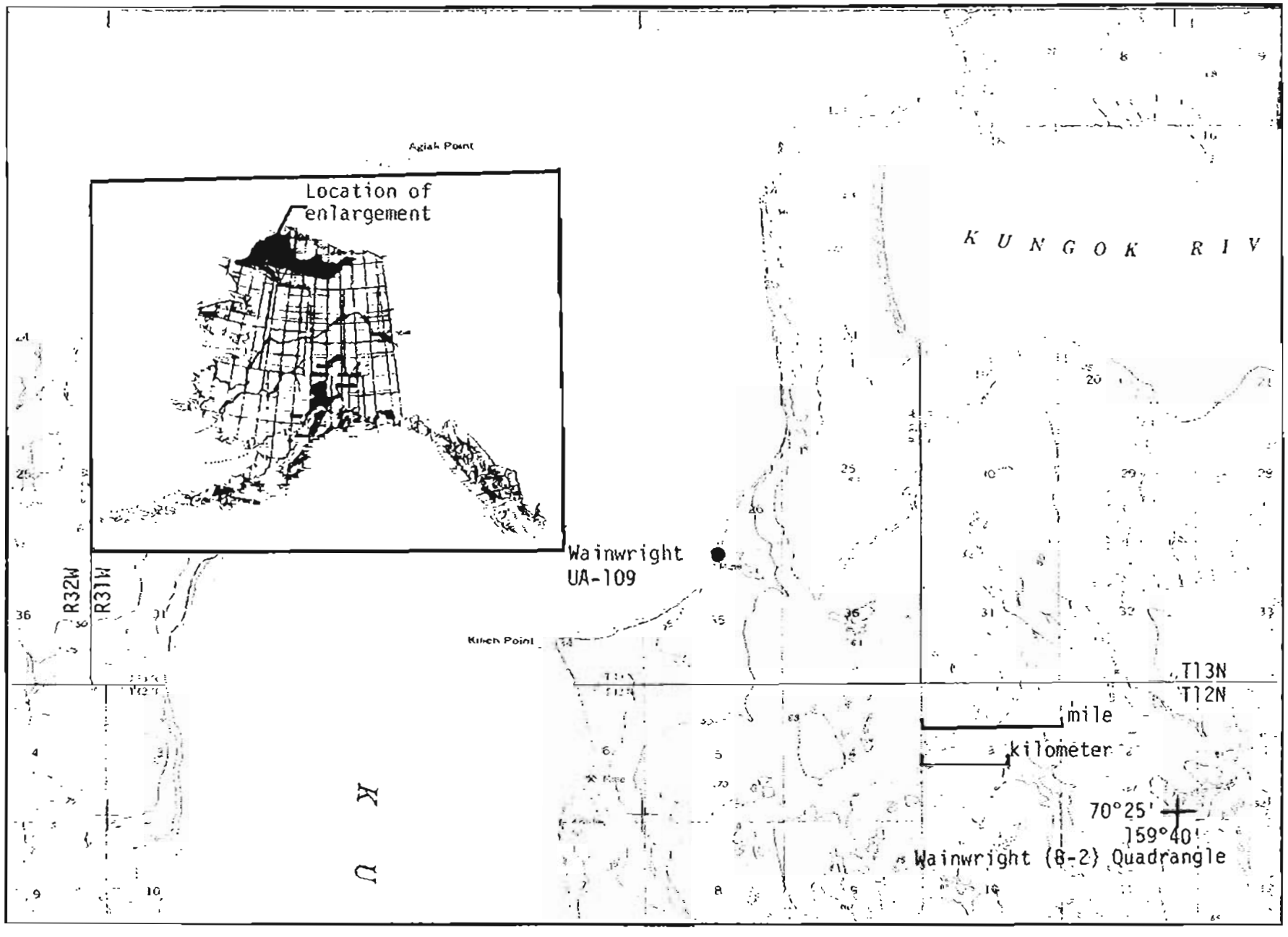

Figure 3: Sampling location on the banks of Kuk River, Northern Alaska Field

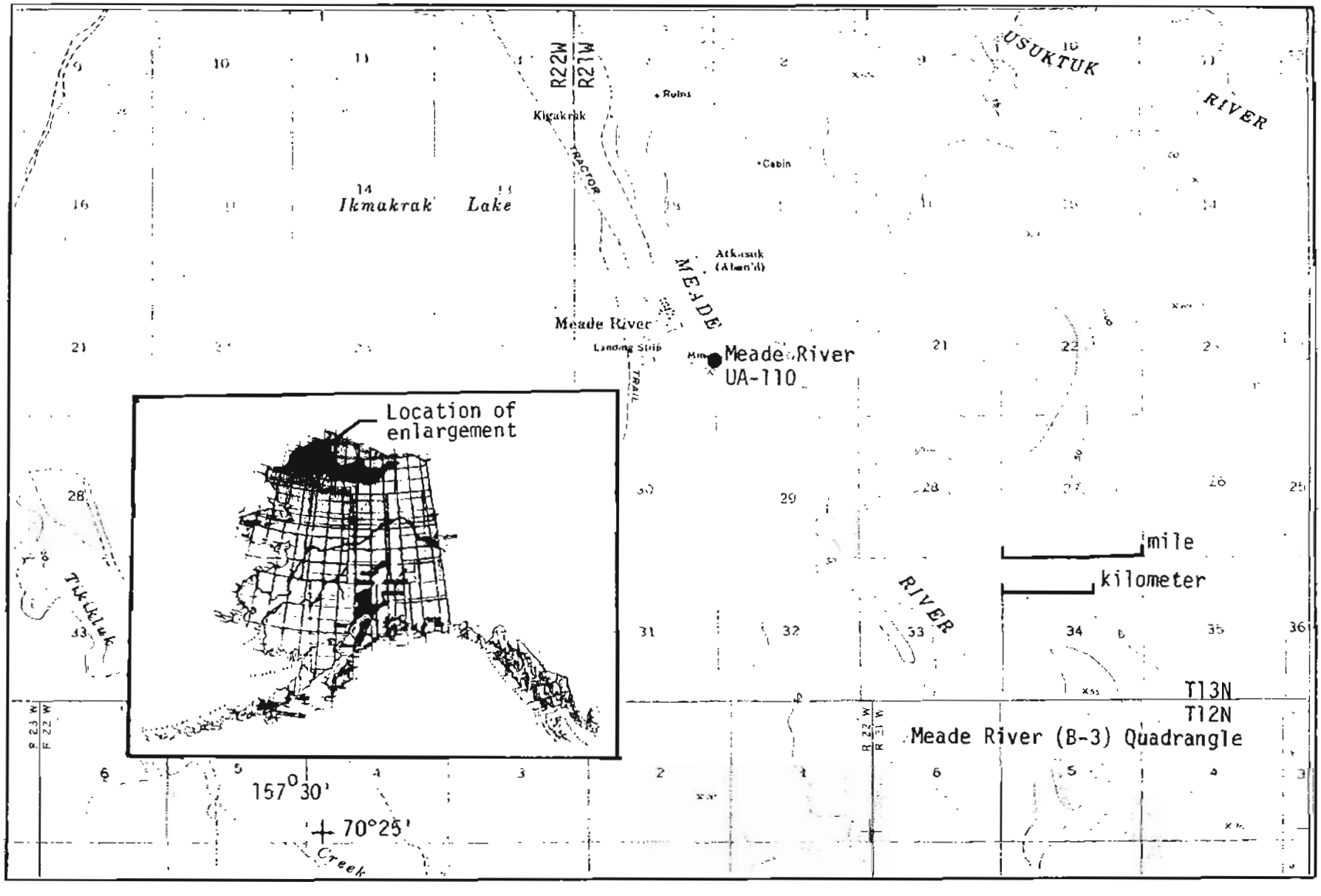

Figure 4: Sampling location of Meade River, Northern Alaska Field

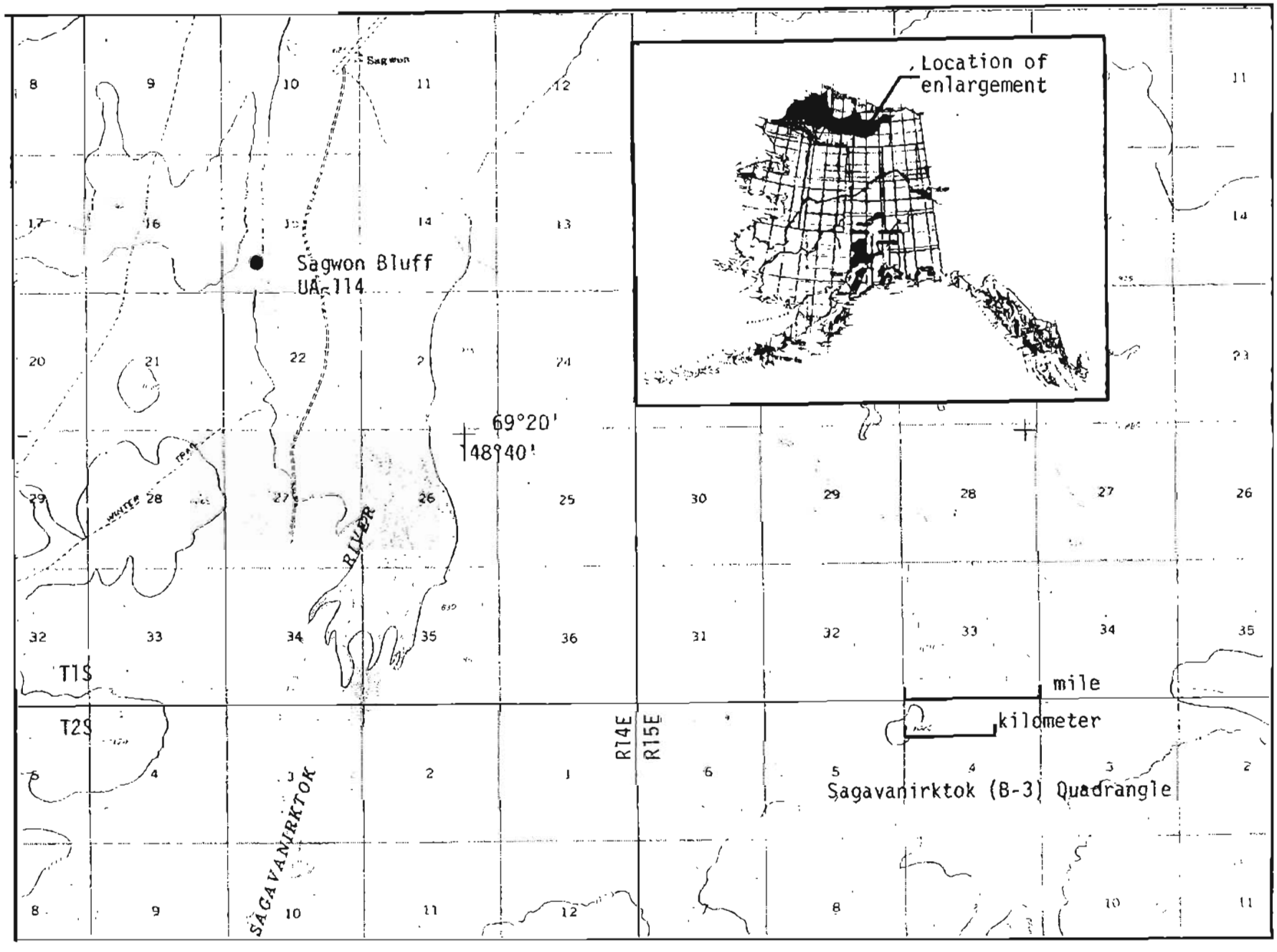

Figure 5: Sampling location at Sagwon Bluff, Northern Alaska Field

Coal was mined from the basin until the mid 1940's. A sample of the Coal Creek coal bed (UA-111) was collected from an outcrop near the former Coal Creek mine (figure 6). The Coal Creek coal bed is eight feet thick and is covered by unconsolidated sediments. The locality can be accessed via an old wagon trail from the Parks Highway. The trail crosses several streams and the access is limited to four-wheel drive vehicles.

Little Tonzona Coal Field

Occurrences of coal near Farewell were first observed by Brooks (15) in 1902. Capps (16) described 20 foot thick coal beds in tertiary nonmarine sedimentary rocks south of Kantishna; however, the Little Tonzona coal bed was first described in 1977 by Player (17). A sample of this coal bed (UA-112) was collected from an outcrop section of the bed.

Coal beds occur in Tertiary nonmarine sandstone, siltstone and volcanic rocks in widespread isolated exposures north and south of Farewell fault from Big River northeast to Kantishna and beyond (17). The sampled bed occurs in an isolated exposure of Tertiary nonmarine sedimentary rocks on the south west bank of the Little Tonzona River (figure 7). Beds strike N60°E to N70°E and dip 55° to 70° northwest (17). The total stratigraphic thickness measured by Player is about 195 feet. Figure 8 is a section of the outcrop as measured by Player (17).

Tramway Bar Coal Field

Occurrence of coal near Tramway Bar was first reported by Schrader (18) in 1899 and has been mined for local use (19). The occurrences are at the northeastern part of the Yukon-Koyukuk Province. The province is a broad tract of cretaceous and tertiary rocks that stretches across west-central and south-central Alaska from the Brooks range to the Yukon River delta (20). Tramway Bar occurrence is the western most outcrop of coal in the basin, and is assigned an upper Cretaceous age (20).

Coal is exposed along the north bank of the Koyukuk River (figure 9) in three uncorrelated beds--a three foot, an eight inch, and a 17 foot six inch bed. The top portion of the 17 foot bed was covered and was difficult to sample. The bottom 13 feet of this uncorrelated coal bed (UA-117) was sampled including bands of interbedded shale. The coal bed dips at 56° and the sample was cut horizontally across the seam at a level of six feet above the river.

COOK INLET SEDIMENTARY BASIN

Nonmarine sedimentary rocks of Cook Inlet basin exceed 18,000 feet in thickness and in some parts of the basin they may extend to 27,000 feet. The rocks outcrop as far north as Peters Hills and continue south to Homer forming a belt 200 miles long and 70 miles wide. Although these formations are known to be coal bearing since the early 1900's, recent discoveries of petroleum and gas fields sparked intensive drilling that resulted in a greater understanding of the geology of these tertiary rocks.

Figure 10 shows stratigraphic nomenclature as proposed by Calderwood and Fackler (21), and modified and updated by Magoon et al. (22). It will be noted that coal seams of possible commercial value are restricted to the Tyonek and Beluga Formations. Figure 10 also shows approximate updated stages of Seldovian, Homerian and Clamgulchian stages indentified by Wolf et al. (23) from paleobatanical and palynological evidence along with age determinations.

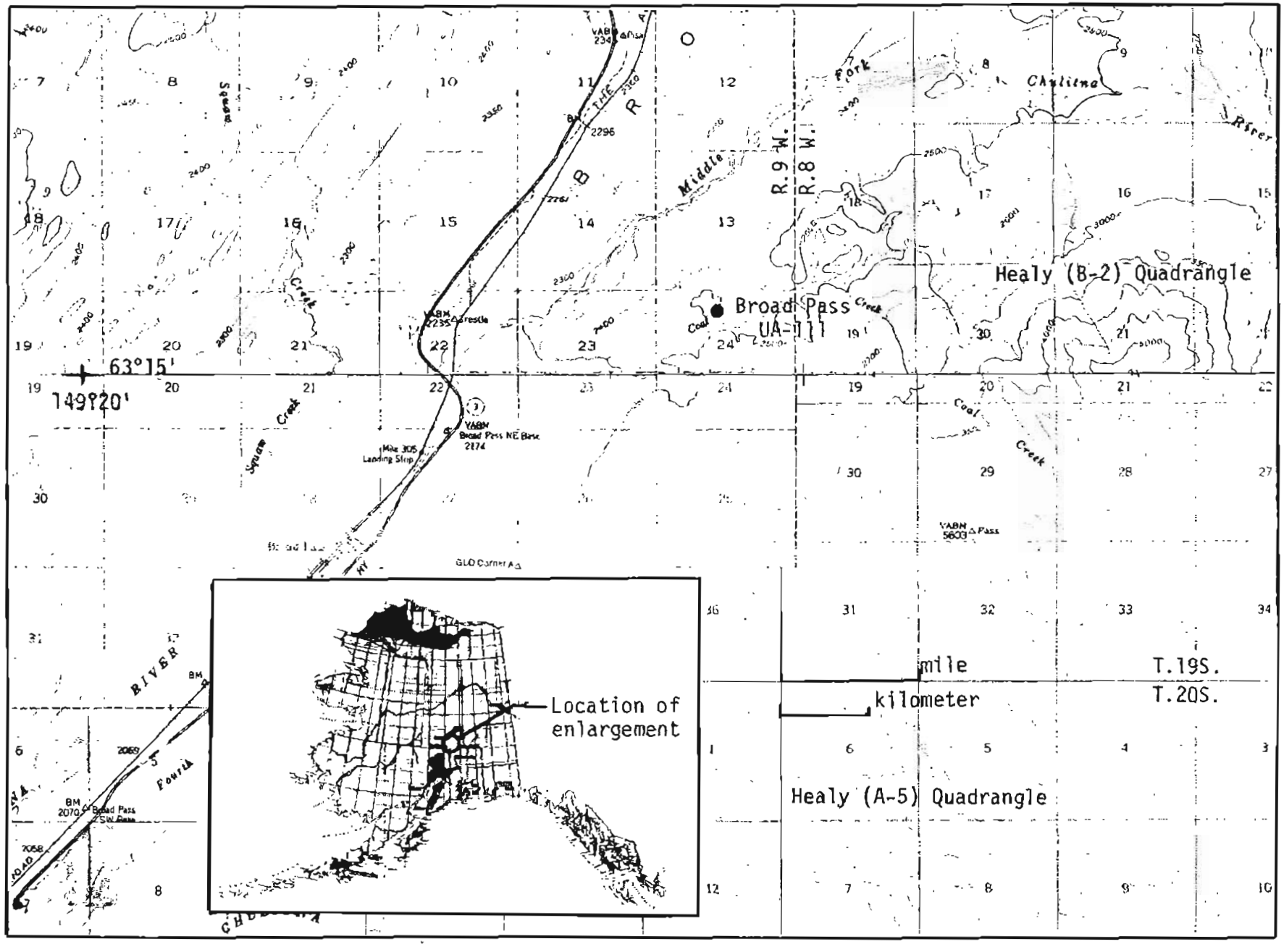

Figure 6 : Sampling Location in the Broad Pass Field

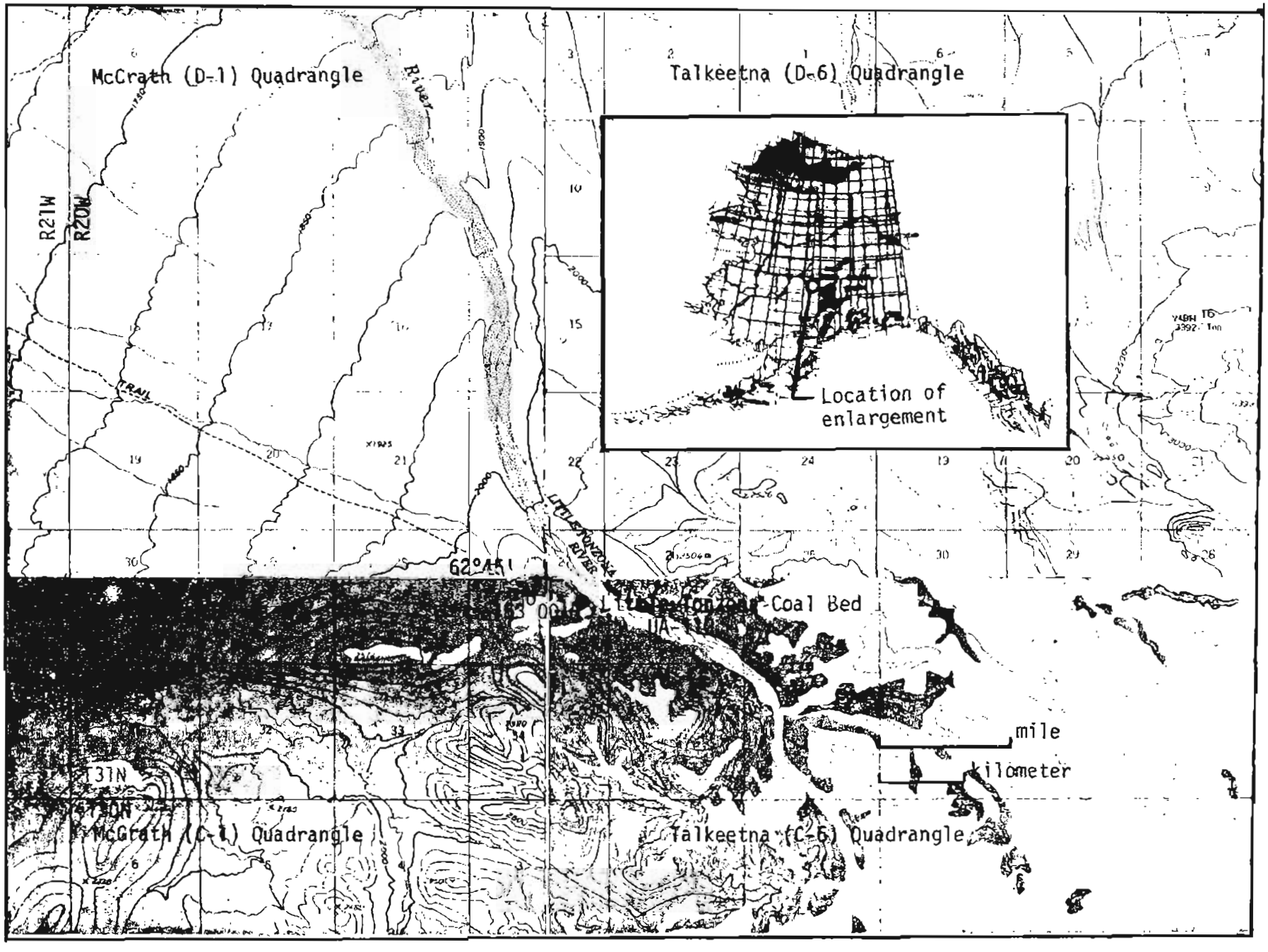

Figure 7: Sampling location of Little Tonzona Field

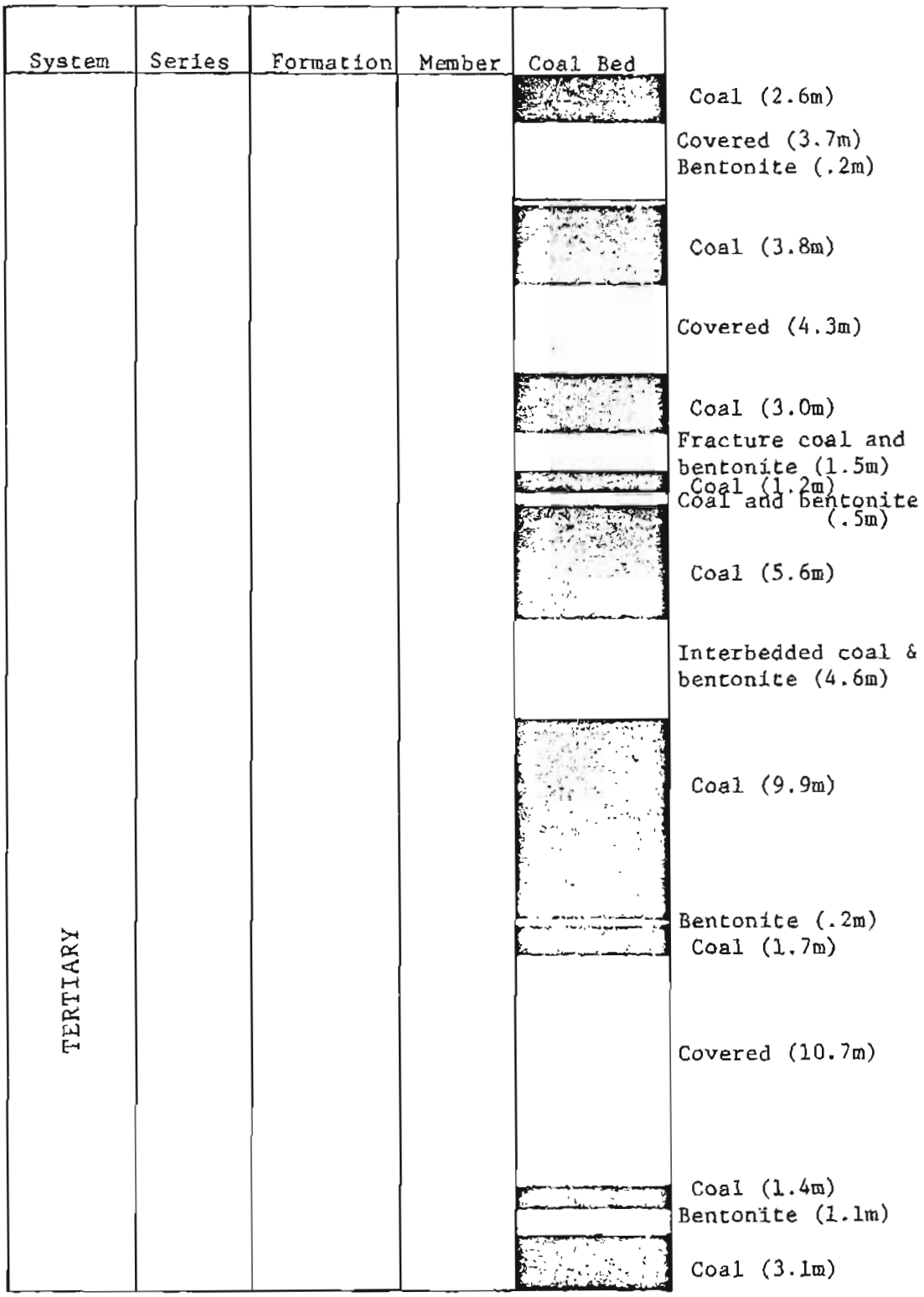

Figure 8: Geological column showing exposed and covered portions of Little Tonzona coal bed. (Source: Player, 1976)

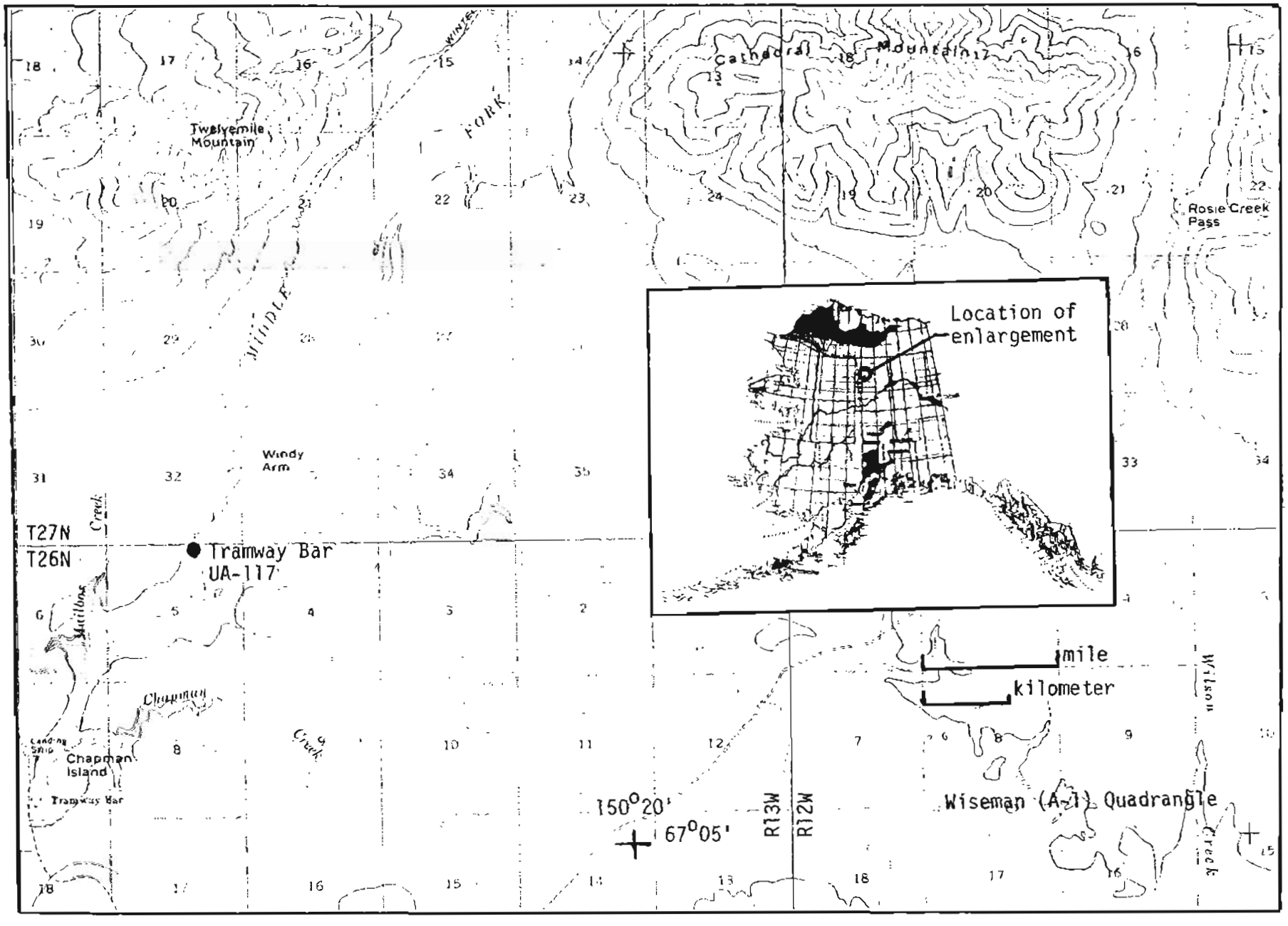

Figure 9: Sampling location of Tramway Bar Field

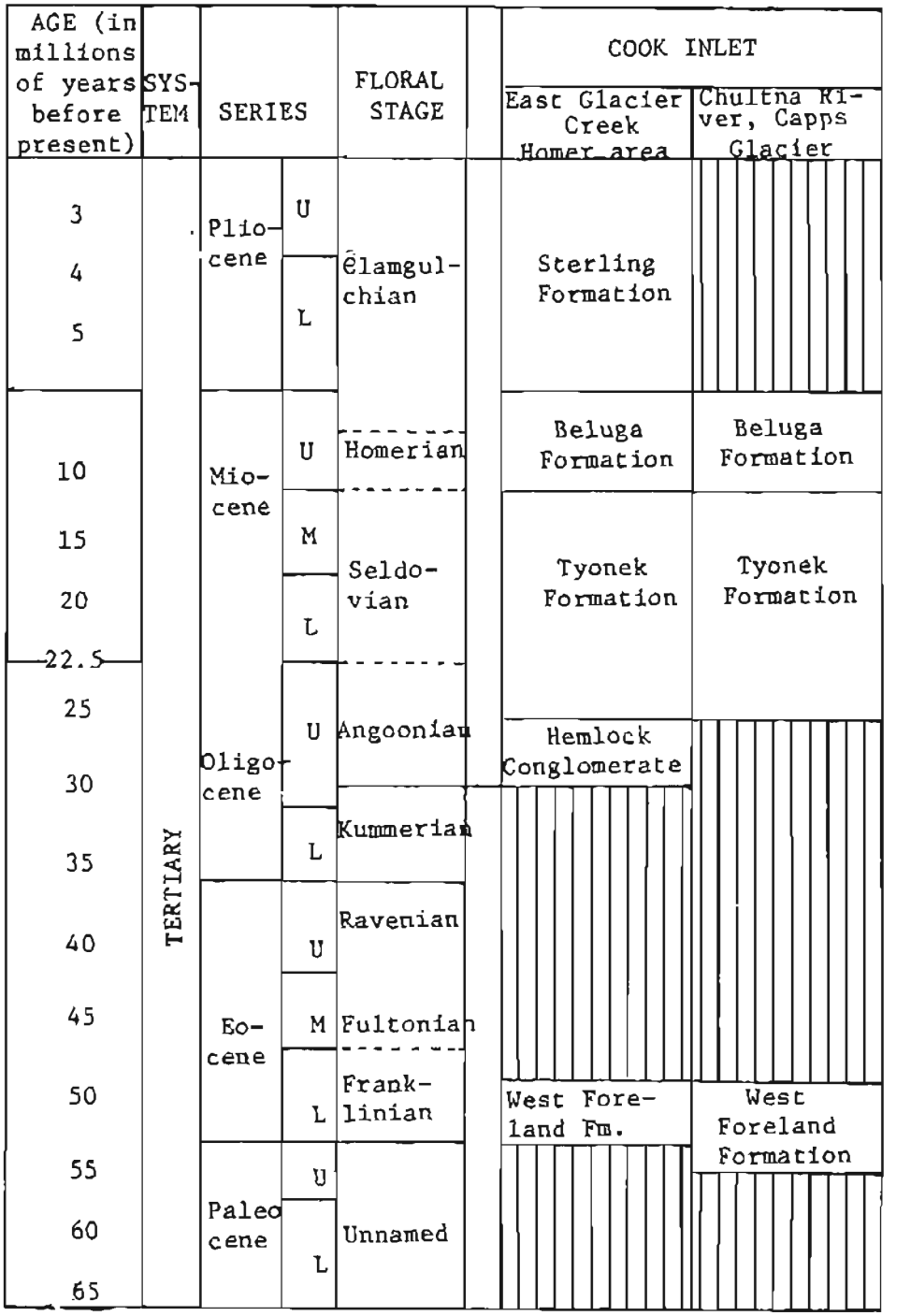

Figure 10: Correlation of Tertiary rocks in the Beluga Coal Field. (Source: Magoon, Adkison and Egbert, 1976)

From purely geographical considerations, the sedimentary basin is divided into three coal fields: Kenai, Beluga, and Yentna.

The coal is of Tertiary age and is limited to the Kenai group (formerly Kenai Formation). Coal is interbedded with coarse to fine grains, sandstone, siltstones, and occasional conglomerates. The Kenai Group is subdivided into four formations which include the Hemlock Conglomerate, Tyonek, Beluga, and Sterling Formations.

Kenai Coal Field

Much of the Kenai lowland is underlain by coal bearing rocks. Coal exposures are found extensively on steep bluffs along the east shore of the Cook Inlet, rising at places to 200 feet above the beach (24). Barnes and Cobb (25) made a detailed study of those outcrops and presented extensive sections of these exposures. The beds are not massive in thickness; however, Barnes identified at least 30 beds ranging in thickness from three to seven feet.

Coal has been mined in the Homer district since 1888. There has been no mining since 1951 when the Homer Coal Corporation ceased operations. Some residents of the Homer areas still collect coal from the beach for domestic use, particularly after a severe storm. The sample collected (UA-118) is from the Cabin coal bed and is six feet thick and has about five feet of overburden at the sampling location (figure 11). A geologic column showing the coal beds in the Kenai field is presented in figure 12. The bed outcrops on a vertical face and sampling was accomplished with the aid of technical rock climbing equipment.

Beluga Coal Field

Barnes (8) defined Beluga-Yentna region as the broad lowland west of lower Susitna River that is bounded on the north and west by the Alaska Range and on the south by Upper Cook Inlet and the Chakachatna River. The Beluga coal field is part of Cook Inlet sedimentary basin and is located approximately 60 miles west of Anchorage on the northwest shore of Cook Inlet. The field can be subdivided into three coal bearing regions. Region 1, the Three Mile Creek Basin, located about six miles from Cook Inlet, contains approximately 22 steeply dipping seams averaging 10 feet in thickness. Region 2, the Chuitna Basin, is located about 17 miles from Cook Inlet. There are at least two mineable coal beds, one of which exceeds 40 feet in thickness, outcrops along the Chuitna River. Region 3, the Capps Basin lies 26 miles from Cook Inlet. This area has two beds in the Tyonek formation (figure 4), the upper Capps bed with an average thickness of 17 feet, and the Waterfall bed (Capps bed of Barnes) with an aggregate thickness from 20-49 feet (figure 13). The latter has an average mineable thickness of 30 feet with interburden varying from 80 to 280 feet (26). Sample No. UA-113 was collected from the Waterfall bed (figure 14), and represents the bottom 30 feet of the bed. The top six feet is dirty and will be sampled separately in future investigations.

Beluga Coal Company, a subsidiary of Placer Amex, holds State of Alaska coal leases in all three basins for a total area of 400 square miles. Barnes estimates the indicated reserves in the 400 square mile area south of Beluga Lake at 200 million tons.

The following is an estimate by Beluga Coal Company of mineable reserves in their leased area (26). Three Mile Basin has an estimated 60 million tons in the 22 steeply dipping beds averaging 10 feet thick at a stripping ratio of 9 to 1. Chuitna Basin has approximately 200 million tons of near surface reserves on the west side of the river. In the Capp Basin the reserves of the Capps and Waterfall beds are estimated at 200 million tons at a stripping ratio of 5 to 1.

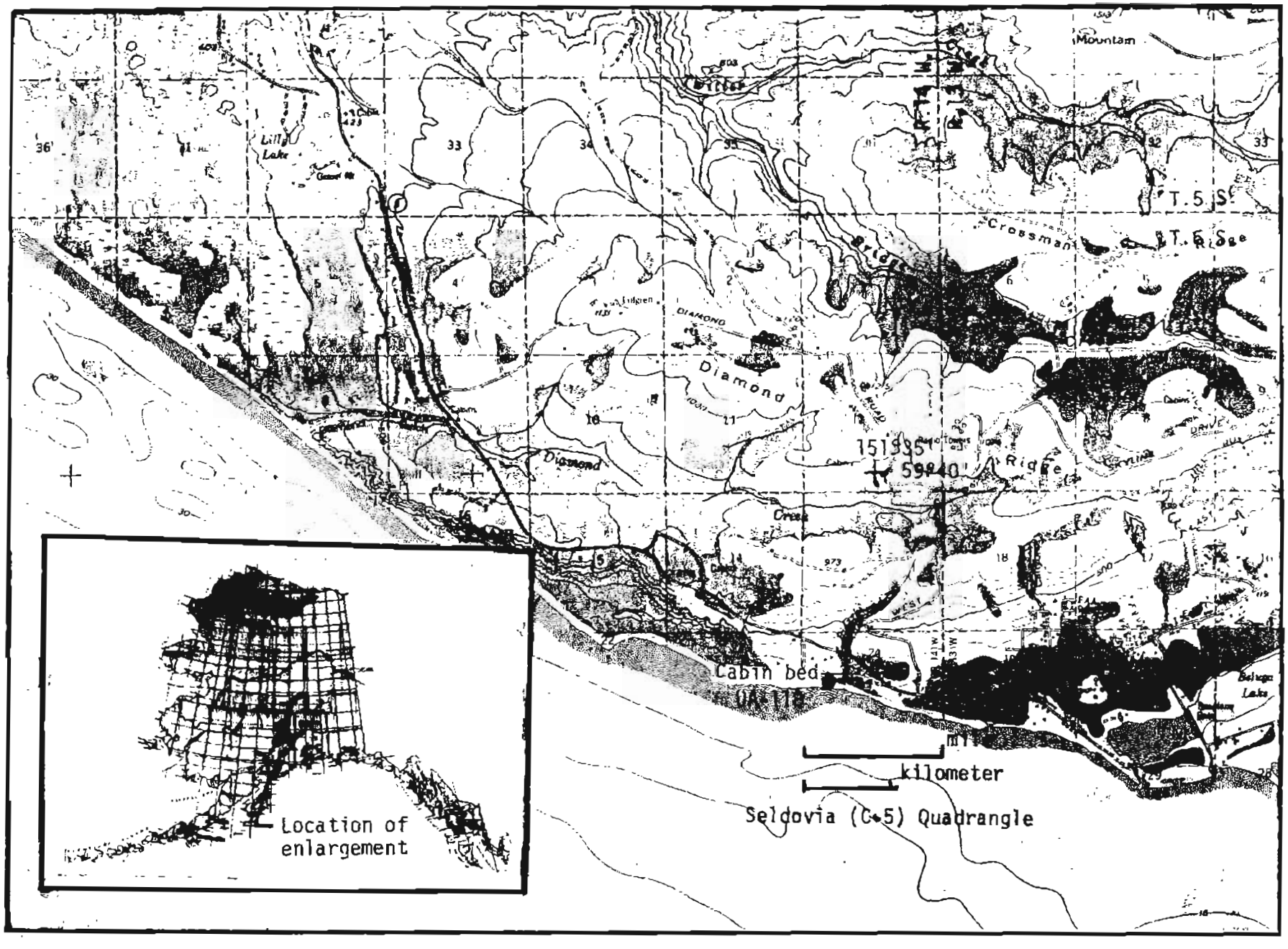

Figure 11: Sampling Location in the Kenai Field

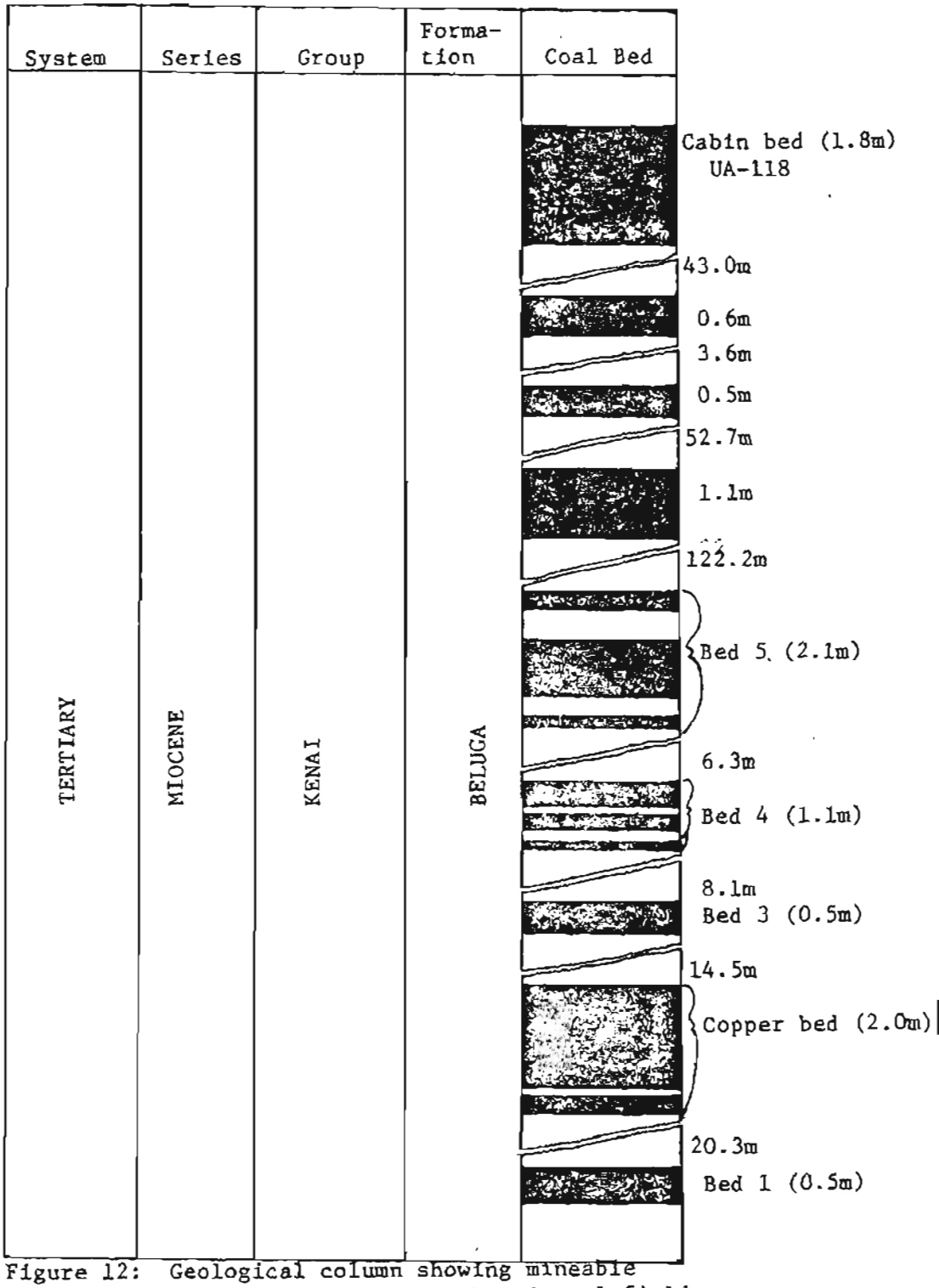

Figure 12: Geological column showing mineable coal beds near Homer, Kenai coal field (Source: Barnes and Cobb, 1959)

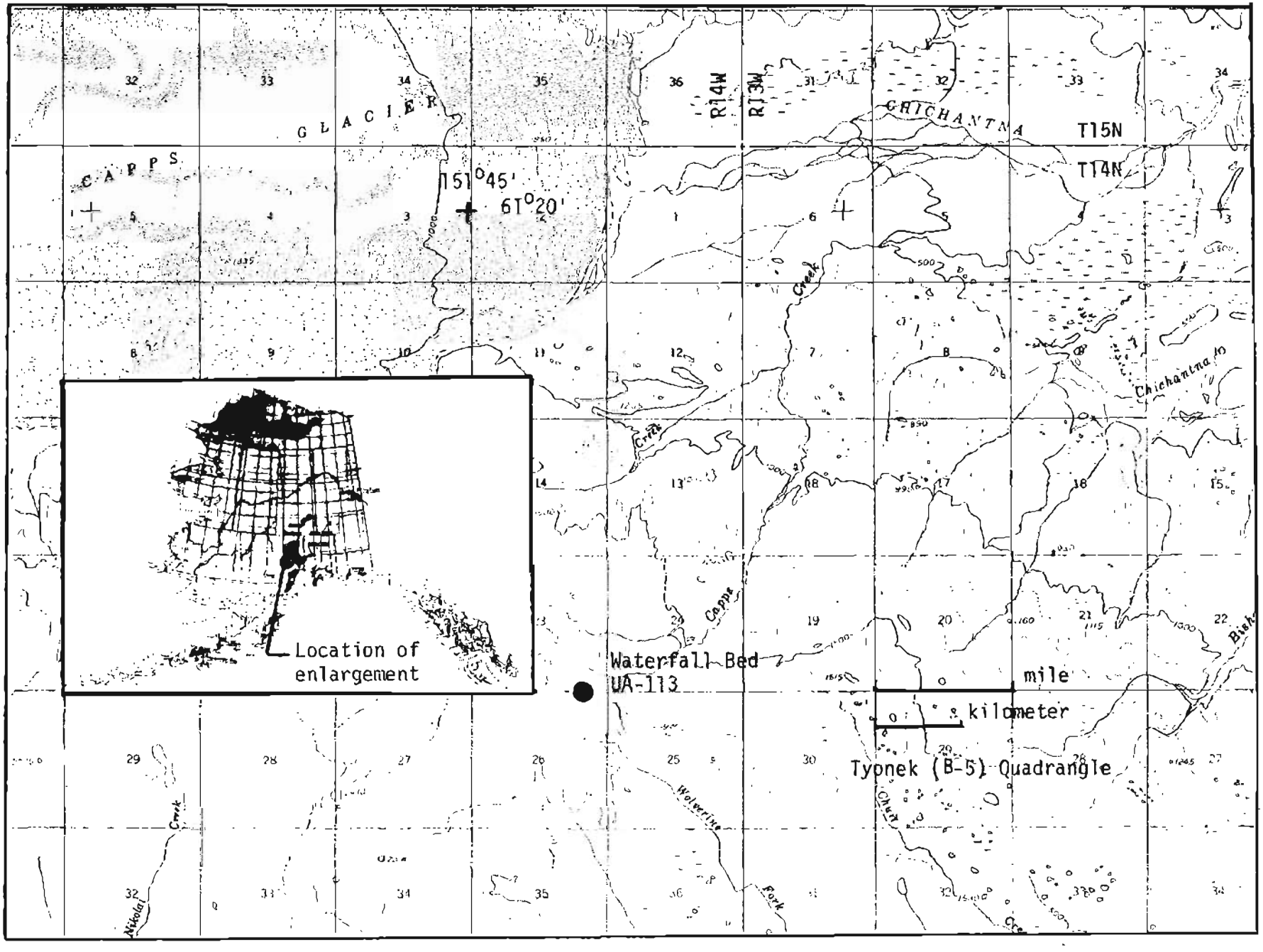

Figure 13: Sampling location in the Beluga Field

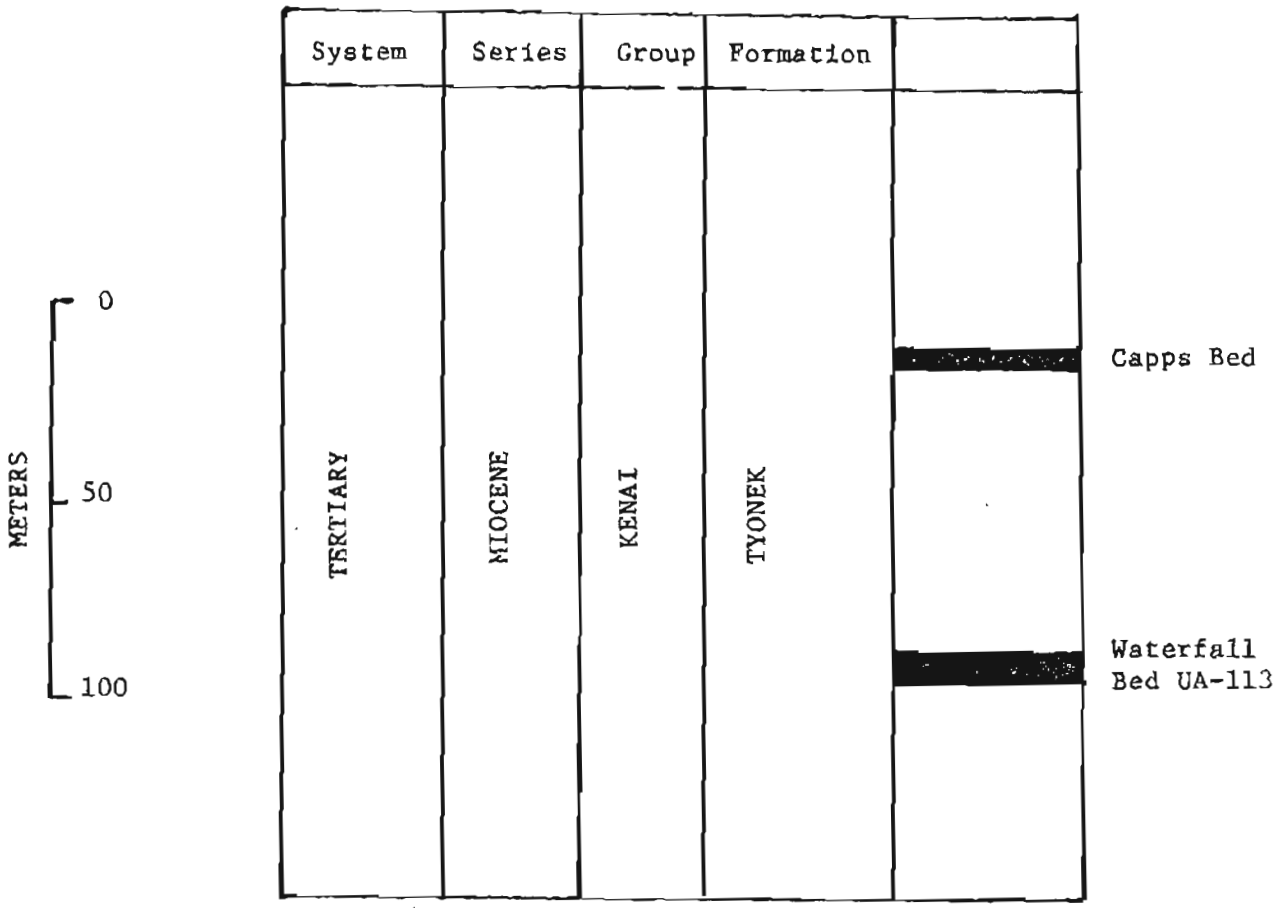

Figure 14: Geological Column showing mineable coal beds in the Capps basin, Beluga Coal field.

The lower part of the Tyonek Formation is well exposed south of the Capps Glacier, and the section is described by Adkison et al. (27). The location is about two miles north of the sample location of UA-113. These beds were designated part of the type section of the Seldovian stage by Wolff, et al. (23).

Yentna Coal Field

There are numerous outcrops of Kenai Group in the northern part of the Beluga-Yentna region. Much of the area is covered by a mantle of Quaternary deposits (8) concludes "outcrops of the Kenai Formation (now Kenai Group), though mostly of small extent, are so widely distributed as to leave little doubt that the formation underlies much of the lowland areas." Occurrences of coal in the Fairview Mountain area was first described by Capps. An outcrop on Chicago Gulch was determined by Wolff, et al. (23) to be Seldovian (figure 10). Of all the coal outcrops in the region, the thickest was Locality 2 (figure 15) described by Barnes (8). This uncorrelated bed is 55 feet thick and has no visible partings. The middle part of the bed was covered with gravel and could not be reached for sampling. A sample (UA-115) was taken of the ten foot section of this uncorrelated bed below the gravel, and the ten foot section of this uncorrelated coal bed above the gravel (UA-116). The sampled outcrop is approximately 23 air miles from Peters Creek and access was via helicopter. Peters Creek is about 25 miles on Peters Creek Road from the Cache Creek Station on the Parks Highway.

Nenana Coal Field

The Nenana coal field is located about 110 miles south of Fairbanks on the Parks Highway at Healy (figure 16). The field extends 80 miles in the east-west direction and is one to thirty miles wide (28)(29)(30). The coal bearing formation consists of sandstones, siltstones, claystone, shale and numerous thick coal beds and is divided into five formations by Wahrhaftig et al. (31). Figure 17 is a generalized geological section showing coal beds exposed at Lower Lignite Creek. A sample of No. 4 bed coal was collected here.

Barnes (2) estimates the original resources of the Nenana field at seven billion tons of which three billion tons are on Lignite Creek. Accurate estimates of recoverable reserves for individual seams are not available. Total measured reserves in the Lignite Creek area are 250 million tons (Denton, personal communication).

LABORATORY PROCEDURES

This investigation closely followed the laboratory procedures described by Cavallaro et al. (32) and described by the authors in Part 1 (1). Figure 18 is a flowsheet of procedures used in the laboratory for processing the samples. Raw coal samples were crushed to 1-1/2 inches, 3/8 inch, and 14 mesh sizes. Minus 100-mesh material was removed from the 1-1/2 inches and 3/8 inch crushed samples, leaving the coarse fraction for float-sink testing in 60 liter containers. Fourteen mesh x 0 samples were separated in glass separatory flasks joined by ground taper joints. Float-sink separations were made at 1.30, 1.40, and 1.60 specific gravities using perchlorethylene-naptha mixtures as heavy liquid. The air dried products were first crushed in a hammer mill to 14-mesh and pulverized to 60-mesh for analysis. Proximate and ultimate analyses of raw coals are presented in Table I. The concentration of major elements and the fusibility of ash are presented in Table II.

All float-sink products were analyzed for ash, moisture, heating value, total sulfur, and pyritic sulfur. All data were calculated on a moisture free basis. American Society for Testing and Materials (ASTM) standard procedures were used for all

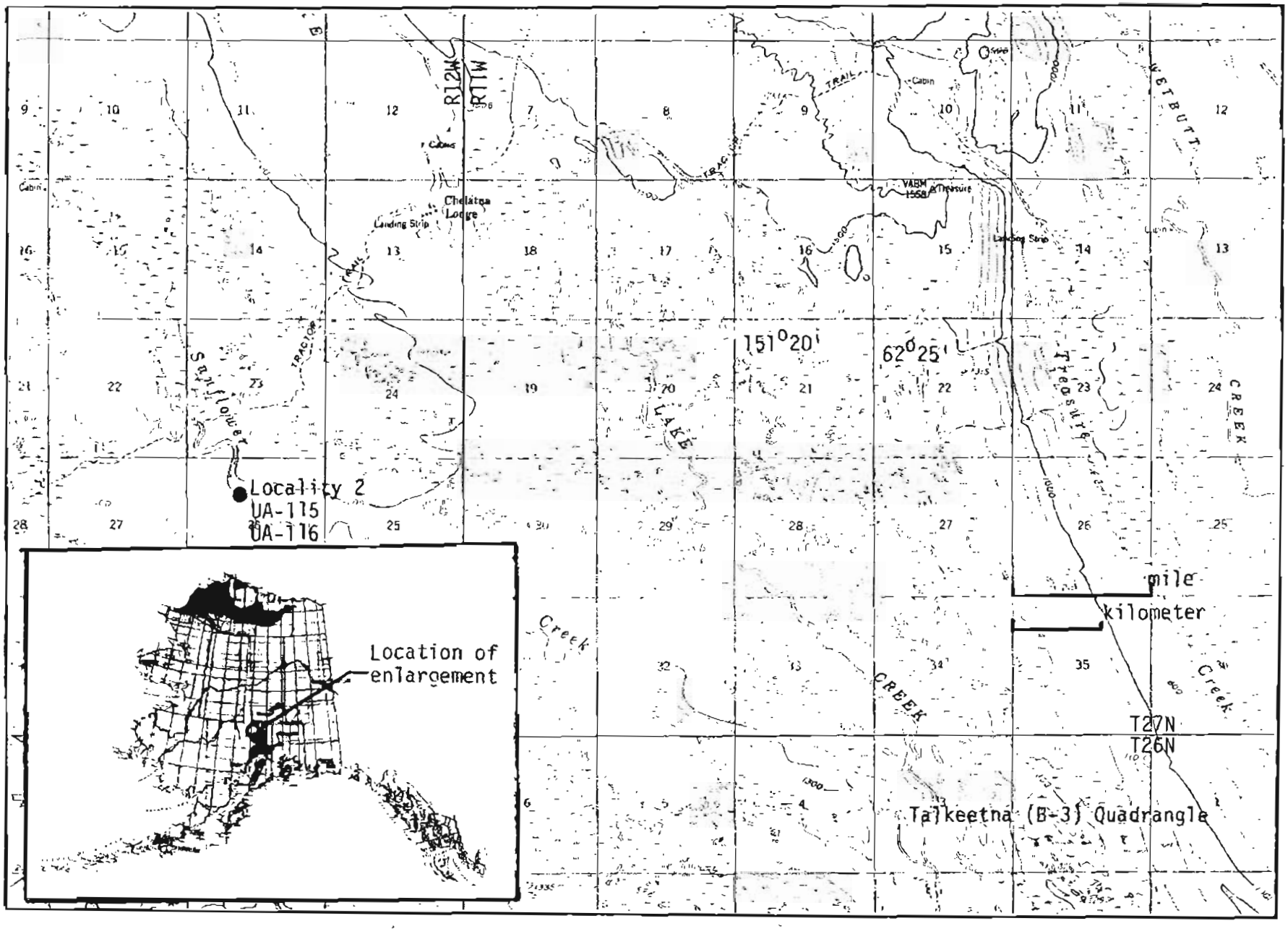

Figure 15: Sampling location in the Yentna Field

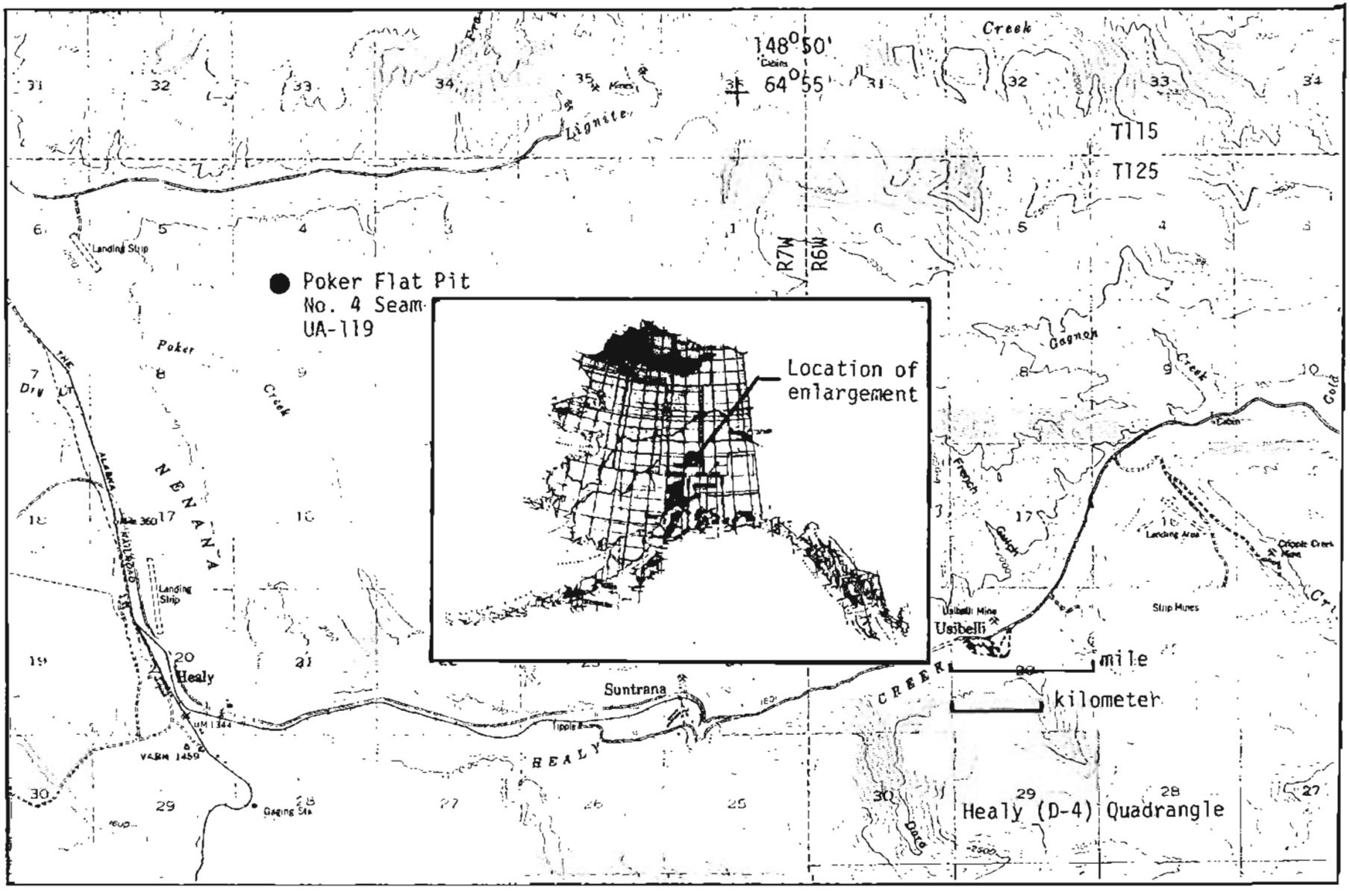

Figure 16: Sampling Location in the Nenana Field

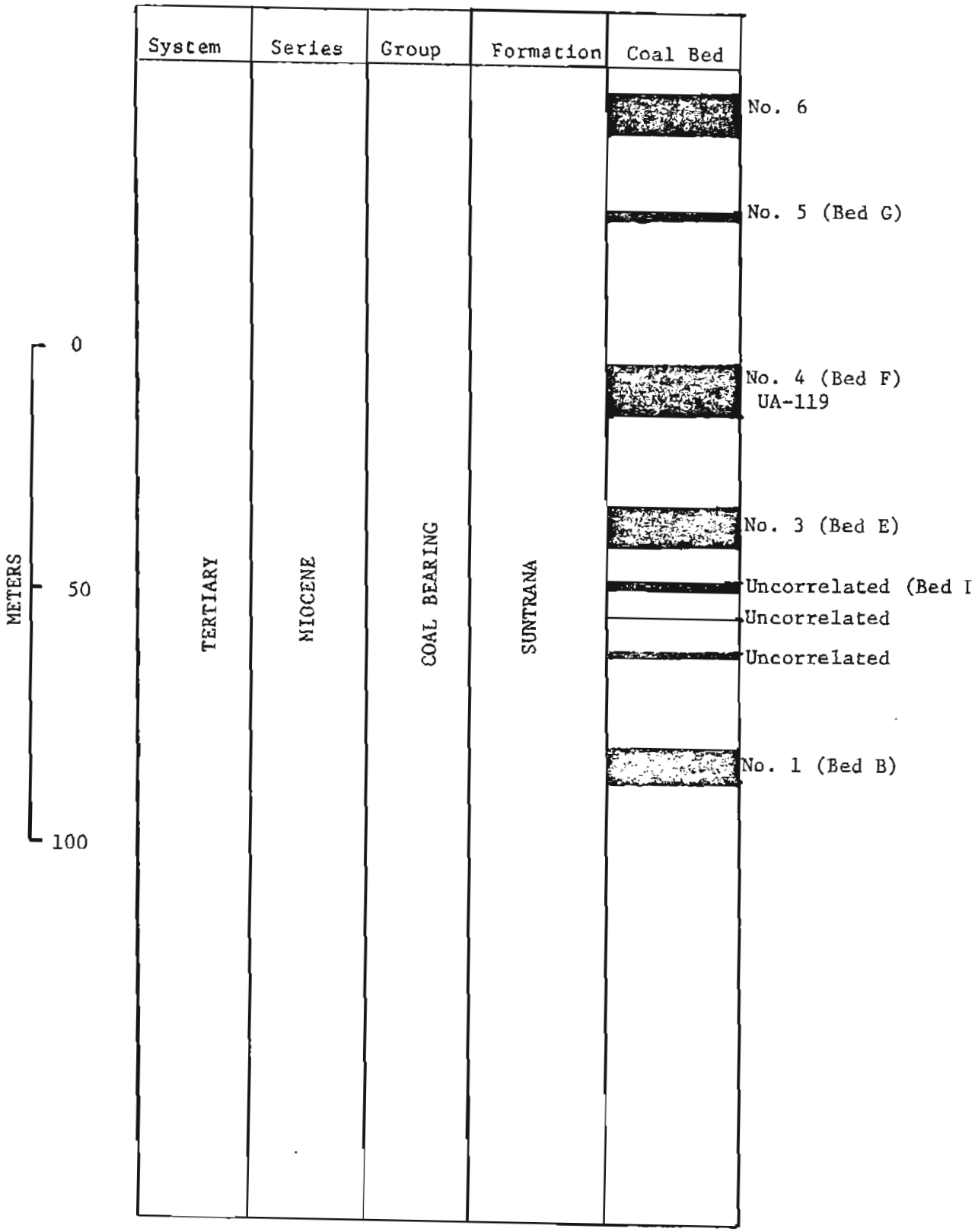

Figure 17: Geological column showing mineable coal beds on Lower Lignite Creek, Nenana coal field.

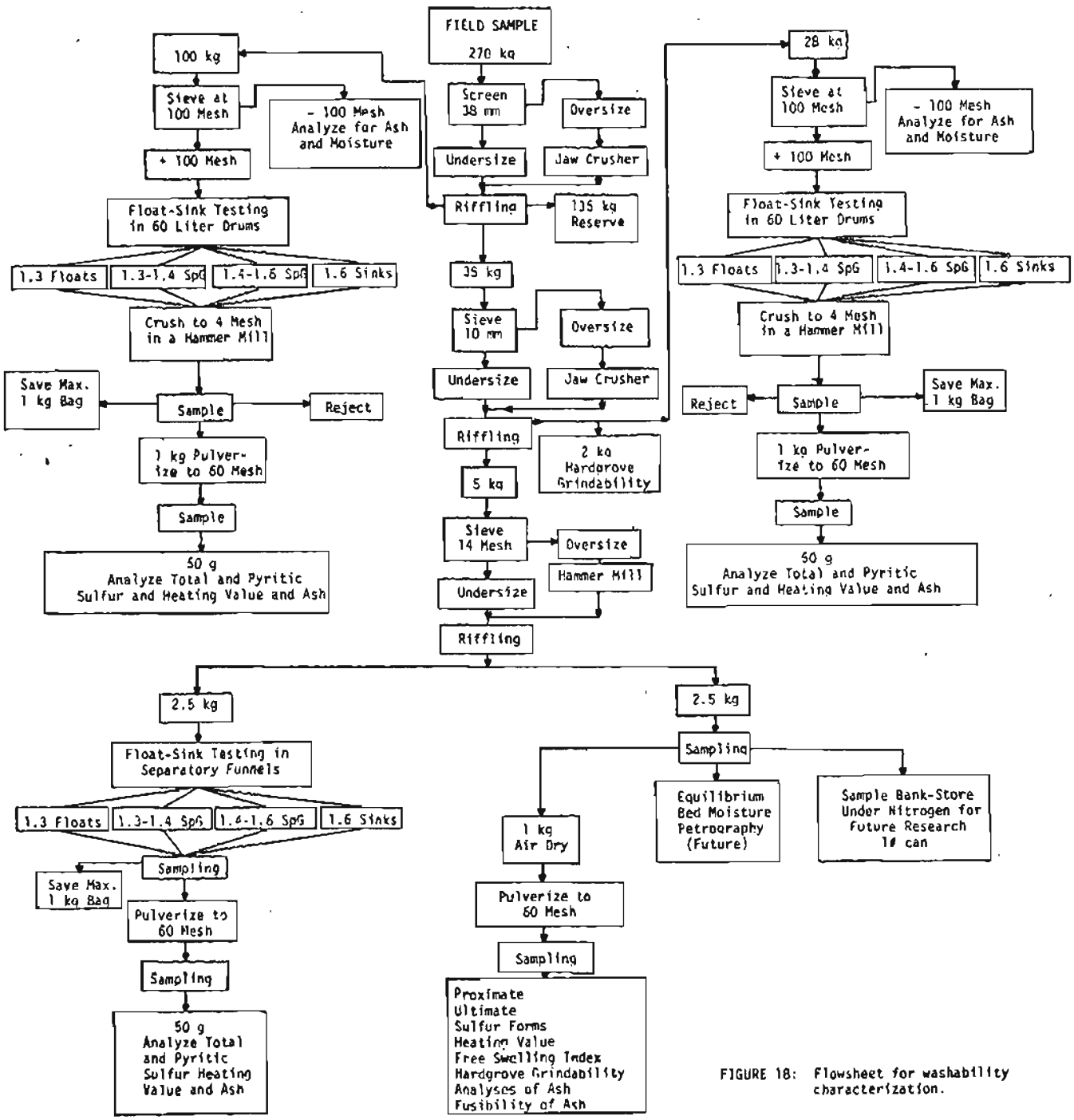

FIGURE 18: Flowsheet for washability characterization.

TABLE I

Proximate and Ultimate Analyses of Raw Coals

Coal Field	ASTM Rank	Thickness Meters (feet)	Sample Numbers	Basis*	Moisture %	Volatile Matter,%	Fixed Carbon,%	Ash %	Heating Value BTU/lb.	C,%	H,%	N,%	O,%	Sulfur Pyritic	Sulfur Total
Northern Alaska Wainwright	Subbit.B	1.5 (5)	UA-109	1	20.28	30.20	44.75	4.77	9292	54.79	5.71	1.13	33.32	0.08	0.28
				2		37.88	56.13	5.99	11655	68.73	4.31	1.42	19.20	0.10	0.35
				3		40.29	59.71		12398	73.10	4.58	1.51	20.43	0.10	0.35
Northern Alaska Meade River	Subbit.B	1.5 (5)	UA-110	1	17.88	30.30	48.22	3.60	10425	60.04	5.87	1.35	28.71	0.06	0.43
				2		36.90	58.72	4.38	12695	73.12	4.72	1.64	15.61	0.07	0.53
				3		38.59	61.41		13277	76.47	4.94	1.71	16.33	0.08	0.55
Broad Pass Coal Creek Seam	Lignite	2.4 (8)	UA-111	1	28.32	33.53	24.08	14.07	6395	38.14	6.06	0.54	41.04	0.03	0.15
				2		46.77	33.60	19.63	8921	53.21	4.04	0.75	22.16	0.04	0.21
				3		58.20	41.80		11100	66.20	5.03	0.93	27.58	0.05	0.26
Little Tonzona Coal bed	Subbit.C.	38.7 (127)	UA-112	1	21.21	37.59	30.36	10.84	7663	45.02	5.80	0.64	36.59	0.06	1.11
				2		47.72	38.53	13.75	9725	57.14	4.34	0.81	22.56	0.08	1.40
				3		55.33	44.67		11277	66.25	5.03	0.94	26.15	0.09	1.63
Beluga Waterfall Seam	Subbit.C.	9.1 (30)	UA-113	1	23.65	35.20	33.34	7.81	8327	47.98	6.25	0.54	37.28	0.01	0.14
				2		46.10	43.67	10.23	10907	62.84	4.71	0.71	21.33	0.01	0.18
				3		51.35	48.65		12151	70.01	5.25	0.79	23.74	0.01	0.21
Northern Alaska Sagwon Bluffs	hv Cb	2.0 (6.5)	UA-114	1	14.71	15.74	15.65	53.90	3591	20.98	3.37	0.53	21.16	0.04	0.06
				2		18.45	18.36	63.19	4210	24.60	2.02	0.62	9.50	0.05	0.07
				3		50.13	49.87		11439	66.83	5.49	1.67	25.81	0.14	0.20
Yentna Locality 2 Lower	Lignite	3.0 (10)	UA-115	1	29.80	38.26	28.61	3.33	7943	45.20	6.76	0.53	44.07	0.01	0.11
				2		54.50	40.76	4.74	11315	64.39	4.87	0.75	25.10	0.01	0.15
				3		57.21	42.79		11879	67.59	5.11	0.79	26.35	0.01	0.16
Yentna Locality 2 Upper	Lignite	3.0 (10)	UA-116	1	29.86	39.29	28.43	2.42	8017	45.48	6.89	0.49	44.67	0.01	0.05
				2		56.02	40.54	3.44	11429	64.84	5.06	0.70	25.89	0.01	0.07
				3		58.02	41.98		11837	67.16	5.24	0.73	26.79	0.01	0.08
Tramway Bar	hv B	4.0 (13)	UA-117	1	6.38	24.29	33.54	35.79	7263	42.72	3.62	0.55	17.18	0.04	0.14
				2		25.94	35.83	38.23	7758	45.64	3.10	0.59	12.29	0.04	0.15
				3		41.99	58.01		12559	73.88	5.02	0.95	19.90	0.07	0.23
Kenai Cabin Bed	Subbit.C	1.8 (6)	UA-118	1	23.01	35.63	32.71	8.65	8028	47.23	6.07	0.62	37.20	0.01	0.23
				2		46.28	42.49	11.23	10428	61.35	4.54	0.81	21.77	0.01	0.30
				3		52.13	47.87		11747	69.11	5.11	0.91	24.53	0.01	0.34
Nenana Poker Flat Pit No. 4 Seam	Subbit.C.	7.3 (24)	UA-119	1	25.29	32.51	32.55	9.85	7779	45.28	6.30	1.13	37.11	0.02	0.33
				2		43.52	43.30	13.18	10412	60.61	4.64	1.51	19.62	0.02	0.44
				3		50.13	49.87		11993	69.81	5.34	1.74	22.60	0.03	0.51

* 1 is Equilibrium bed moisture basis
2 is Moisture-free basis
3 is Moisture-ash-free basis

TABLE II

Concentration of Major Elements and Fusibility of Ash of the Raw Coal Samples

Concentration of Major Elements in Coal Ash, percent

Sample No.	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	SO_3	MnO
UA-109	41.7	5.9	18.8	13.0	13.2	2.16	1.0	0.1	13.1	0.29
UA-110	43.8	23.3	6.1	3.3	4.4	.97	1.8	1.3	2.1	0.06
UA-111	45.4	29.3	4.6	1.1	9.1	.16	2.1	1.2	3.2	0.17
UA-112	39.8	19.4	6.9	3.3	22.7	.27	1.2	0.9	17.2	0.05
UA-113	41.0	28.9	6.7	1.9	16.6	.09	2.1	0.8	7.9	0.10
UA-114	66.5	20.1	3.9	2.2	1.8	.16	3.5	1.3	.7	0.04
UA-115	16.8	33.3	9.5	6.3	28.0	.07	1.0	1.1	9.1	0.12
UA-116	11.6	27.9	10.6	7.4	37.2	.08	0.6	0.8	10.5	0.13
UA-117	52.8	30.8	5.1	1.4	2.3	.51	4.0	1.7	.9	0.05
UA-118	37.4	21.0	5.7	3.6	25.3	.08	1.3	0.9	6.2	0.11
UA-119	43.4	22.7	6.7	2.7	16.6	1.08	2.2	1.1	6.5	0.21

Fusibility of Ash, °F

Sample No.	Initial Deformation	Softening	Fluid
UA-109	2540	2590	2630
UA-110	2500	2540	2580
UA-111	2300	2350	2440
UA-112	2060	2090	2120
UA-113	2400	2450	2500
UA-114	2670	2730	2840
UA-115	2520	2550	2580
UA-116	2140	2170	2200
UA-117	2680	2730	2840
UA-118	2090	2120	2150
UA-119	2130	2180	2380

analyses except for a slight modification made in the procedure for the determination of pyritic sulfur. In the modified procedure, 1 g. of coal sample was digested with 50 ml. of 2:3 HCl for 30 minutes in a 250 ml. flask connected to a water cooled condenser. The contents were cooled, filtered, and washed. The filter paper with the residue was inserted back into the flask and digested again with 50 ml. of 1:7 HNO_3 for 30 minutes. The contents were again filtered and washed. The filtrate was made up to 200 ml. and the Fe content in the solution was determined using a Perkin-Elmer 303 atomic absorption spectrophotometer. Pyritic sulfur is calculated assuming that the determined iron is entirely from pyrite (FeS_2).

The Hardgrove Grindability Indexes of the samples were determined with air dried samples as per ASTM designation D409-71 using standards HGI 28, HGI 41, HGI 54, HGI 80, and HGI 92, supplied by ASTM. For subbituminous coals, grindability of the samples was also determined in "as received" condition with minimum loss of bed-moisture as this would be of more practical significance. Table III shows the Free Swelling Indexes and shows all the coals were nonfriable with HGI's ranging from 23 to 58. It is felt that sample UA-117 should have shown some swelling properties; however, since the sample was collected at the outcrop it was probably weathered, thus reducing its caking characteristics.

INTERPRETATION OF WASHABILITY DATA

Tables IV through XIV show washability data for the nine samples processed. The tables show weight-percent distribution, ash, heating value, pyritic sulfur, and total sulfur on a moisture free basis for the various gravimetric fractions as well as values for cumulated floats. The quality of the float at any of the three densities can be directly read from the tables. The tables also show cumulative sink weight-percent and ash content that may be expected at any of the three densities.

Northern Alaska Coal Field

Coal beds near Wainwright have been known since 1889 (19) and have been mined on a small scale. The mined coal is stored in sacks and transported by boat during summer and overland during winter for local use. Although several hundred tons have been mined in the past, current extraction rate is only a few tons a year. There has been increased interest in these coals for possible use in power generation at Wainwright.

This uncorrelated coal bed sample (UA-109) is subbituminous "B" rank and is five feet thick. The bottom of the bed was about four feet above the Kuk River level in August at the time of sampling. The raw coal sample contained 6.0 percent ash and 0.35 percent total sulfur. This coal was of low ash and low sulfur content as mined, however, crushing to 14 mesh top size and removing the sink 1.60 specific gravity material would provide a product analyzing 2.8 percent ash and 12,167 Btu/lb at a yield of 94.2 percent (Table IV).

The No. 2 bed coal sample (UA-110) contained 4.4 percent ash and 0.52 percent total sulfur. Washing 1-1/2 inches x 100 mesh coal at 1.30 specific gravity can give a product with 2.3 percent ash, 0.46 percent total sulfur and 13,155 Btu/lb heating value with 78.4 percent yield. Washing at 1.40 specific gravity can give 96.9 percent yield with 4.1 percent ash. Washing 14 mesh x 0 coal at 1.40 specific gravity will give 90.4 percent yield with 2.2 percent ash (Table V).

Sagwon Bluffs was sampled to obtain a representative sample of low rank coal in the western rock of the Northern Alaska field. The bed is readily accessible from the Trans Alaska Pipeline Haul Road. Table I shows this uncorrelated coal bed sample

TABLE III

Hardgrove Grindability and Free Swelling Indexes of Raw Coals

Sample Number	Air dried samples	
	HGI	FSI
UA-109	54	0
UA-110	58	0
UA-111	49	0
UA-112	28	0
UA-113	23	0
UA-115	35	0
UA-116	32	0
UA-117	45	0
UA-118	23	0
UA-119	27	0

TABLE IV

Washability Analyses of an Uncorrelated Bed Coal Sample (UA-109)
Northern Alaska Field, Wainwright, Alaska

Raw Coal Bed Moisture = 20.28

SPECIFIC GRAVITY		ACTUAL PRODUCTS					CUMULATIVE FLOAT					CUMULATIVE SINK	
					Sulfur percent					Sulfur percent			
Sink	Float	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %
Float-Sink Size 1 1/2 inches x 100 Mesh													
	1.30	65.33	2.50	12516	0.04	0.24	65.33	2.50	12516	0.04	0.24	100.00	6.21
1.30	1.40	26.44	5.99	11649	0.08	0.32	91.77	3.51	12266	0.05	0.26	34.67	13.19
1.40	1.60	2.90	17.61	9473	0.27	0.39	94.67	3.94	12181	0.06	0.27	8.23	36.33
1.60		5.33	46.51	4039	0.47	0.57	100.00	6.21	11747	0.08	0.28	5.33	46.51
Minus 100 Mesh		0.93	14.50	10738	0.36	1.18	[1]100.00	6.29	11737	0.08	0.29		
Float-Sink Size 3/8 inch x 100 Mesh													
	1.30	63.60	2.08	12480	0.01	0.31	63.60	2.08	12480	0.01	0.31	100.00	5.84
1.30	1.40	27.51	4.06	11860	0.04	0.32	91.11	2.68	12293	0.02	0.31	36.40	12.41
1.40	1.60	3.49	14.19	10206	0.18	0.29	94.60	3.10	12216	0.02	0.31	8.89	38.23
1.60		5.40	53.77	2767	0.69	0.73	100.00	5.84	11706	0.06	0.33	5.40	53.77
Minus 100 Mesh		5.60	7.86	11667	0.15	0.56	[1]100.00	5.95	11704	0.06	0.34		
Float-Sink Size 14 Mesh x 0													
	1.30	18.65	2.38	12353	0.03	0.25	18.65	2.38	12353	0.03	0.25	100.00	5.98
1.30	1.40	67.65	2.50	12200	0.02	0.32	86.30	2.47	12233	0.02	0.30	81.35	6.81
1.40	1.60	7.85	6.37	11446	0.11	0.31	94.15	2.80	12167	0.03	0.31	13.70	28.08
1.60		5.85	57.22	2376	0.73	0.80	100.00	5.98	11595	0.07	0.33	5.85	57.22

All results are on a Moisture Free Basis.

[1]Cumulative float-sink plus minus 100 mesh material.

TABLE V

Washability Analyses of the No. 2 Bed Coal Sample (UA-110)
Northern Alaska Field, Meade River, Alaska

Raw Coal Bed Moisture = 17.88

SPECIFIC GRAVITY		ACTUAL PRODUCTS					CUMULATIVE FLOAT					CUMULATIVE SINK	
					Sulfur percent					Sulfur percent			
Sink	Float	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %
Float-Sink Size 1 1/2 inches x 100 Mesh													
	1.30	78.44	2.27	13155	0.03	0.46	78.44	2.27	13155	0.03	0.46	100.00	4.91
1.30	1.40	18.49	11.75	11681	0.03	0.51	96.93	4.08	12874	0.03	0.47	21.56	14.53
1.40	1.60	2.81	28.90	9136	0.03	0.40	99.74	4.78	12769	0.03	0.47	3.07	31.25
1.60		0.26	56.66	4826	0.07	0.28	100.00	4.91	12748	0.03	0.47	0.26	56.66
Minus 100 Mesh		1.46	37.81	7604	0.79	1.40	[1]100.00	5.38	12674	0.04	0.48		
Float-Sink Size 3/8 inch x 100 Mesh													
	1.30	74.89	2.06	13194	0.02	0.48	74.89	2.06	13194	0.02	0.48	99.00	5.01
1.30	1.40	19.24	9.43	12161	0.05	0.55	94.13	3.57	12983	0.03	0.49	24.11	14.16
1.40	1.60	3.92	27.16	9642	0.05	0.43	98.05	4.51	12849	0.03	0.49	4.87	32.83
1.60		0.95	56.25	4952	0.10	0.28	100.00	5.01	12774	0.03	0.49	0.95	56.25
Minus 100 Mesh		5.26	16.25	10882	0.38	0.86	[1]100.00	5.57	12679	0.05	0.51		
Float-Sink Size 14 Mesh x 0													
	1.30	62.98	2.02	13587	0.02	0.36	62.98	2.02	13587	0.02	0.36	100.00	4.56
1.30	1.40	26.38	2.46	13364	0.02	0.34	89.36	2.15	13521	0.02	0.35	37.02	8.89
1.40	1.60	7.64	11.90	11503	0.08	0.46	97.00	2.92	13362	0.02	0.36	10.64	24.83
1.60		3.00	57.77	2201	1.50	1.70	100.00	4.56	13027	0.07	0.40	3.00	57.77

All results are on a Moisture Free Basis.

[1]Cumulative float-sink plus minus 100 mesh material.

(UA-114) contained 63.2 percent ash, less than 0.1 percent total sulfur and 4,210 Btu/lb. Washing the 3/8 inch top size coal sample at 1.60 specific gravity would reduce the ash to 14.8 percent, upgrade the calorific value to 10,139 Btu/lb, however, the yield would only be 22.8 percent (Table VI).

Broad Pass Coal Field

Coal was mined in the Coal Creek basin during 1920 to 1921 by Coal Creek Mine. A 2-1/2 mile wagon road was used for transportation to Broad Pass station and was sold to the Alaska Railroad Co. during its construction (12). Completion of the construction marked the end of mining due to lack of other markets. This was a sample of Coal Creek bed coal (UA-111) and is lignite in rank. The raw coal has 19.6 percent ash and washing 1-1/2 inches x 100 mesh coal at 1.40 specific gravity will give a product containing 11.4 percent ash, 9,939 Btu/lb heating value and 0.22 percent total sulfur, with 82.2 percent yield on a moisture free basis (Table VII).

Little Tonzona Coal Field

The raw coal was a sample of the Tonzona coal bed (UA-112) and has 13.8 percent ash and 1.40 percent of sulfur. The sulfur is usually high for Alaskan coals. The only other seam of those studied that had a sulfur content more than 1 percent was the mine seam in the Jarvis Creek field (UA-106) (1). Pyritic sulfur in the Little Tonzona coal bed is low and washing will not reduce the sulfur content of the product. Washing the 1-1/2 inches x 100 mesh coal at 1.40 specific gravity will give 83.4 percent yield with 8.9 percent ash and 10,539 Btu/lb heating value on a moisture free basis. Separation at 1.60 specific gravity, however, will increase the yield to 96.7 percent with ash content reduced to only 11 percent. Crushing to 3/8 inch and 14 mesh top size did not result in significant additional liberation of impurities (Table VIII).

Tramway Bar Area

Coal at the Tramway Bar occurrence has been used locally by gold miners on a very small scale. The uncorrelated coal bed sample (UA-117) has several thin refuse bands that contribute to the 38.2 percent ash contained in the raw coal. The raw coal has low total sulfur, 0.15 percent and very low pyritic sulfur. Washing the 1-1/2 inches x 100 mesh material at 1.60 specific gravity will give a product with 11.5 percent ash and 0.27 percent total sulfur and 11,523 Btu/lb heating value at a yield of 46.8 percent (Table IX). Further crushing would be of little benefit in the additional liberation of impurities.

COOK INLET SEDIMENTARY BASIN

Beluga Coal Field

The Waterfall bed has been well drilled and delineated by the lease holder, Beluga Coal Company. The sample (UA-113) collected represents the lower 30 feet of the seam. The top six feet is very dirty and is not included in this sample and it is suggested that separate washability studies be made on this portion. The raw coal is quite low in ash, and sulfur 10.2 percent and 0.18 percent, respectively, on a moisture free basis. Washing 1-1/2 inches x 100 mesh coal at 1.40 specific gravity gave a product with 7.2 percent ash, 0.20 percent total sulfur, and 11,222 Btu/lb at

TABLE VI

Washability Analyses of an Uncorrelated Bed Coal Sample (UA-114)
Northern Alaska Field, Sagwon Bluffs, Alaska

Raw Coal Bed Moisture = 14.71

SPECIFIC GRAVITY		ACTUAL PRODUCTS					CUMULATIVE FLOAT					CUMULATIVE SINK	
					Sulfur percent					Sulfur percent			
Sink	Float	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %
Float-Sink Size 1 1/2 inches x 100 Mesh													
	1.30	0.17	6.51	14088	0.01	0.14	0.17	6.51	14088	0.01	0.14	100.00	58.96
1.30	1.40	14.57	9.70	11305	0.01	0.16	14.74	9.70	11337	0.01	0.16	99.83	59.04
1.40	1.60	11.76	29.00	8393	0.01	0.16	26.50	16.49	10031	0.01	0.16	85.26	68.03
1.60		73.50	74.27	2449	0.03	0.07	100.00	58.96	4458	0.02	0.09	73.50	74.27
Minus 100 Mesh		2.45	70.03	2716	0.05	0.09	[1]100.00	59.22	4416	0.02	0.09		
Float-Sink Size 3/8 inch x 100 Mesh													
	1.30	0.12	6.60	14170	0.01	0.12	0.12	6.60	14170	0.01	0.12	100.00	61.05
1.30	1.40	13.28	8.88	11182	0.01	0.12	13.40	8.88	11209	0.01	0.12	99.88	61.11
1.40	1.60	9.35	26.43	8605	0.01	0.11	22.75	14.75	10139	0.01	0.12	89.60	69.47
1.60		77.25	74.68	2384	0.02	0.06	100.00	61.05	4148	0.02	0.07	77.25	74.68
Minus 100 Mesh		4.33	68.46	2627	0.03	0.09	[1]100.00	61.36	4085	0.02	0.07		
Float-Sink Size 14 Mesh x 0													
	1.30	0.10	7.52	11273	0.02	0.25	0.10	7.52	11273	0.02	0.25	100.00	59.87
1.30	1.40	11.74	10.88	11094	0.02	0.16	11.84	10.88	11096	0.02	0.16	99.90	59.92
1.40	1.60	10.27	18.26	9599	0.02	0.14	22.11	12.51	10400	0.02	0.15	88.16	66.89
1.60		77.89	73.31	2513	0.03	0.06	100.00	59.87	4257	0.03	0.08	77.89	73.31

All results are on a Moisture Free Basis.

[1]Cumulative float-sink plus minus 100 mesh material.

TABLE VII

Washability Analyses of the Coal Creek Bed Coal Sample (UA-111)
Broad Pass Field, Broad Pass Station, Alaska

Raw Coal Bed Moisture = 28.32

SPECIFIC GRAVITY		ACTUAL PRODUCTS					CUMULATIVE FLOAT					CUMULATIVE SINK	
					Sulfur percent					Sulfur percent			
Sink	Float	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %
Float-Sink Size 1 1/2 inches x 100 Mesh													
	1.30	34.67	4.18	11172	0.01	0.21	34.67	4.18	11172	0.01	0.21	100.00	17.85
1.30	1.40	47.58	16.74	9040	0.02	0.22	82.25	11.45	9939	0.02	0.22	65.33	25.10
1.40	1.60	10.62	35.45	6716	0.03	0.13	92.87	14.19	9570	0.02	0.21	17.75	47.51
1.60		7.13	65.47	3198	0.05	0.08	100.00	17.85	9116	0.02	0.20	7.13	65.47
Minus 100 Mesh		1.89	36.89	6571	0.01	0.10	[1]100.00	18.20	9069	0.02	0.20		
Float-Sink Size 3/8 inch x 100 Mesh													
	1.30	31.26	4.15	11389	0.01	0.20	31.26	4.15	11389	0.01	0.20	100.00	17.52
1.30	1.40	47.48	14.83	9402	0.04	0.30	78.74	10.59	10191	0.03	0.26	68.74	23.60
1.40	1.60	13.15	31.18	7226	0.04	0.11	91.89	13.54	9767	0.03	0.24	21.26	43.18
1.60		8.11	62.64	3512	0.05	0.10	100.00	17.52	9259	0.03	0.23	8.11	62.64
Minus 100 Mesh		6.58	33.66	7029	0.01	0.19	[1]100.00	18.52	9121	0.03	0.23		
Float-Sink Size 14 Mesh x 0													
	1.30	27.98	2.62	11530	0.01	0.18	27.98	2.62	11530	0.01	0.18	100.00	16.83
1.30	1.40	51.29	14.70	9435	0.01	0.19	79.27	10.44	10174	0.01	0.19	72.02	22.35
1.40	1.60	12.38	29.67	7307	0.01	0.15	91.65	13.03	9787	0.01	0.18	20.73	41.26
1.60		8.35	58.45	3768	0.04	0.12	100.00	16.83	9285	0.01	0.18	8.35	58.45

All results are on a Moisture Free Basis

[1]Cumulative float-sink plus minus 100 mesh material.

TABLE VIII

Washability Analyses of the Little Tonzona Bed Coal Sample (UA-112)
Little Tonzona Field, Farewell, Alaska

Raw Coal Bed Moisture = 21.21

SPECIFIC GRAVITY		ACTUAL PRODUCTS					CUMULATIVE FLOAT					CUMULATIVE SINK	
					Sulfur percent					Sulfur percent			
Sink	Float	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %
Float-Sink Size 1 1/2 inches x 100 Mesh													
	1.30	3.64	5.34	11681	0.03	1.33	3.64	5.34	11681	0.03	1.33	100.00	13.55
1.30	1.40	79.76	9.02	10487	0.06	1.40	83.40	8.86	10539	0.06	1.40	96.36	13.86
1.40	1.60	12.32	26.37	8251	0.05	1.24	95.72	11.11	10245	0.06	1.38	16.60	37.09
1.60		4.28	67.96	2908	0.06	0.67	100.00	13.55	9931	0.06	1.35	4.28	67.96
Minus 100 Mesh		0.96	52.27	5108	0.08	1.07	[1]100.00	13.92	9885	0.06	1.35		
Float-Sink Size 3/8 inch x 100 Mesh													
	1.30	5.33	4.63	11618	0.02	1.46	5.33	4.63	11618	0.02	1.46	100.00	13.81
1.30	1.40	74.54	9.26	10266	0.06	1.64	79.87	8.95	10356	0.06	1.63	94.67	14.33
1.40	1.60	15.42	22.15	8520	0.06	1.41	95.29	11.09	10059	0.06	1.59	20.13	33.09
1.60		4.71	68.89	2688	0.11	0.62	100.00	13.81	9712	0.06	1.55	4.71	68.89
Minus 100 Mesh		4.10	44.41	6071	0.08	0.97	[1]100.00	15.00	9568	0.06	1.53		
Float-Sink Size 14 Mesh x 0													
	1.30	0.42	8.71	10755	0.02	1.34	0.42	8.71	10755	0.02	1.34	100.00	14.09
1.30	1.40	74.52	9.87	10429	0.05	1.41	74.94	9.87	10431	0.05	1.41	99.58	14.11
1.40	1.60	18.49	19.12	8862	0.06	1.38	93.43	10.78	10120	0.05	1.40	25.06	30.17
1.60		6.57	61.25	3762	0.10	1.00	100.00	14.09	9703	0.06	1.38	6.57	61.25

All results are on a Moisture Free Basis.

[1]Cumulative float-sink plus minus 100 mesh material.

TABLE IX

Washability Analyses of an Uncorrelated Bed Coal Sample (UA-117)
Tramway Bar Field, Wiseman, Alaska

Raw Coal Bed Moisture = 6.38

SPECIFIC GRAVITY		ACTUAL PRODUCTS					CUMULATIVE FLOAT					CUMULATIVE SINK	
					Sulfur percent					Sulfur percent			
Sink	Float	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %
Float-Sink Size 1 1/2 inches x 100 Mesh													
	1.30	0.03	4.57	12093	0.02	0.20	0.03	4.57	12093	0.02	0.20	100.00	40.67
1.30	1.40	22.12	6.25	12183	0.02	0.29	22.15	6.25	12183	0.02	0.29	99.97	40.68
1.40	1.60	24.63	16.19	10930	0.02	0.26	46.78	11.48	11523	0.02	0.27	77.85	50.47
1.60		53.22	66.33	3483	0.07	0.08	100.00	40.67	7244	0.05	0.17	53.22	66.33
Minus 100 Mesh		0.85	56.75	4963	0.06	0.10	[1]100.00	40.80	7225	0.05	0.17		
Float-Sink Size 3/8 inch x 100 Mesh													
	1.30	0.07	3.56	11995	0.01	0.26	0.07	3.56	11995	0.01	0.26	100.00	39.05
1.30	1.40	23.94	5.65	12610	0.01	0.29	24.01	5.64	12608	0.01	0.29	99.93	39.07
1.40	1.60	23.42	13.76	11393	0.01	0.12	47.43	9.65	12008	0.01	0.21	75.99	49.60
1.60		52.57	65.57	3693	0.02	0.08	100.00	39.05	7637	0.02	0.14	52.57	65.57
Minus 100 Mesh		2.52	55.43	5197	0.04	0.09	[1]100.00	39.13	7577	0.02	0.14		
Float-Sink Size 14 Mesh x 0													
	1.30	0.13	3.75	12050	0.02	0.20	0.13	3.75	12050	0.02	0.20	100.00	38.63
1.30	1.40	24.22	5.35	12570	0.01	0.32	24.35	5.34	12567	0.01	0.32	99.87	38.68
1.40	1.60	27.68	17.43	10867	0.05	0.21	52.03	11.77	11663	0.03	0.26	75.65	49.34
1.60		47.97	67.76	3208	0.06	0.06	100.00	38.63	7607	0.05	0.16	47.97	67.76

All results are on a Moisture Free Basis

[1]Cumulative float-sink plus minus 100 mesh material.

a yield of 92.7 percent. Crushing to 3/8 inch and 14 mesh top size followed by float-sink testing did not show any further improvement in the quality of the product (Table X).

Yentna Coal Field

The Uncorrelated bed coal outcrop at Locality 2 (Barnes) was sampled in two sections, the lower ten feet (UA-115) and the upper ten feet (UA-116). The total bed is 67 feet thick. The coal has no visible bands of shale and is uniform in appearance. The ash and sulfur in both of the samples is very low. Table XI shows washability analysis for (UA-115), the lower 10 feet of the seam, which is quite clean containing 4.7 percent ash and 0.15 percent total sulfur. The upper 10 feet of the bed (UA-116) is better coal than (UA-115) containing 3.6 percent ash and 0.11 percent total sulfur (Table XII). Cleaning of these coals would be of minimal benefit.

Table XIII shows combined washability data for (UA-115) and (UA-116) and represents 30 percent of the total bed. It appears that the unsampled portion of the seam is equally good. With such low ash and low sulfur these seams could prove to be some of the most environmentally acceptable coal in the nation.

Kenai Coal Field

The Cabin Bed sample (UA-118) is one of the numerous beds exposed on the beach cliffs near Homer and was mined on a small scale. The bed does not have any visible refuse bands at the sample location. Raw coal has 11.2 percent ash and 0.30 percent total sulfur on a moisture free basis. The coal has only traces of pyritic sulfur. Washing the 1-1/2 inches x 100 mesh material at 1.40 specific gravity gave a product analyzing 8.5 percent ash and 0.43 percent total sulfur with a yield of 89.3 percent. Washing 3/8 inch x 100 mesh coal at 1.40 specific gravity will give 90.8 percent yield with 8.3 percent ash and 0.48 percent total sulfur on a moisture free basis (Table XIV).

Nenana Coal Field

A sample of the No. 4 bed coal (UA-119) was collected from the Lower Lignite Creek, Poker Flat pit, of the Usibelli Coal Mine and is the middle seam of the three extractable seams in the mining area. Overburden of this bed was first stripped during the summer of 1977 and the bed was mined for the first time in 1978. This bed has the largest mineable reserves of the three seams, No. 6, No. 4 and No. 3. The raw coal analyzed 13.2 percent ash and 0.44 percent total sulfur. Washing 1-1/2 inches x 100 mesh coal at 1.40 specific gravity (Table XV) gave a 96.8 percent yield with 9.5 percent ash and 0.28 percent total sulfur on a moisture free basis. Pyritic sulfur in the sample is low and washing will not have any significant influence on the sulfur.

CONCLUSIONS

Washability studies showed that coals from Wainwright can be cleaned to less than 2.5 percent ash and with sulfur as low as 0.24 percent for Wainwright and 0.46 percent for Meade River coals.

Coal from Coal Creek basin of the Broad Pass coal field can give a low ash product with fine crushings.

Sulfur in the Little Tonzona coal bed is high and very little of it is in pyritic form. Although washing will reduce ash, it will not reduce sulfur in the product.

TABLE X

Washability Analyses of Waterfall Bed Coal Sample (UA-113)
Beluga Coal Field, Alaska

Raw Coal Bed Moisture = 20.56

SPECIFIC GRAVITY		ACTUAL PRODUCTS					CUMULATIVE FLOAT					CUMULATIVE SINK	
					Sulfur percent					Sulfur percent			
Sink	Float	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %
Float-Sink Size 1 1/2 inches x 100 Mesh													
	1.30	41.23	4.86	11652	0.01	0.15	41.23	4.86	11652	0.01	0.15	100.00	9.45
1.30	1.40	51.44	9.04	10877	0.01	0.24	92.67	7.18	11222	0.01	0.20	58.77	12.67
1.40	1.60	5.31	32.39	7029	0.01	0.24	97.98	8.55	10995	0.01	0.20	7.33	38.12
1.60		2.02	53.17	5031	0.04	0.20	100.00	9.45	10874	0.01	0.20	2.02	53.17
Minus 100 Mesh		0.80	24.42	8937	0.02	0.22	[1]100.00	9.57	10859	0.01	0.20		
Float-Sink Size 3/8 inch x 100 Mesh													
	1.30	49.73	4.81	11860	0.01	0.15	49.73	4.81	11860	0.01	0.15	100.00	9.15
1.30	1.40	42.40	10.43	10972	0.01	0.16	92.13	7.40	11451	0.01	0.15	50.27	13.44
1.40	1.60	5.63	19.80	8488	0.01	0.19	97.76	8.11	11281	0.01	0.16	7.87	29.65
1.60		2.24	54.42	4969	0.02	0.18	100.00	9.15	11139	0.01	0.16	2.24	54.42
Minus 100 Mesh		4.74	18.12	9844	0.02	0.11	[1]100.00	9.56	11080	0.01	0.16		
Float-Sink Size 14 Mesh x 0													
	1.30	17.80	5.24	11776	0.01	0.19	17.80	5.24	11776	0.01	0.19	100.00	9.97
1.30	1.40	70.67	7.77	11262	0.01	0.17	88.47	7.26	11365	0.01	0.17	82.20	10.99
1.40	1.60	9.24	24.67	8803	0.01	0.17	97.71	8.91	11123	0.01	0.17	11.53	30.72
1.60		2.29	55.14	4573	0.02	0.17	100.00	9.97	10973	0.01	0.17	2.29	55.14

All results are on a Moisture Free Basis

[1]Cumulative float-sink plus minus 100 mesh material.

TABLE XI

Washability Analyses of Lower 10 Feet of an Uncorrelated Bed Coal Sample (UA-115)
Yentna Field, Alaska

Raw Coal Bed Moisture = 29.80

SPECIFIC GRAVITY		ACTUAL PRODUCTS					CUMULATIVE FLOAT					CUMULATIVE SINK	
					Sulfur percent					Sulfur percent			
Sink	Float	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %
Float-Sink Size 1 1/2 inches x 100 Mesh													
	1.30	97.65	4.54	11531	0.01	0.15	97.65	4.54	11531	0.01	0.15	100.00	5.02
1.30	1.40	1.31	9.82	9587	0.01	0.04	98.96	4.61	11505	0.01	0.15	2.35	25.11
1.40	1.60	0.50	22.02	9218	0.01	0.14	99.46	4.70	11494	0.01	0.15	1.04	44.38
1.60		0.54	65.08	3846	0.04	0.07	100.00	5.02	11452	0.01	0.15	0.54	65.08
Minus 100 Mesh		0.81	21.28	9268	0.03	0.13	[1]100.00	5.15	11434	0.01	0.15		
Float-Sink Size 3/8 inch x 100 Mesh													
	1.30	95.81	4.17	11587	0.01	0.14	95.81	4.17	11587	0.01	0.14	100.00	4.53
1.30	1.40	3.80	8.55	10854	0.01	0.13	99.61	4.34	11559	0.01	0.14	4.19	12.65
1.40	1.60	0.21	28.35	8694	0.05	0.19	99.82	4.39	11553	0.01	0.14	0.39	52.59
1.60		0.18	80.87	1630	0.05	0.08	100.00	4.53	11535	0.01	0.14	0.18	80.87
Minus 100 Mesh		3.20	8.60	11108	0.03	0.10	[1]100.00	4.66	11522	0.01	0.14		
Float-Sink Size 14 Mesh x 0													
	1.30	97.89	4.18	11384	0.01	0.16	97.89	4.18	11384	0.01	0.16	100.00	4.45
1.30	1.40	1.00	7.82	10430	0.02	0.15	98.89	4.22	11374	0.01	0.16	2.11	16.87
1.40	1.60	0.62	16.00	9275	0.05	0.18	99.51	4.29	11361	0.01	0.16	1.11	25.02
1.60		0.49	36.43	2522	0.07	0.08	100.00	4.45	11318	0.01	0.16	0.49	36.43

All results are on a Moisture Free Basis.

[1]Cumulative float-sink plus minus 100 mesh material.

TABLE XII

Washability Analyses of Upper 10 Feet of an Uncorrelated Bed Coal Sample (UA-116)
Yentna Coal Field, Alaska

Raw Coal Bed Moisture = 29.86

SPECIFIC GRAVITY		ACTUAL PRODUCTS					CUMULATIVE FLOAT					CUMULATIVE SINK	
					Sulfur percent					Sulfur percent			
Sink	Float	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %
Float-Sink Size 1 1/2 inches x 100 Mesh													
	1.30	99.10	3.56	11401	0.01	0.10	99.10	3.56	11401	0.01	0.10	100.00	3.75
1.30	1.40	0.58	11.39	10160	0.01	0.13	99.68	3.61	11394	0.01	0.10	0.90	25.11
1.40	1.60	0.20	33.46	7213	0.11	0.11	99.88	3.67	11385	0.01	0.10	0.32	49.99
1.60		0.12	77.54	2116	0.10	0.03	100.00	3.75	11374	0.01	0.10	0.12	77.54
Minus 100 Mesh		0.77	12.41	10662	0.05	0.09	[1]100.00	3.82	11369	0.01	0.10		
Float-Sink Size 3/8 inch x 100 Mesh													
	1.30	96.99	3.50	11393	0.01	0.13	96.99	3.50	11393	0.01	0.13	100.00	3.66
1.30	1.40	2.87	7.60	9627	0.01	0.19	99.86	3.62	11342	0.01	0.13	3.01	8.79
1.40	1.60	0.10	21.17	9293	0.04	0.24	99.96	3.64	11340	0.01	0.13	0.14	33.12
1.60		0.04	62.98	4199	0.08	0.14	100.00	3.66	11337	0.01	0.13	0.04	62.98
Minus 100 Mesh		3.01	4.21	10470	0.01	0.11	[1]100.00	3.68	11312	0.01	0.13		
Float-Sink Size 14 Mesh x 0													
	1.30	99.17	3.25	11499	0.01	0.10	99.17	3.25	11499	0.01	0.10	100.00	3.41
1.30	1.40	0.41	6.21	10819	0.02	0.14	99.58	3.26	11496	0.01	0.10	0.83	22.28
1.40	1.60	0.24	14.22	9352	0.09	0.20	99.82	3.29	11491	0.01	0.10	0.42	37.98
1.60		0.18	69.65	3511	0.14	0.10	100.00	3.41	11477	0.01	0.10	0.18	69.65

All results are on a Moisture Free Basis.

[1]Cumulative float-sink plus minus 100 mesh material.

TABLE XIII

Composite Washability Analyses of 20 Feet of Uncorrelated Bed Coal Sample (UA-115 & UA-116)
Yentna Coal Field, Alaska

Raw Coal Bed Moisture = 29.83

SPECIFIC GRAVITY		ACTUAL PRODUCTS					CUMULATIVE FLOAT					CUMULATIVE SINK	
					Sulfur percent					Sulfur percent			
Sink	Float	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %
Float-Sink Size 1 1/2 inches x 100 Mesh													
	1.30	98.38	4.05	11466	0.01	0.10	98.38	4.05	11466	0.01	0.10	100.00	4.40
1.30	1.40	0.94	10.86	9763	0.01	0.07	99.32	4.11	11450	0.01	0.10	1.62	25.48
1.40	1.60	0.35	25.29	8645	0.04	0.13	99.67	4.19	11440	0.01	0.10	0.68	45.70
1.60		0.33	67.35	3531	0.05	0.06	100.00	4.40	11414	0.01	0.10	0.33	67.35
Minus 100 Mesh		0.79	16.96	9947	0.04	0.11	[1]100.00	4.50	11402	0.01	0.10		
Float-Sink Size 3/8 inch x 100 Mesh													
	1.30	96.40	3.84	11489	0.01	0.13	96.40	3.84	11489	0.01	0.13	100.00	4.10
1.30	1.40	3.34	8.08	9614	0.01	0.14	99.74	3.98	11426	0.01	0.13	3.60	10.95
1.40	1.60	0.15	26.03	8887	0.04	0.21	99.89	4.02	11422	0.01	0.13	0.26	47.86
1.60		0.11	77.62	2097	0.06	0.09	100.00	4.10	11412	0.01	0.13	0.11	77.62
Minus 100 Mesh		3.10	6.47	10799	0.02	0.10	[1]100.00	4.17	11394	0.01	0.13		
Float-Sink Size 14 Mesh x 0													
	1.30	98.53	3.71	11441	0.01	0.13	98.53	3.71	11441	0.01	0.13	100.00	3.93
1.30	1.40	0.71	7.35	10543	0.02	0.15	99.24	3.74	11435	0.01	0.13	1.47	18.40
1.40	1.60	0.43	15.50	9296	0.06	0.19	99.67	3.79	11426	0.01	0.13	0.76	28.58
1.60		0.33	60.72	2788	0.09	0.09	100.00	3.93	11397	0.01	0.13	0.33	60.72

All results are on a Moisture Free Basis.

[1]Cumulative float-sink plus minus 100 mesh material.

TABLE XIV

Washability Analyses of Cabin Bed Coal Sample (UA-118)
Kenai Coal Field, Homer, Alaska

Raw Coal Bed Moisture = 23.01

SPECIFIC GRAVITY		ACTUAL PRODUCTS					CUMULATIVE FLOAT					CUMULATIVE SINK	
					Sulfur percent					Sulfur percent			
Sink	Float	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %
Float-Sink Size 1 1/2 inches x 100 Mesh													
	1.30	34.98	4.49	11578	0.03	0.48	34.98	4.49	11578	0.03	0.48	100.00	11.83
1.30	1.40	54.35	11.12	10531	0.01	0.40	89.33	8.52	10941	0.02	0.43	65.02	15.77
1.40	1.60	8.58	32.50	7855	0.02	0.35	97.91	10.62	10671	0.02	0.42	10.67	39.47
1.60		2.09	68.09	3116	0.13	0.10	100.00	11.83	10513	0.02	0.42	2.09	68.09
Minus 100 Mesh		0.62	26.56	8855	0.02	0.42	[1]100.00	11.92	10502	0.02	0.42		
Float-Sink Size 3/8 inch x 100 Mesh													
	1.30	39.05	5.03	11644	0.01	0.51	39.05	5.03	11644	0.01	0.51	100.00	10.95
1.30	1.40	51.71	10.79	10845	0.01	0.47	90.76	8.31	11189	0.01	0.48	60.75	14.78
1.40	1.60	5.19	25.87	9041	0.11	0.42	95.95	9.26	11073	0.02	0.48	9.24	36.82
1.60		4.05	50.85	5594	0.05	0.31	100.00	10.95	10851	0.02	0.48	4.05	50.85
Minus 100 Mesh		3.55	15.79	10303	0.01	0.43	[1]100.00	11.12	10832	0.02	0.48		
Float-Sink Size 14 Mesh x 0													
	1.30	21.00	4.04	11880	0.02	0.50	21.00	4.04	11880	0.02	0.50	100.00	10.95
1.30	1.40	56.70	7.26	11279	0.01	0.45	77.70	6.39	11441	0.01	0.46	79.00	12.79
1.40	1.60	16.80	21.03	9604	0.01	0.39	94.50	8.99	11115	0.01	0.45	22.30	26.84
1.60		5.50	44.60	6030	0.06	0.34	100.00	10.95	10835	0.01	0.44	5.50	44.60

All results are on a Moisture Free Basis.

[1]Cumulative float-sink plus minus 100 mesh material.

TABLE XV

Washability Analyses of the No. 4 Bed Coal Sample (UA-119)
Usibelli Coal Mine, Nenana Coal Field, Healy, Alaska

Raw Coal Bed Moisture = 25.29

SPECIFIC GRAVITY		ACTUAL PRODUCTS					CUMULATIVE FLOAT					CUMULATIVE SINK	
					Sulfur percent					Sulfur percent			
Sink	Float	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %
Float-Sink Size 1 1/2 inches x 100 Mesh													
	1.30	25.50	5.54	11441	0.03	0.21	25.50	5.54	11441	0.03	0.21	100.00	10.21
1.30	1.40	71.29	10.88	10644	0.01	0.30	96.79	9.47	10854	0.02	0.28	74.50	11.80
1.40	1.60	2.99	32.24	7978	0.02	0.86	99.78	10.16	10768	0.02	0.29	3.21	32.33
1.60		0.22	33.49	7771	0.13	0.51	100.00	10.21	10761	0.02	0.29	0.22	33.49
Minus 100 Mesh		0.77	15.75	10102	0.03	0.57	[1]100.00	10.25	10756	0.02	0.29		
Float-Sink Size 3/8 inch x 100 Mesh													
	1.30	34.41	5.36	11245	0.01	0.17	34.41	5.36	11245	0.01	0.17	100.00	9.17
1.30	1.40	61.08	10.52	10575	0.01	0.34	95.49	8.66	10816	0.01	0.28	65.59	11.16
1.40	1.60	4.09	19.73	9739	0.11	0.50	99.58	9.12	10772	0.01	0.29	4.51	19.86
1.60		0.42	21.11	9335	0.05	0.38	100.00	9.17	10766	0.01	0.29	0.42	21.11
Minus 100 Mesh		3.07	8.30	10801	0.03	0.23	[1]100.00	9.14	10767	0.01	0.29		
Float-Sink Size 14 Mesh x 0													
	1.30	1.03	4.66	11502	0.02	0.20	1.03	4.66	11502	0.02	0.20	100.00	9.48
1.30	1.40	69.33	8.23	10886	0.01	0.26	70.36	8.18	10895	0.01	0.26	98.97	9.53
1.40	1.60	28.79	11.29	10456	0.01	0.54	99.15	9.08	10768	0.01	0.34	29.64	12.56
1.60		0.85	55.62	4766	0.06	0.18	100.00	9.48	10717	0.01	0.34	0.85	55.62

All results are on a Moisture Free Basis.

[1]Cumulative float-sink plus minus 100 mesh material.

The lower 30 feet of the Waterfall seam in the Capps basin of the Beluga coal field is quite low in ash. Washing, however, has shown significant improvements in the quality of the product.

The 55-foot-thick seam at Locality 2 in the Yentna coal field is low in ash and washing will not significantly reduce ash.

The high volatile bituminous coal from Tramway Bar and subbituminous "C" coals from Cabin bed, Kenai field and No. 4 bed in the lower Lignite Creek of Nenana field can yield significantly improved products by washing.

With the exception of Little Tonzona coal bed all other coals reported in this study are low in total sulfur, 1.3 specific gravity float products ranging from 0.05 percent to 0.46 percent sulfur.

The results of this type of study are highly valuable in planning the utilization of Alaskan coals not only for Alaska but also as a source of low sulfur fuel for the nation. An additional 15 samples are now being studied and will be reported in a subsequent publication. It is recommended that similar studies be undertaken on all coal seams of potential economic significance.

REFERENCES

1. Rao, P. Dharma and Wolff, E.N., 1978, Characterization and evaluation of washability of Alaskan coals, Part I. Selected seams from Nenana, Matanuska and Jarvis Creek fields: Report No. 41, Mineral Industry Research Laboratory, University of Alaska, August 1978, 35 p.

2. Barnes, F.F., 1967, Coal resources of Alaska: U.S. Geol. Survey Bull. 1232-B, 89 p.

3. Barnes, F.F., 1967, Coal resources of the Cape Lisburne - Colville River region, Alaska: U.S. Geol. Survey Bull. 1242-E, 37 p.

4. McGee, D.L., 1976, Gasification prospects and application in Cook Inlet, Alaska: in Focus on Alaska's Coal '75: University of Alaska, Mineral Industry Research Laboratory, pp. 219-226.

5. Tailleur, I.L., Brosge, W.P., 1976, Coal resources of northern Alaska may be Nation's largest, in Focus on Alaska's Coal '75: University of Alaska, Mineral Industry Research Laboratory, pp. 219-226.

6. Martin, G.C., and Callahan, J.E., 1978, Preliminary report on the coal resources of the National Petroleum Reserve in Alaska: U.S. Geol. Survey Open File Report 78-1033, 23 p.

7. Chapman, R.M. and Sable, E.G., 1960, Geology of the Utukok-Corwin region, northwestern Alaska, Part 3, Area Geology: U.S. Geol. Survey Prof. Paper 303-C, 167 p.

8. Barnes, F.F., 1966, Geology and coal resources of the Beluga-Yentna region, Alaska: U.S. Geol. Survey Bull. 1202-C, 54 p.

9. Tonges, A.L. and Jolley, T.R., 1947, Investigation of coal deposits for local use in the Arctic regions of Alaska and proposed mine development: U.S. Bureau of Mines, RI 4150, 19 p.

10. Sanford, R.S. and Pierce, H.C., 1946, Exploration of coal deposits of the Point Barrow and Wainwright areas, northern Alaska: U.S. Bureau of Mines, RI 3934, 17 p.

11. Ferrians, O.J., 1971, Preliminary engineering geologic maps of the proposed Trans-Alaska Pipeline route, Beecy Point and Sagavanirktok quadrangles: U.S. Geol. Survey Open-File Map.

12. Keller, S.A., Morris, R.M., and Detterman, R.L., 1961, Geology of the Shaviovik and Sagavanirktok Rivers region, Alaska: U.S. Geol. Survey Prof. Paper 303-D, pp. 169-222.

13. Wahrhatig, Clyde, 1944, Coal deposits of the Costello Creek Basin, Alaska, U.S. Geol. Survey Open File Rept. 8, 7 p.

14. Hopkins, D.M., 1951, Lignite deposits near Broad Pass Station, Alaska: in Barnes, F.F. and others, Coal investigations in south-central Alaska, 1944-46: U.S. Geol. Survey Bull. 963-E, pp. 187-191.

15. Brooks, A.H., 1911, Mount McKinley region, Alaska: U.S. Geol. Survey Prof. Paper 70, 234 p.

16. Capps, S.R., 1919, Kantishna region, Alaska: U.S. Geol. Survey Bull. 687, 118 p.

17. Player, A.F., 1976, The Little Tonzona coal bed near Farewell, Alaska; An important extension of the coal field north of the Alaska Range: a report by Gary Player Ventures, Box 476-M, Star Route A, Anchorage, Alaska 99507, 10 p.

18. Schrader, F.C., 1900, Preliminary Report on reconnaissance along the Chandalar and Koyukuk Rivers, Alaska in 1899: U.S. Geol. Survey Twenty-First Annual Report Part 2, 485 p.

19. Smith, P., Mertie, J.B., Jr., 1930, Geology and mineral resources of northwestern Alaska: U.S. Geol. Survey Bull. 815, 351 p.

20. Patton, W.W., Jr., 1973, Reconnaissance geology of the northern Yukon-Koyukuk Province, Alaska: U.S. Geol. Survey Prof. Paper 774-A, 17 p.

21. Calderwood, K.W., and Fackler, W.C., 1972, Proposed nomenclature for Kenai Group, Cook Inlet Basin, Alaska: American Association of Petroleum Geologists Bull. vol. 56, No. 4, pp. 739-754.

22. Magoon, L.B., Adkison, W.L., and Egbert, R.M., 1976, Map showing geology, wild cat wells, Tertiary plant fossil localities, K-Ar age dates, and petroleum operations, Cook Inlet area, Alaska: U.S. Geol. Survey, Misc. Inv. Series. Map I-1019.

23. Wolf, Jack A., Hopkins, D.M., and Leopold, Estella A., 1966, Tertiary stratigraphy and paleobotany of the Cool Inlet region, Alaska: U.S. Geol. Survey Prof. Paper 398-A, 29 p.

24. Tonges, A.L., and Jolley, T.R., 1949, Investigations of coal deposits in southcentral Alaska and the Kenai Peninsula: U.S. Bureau of Mines, RI 4520, 37 p.

25. Barnes, F.F., and Cobb, E.H., 1959, Geology and coal resources, Homer district, Alaska: U.S. Geol. Survey Bull. 1058-F, 217-260 p.

26. Laird, A.M., 1978, Development of the Beluga coal field, a status report: A paper presented at the annual convention, Alaska Miners Association, October, 1978, 7 p.

27. Adkinson, W.L., Kelley, J.S., and Newman, K.R., 1975, Lithology and palynology of Tertiary rocks exposed near Capps glacier and along Chuitna River, Tyonek quadrangle, southern Alaska: U.S. Geol. Survey Open-File Report 75-21, 58 p.

28. Wahrhaftig, Clyde, C.A. Hickcox, and Jacob Freedman, Coal Deposits on Healy and Lignite Creeks, Nenana Coal Field, Alaska, in Barnes, F.F. and others, Coal Investigations in Southcentral Alaska, 1944-46: U.S. Geol. Survey Bull. 963-E, 1951, p. 141-165.

29. Wahrhaftig, Clyde, Geology and Coal Deposits of the Western Part of the Nenana Coal Field, Alaska, in Barnes, F.F. and others, Coal Investigations in Southcentral Alaska, 1944-46: U.S. Geol. Survey Bull. 963-E, 1951, p. 169-186.

30. Wahrhaftig, Clyde and Joseph H. Birmon, Stripping Coal Deposits on Lower Lignite Creek, Nenana Coal Field, Alaska: U.S. Geol. Survey Circular 310, 11 pp.

31. Wahrhatig, Clyde, Wolfe, Jack A., Leopold, Estella B., and Lanphere, Marvin A., 1969, The coal-bearing group in the Nenana coal field, Alaska: U.S. Geol. Survey Bull. 1274D, 30 p.

32. Cavallaro, J.A., M.T. Johnston, and A.W. Deurbrouck, Sulfur Reduction Potential of the Coals of the United States: U.S. Bureau of Mines, RI 8118, 1976, 323 p.