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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Geology of T. 1 S., R. 44 W., unsurveyed, Umiat principal meridian, in the Kukpowruk coal field, Alaska

By

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INTRODUCTION

T. 1 S., R. 44 W., on the Kukpowruk River, is at approximate lat 69°20' N., long 162°30' W. Point Barrow, the nearest sizable town is about 200 miles northeast. Point Lay, a permanently inhabited community, is about 28 miles north-northwest on the coast of the Chukchi Sea (fig. 1). The township is unsurveyed. Section lines are plotted according to official Bureau of Land Management protraction diagrams.

The township is on the boundary between the northern section of the Arctic Foothills and the Arctic Coastal Plain physiographic provinces (Wahrhaftig, 1965). The northern and northwestern part of the township lies in the coastal plain where the relief is less than 150 feet and the drainage is very poor. The area is covered by lakes, ponds, and muskeg. The surface is characterized by frost polygons and other permafrost features. Outcrops in the Coastal Plain are found only along the banks of the two main rivers, the Kukpowruk and the Epizetka. The southern part of the township is in the Arctic Foothills Province; it has a relief of about 350 feet, with low broad ridges that reflect the distribution of underlying resistant rocks. Outcrops are more common in the foothills area than in the coastal plain, but only those along the riverbanks are in place. Outcrops in the foothills area consist of rubble derived from underlying sandstone beds. The rubble forms traces which are conspicuous features on aerial photographs but are not always reliable for correlation.

Previous Investigations

The coal deposits of the Cape Lisburne to Wainwright area along the coast were known and exploited by whalers as early as 1879 (Schrader, 1904, p. 109). F. C. Schrader was the first geologist to visit the general area in 1901, and he briefly mentioned the coal exposed along the coast. A geologic reconnaissance of the Cape Lisburne to Cape Beaufort area was made by A. J. Collier in 1904, but his work was restricted mainly to the coastal area (Collier, 1906). In 1923, after establishment of the Naval Petroleum Reserve No. 4, W. T. Foran began a reconnaissance exploration at Cape Beaufort and traveled up the Kukpowruk River for 35 miles,

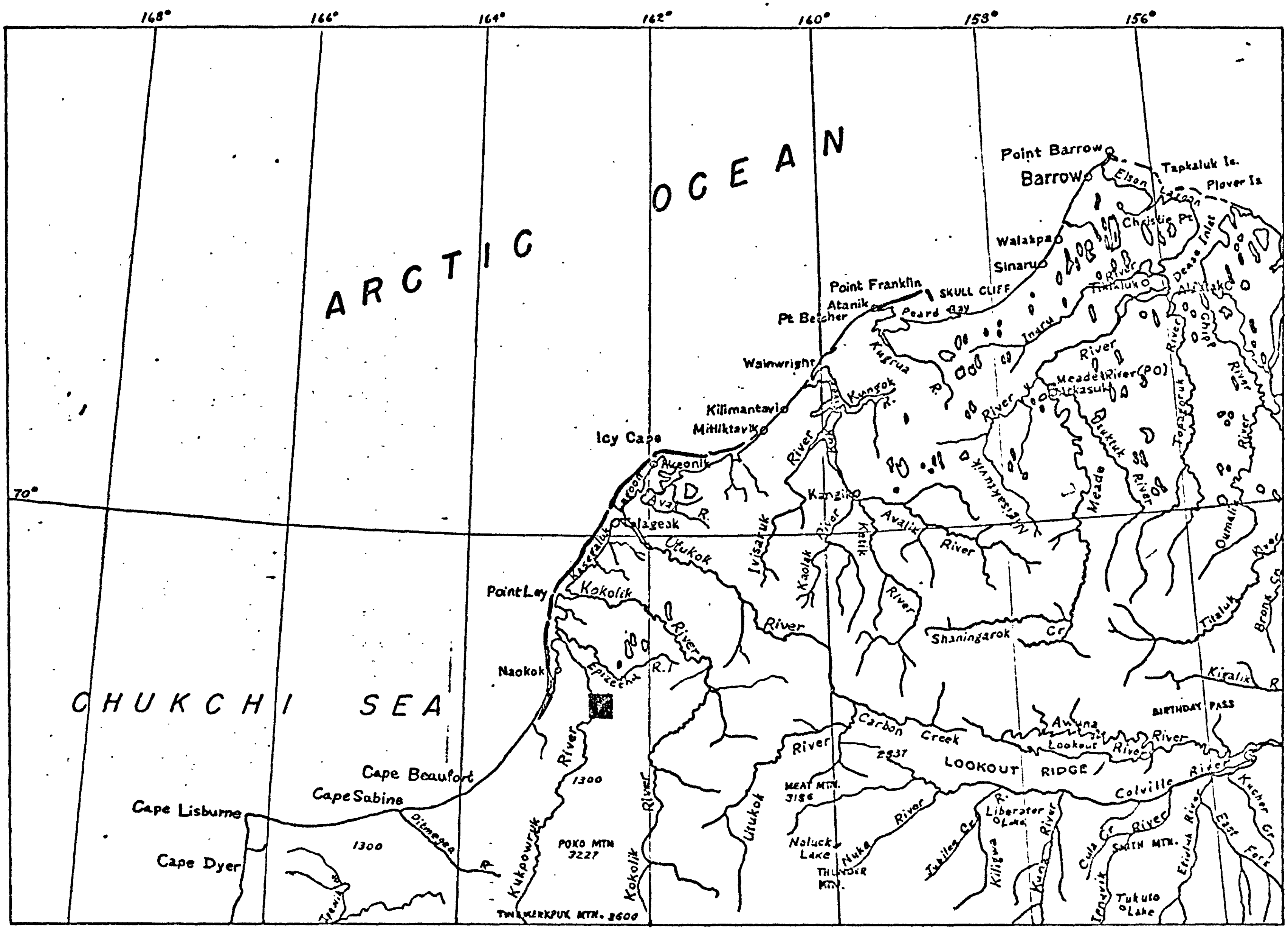

Fig. 1 LOCATION MAP — T. 1 S., R. 44 W., UMIAT PRINCIPAL MERIDIAN, ALASKA

traversing the western part of T. 1 S., R. 44 W. His account is the first published description of the coal beds exposed along the Kukpowruk River within the township, including a 20-foot bed which accounts for more than half the measured reserves in the township (Paige and others, 1925). Toenges and Jolley (1947) examined coal beds along the Kukpowruk River for possible local use, and sampled the 20-foot bed for chemical analysis. During the exploration of Naval Petroleum Reserve No. 4, between 1947 and 1953, the major rivers of the region, including the Kukpowruk River, were traversed by boat, and geologic mapping was done within the limits of foot travel along the rivers (Chapman and Sable, 1960). Planimetric and geologic mapping was extended into the areas away from the rivers by means of aerial photographs. (Topographic mapping at scales of 1:63,360 and 1:50,000 has since become available.) A tunnel was driven into the 20-foot bed by a Mr. Robbins acting for the Morgan Coal Co. in the early 1950's. The tunnel is 76 feet long, and it crosses the bedding and angles toward the bottom of the coal bed. A 23-foot raise, which does not reach the top of the bed, is at the end of the tunnel. A channel sample of coal representing a true thickness of 23 feet 8½ inches was taken by Robbins in 1954. The coal in the tunnel was sampled again in August and September 1961 by Arthur W. Hueck of the Union Carbide and Ore Co. Hueck took six channel samples in the raise representing 20 feet 5 inches of coal. The U.S. Bureau of Mines took seven samples from the 20-foot bed in 1962 and 1963 for coking tests and also sampled a 4.5-foot bed approximately 425 feet stratigraphically above the 20-foot bed (Warfield and others, 1966). The Bureau of Mines drilled four holes in 1966 to obtain core samples of the 20-foot bed at various depths to determine whether the coking characteristics of the bed vary with depth or distance from the outcrop.

Fieldwork

The field investigations for T. 1 S., R. 44 W., in the Kukpowruk coal field were made during July and August 1966 and July and August 1967. The field party in 1966 consisted of A. A. Wanek, geologist, Charles McLaughlin, field assistant, and Gordon MacDonald, cook. In 1967, the field party consisted of J. E. Callahan, W. L. Rohrer, E. M. Schell, A. A. Wanek, and H. D. Zeller, geologists, and Ned Lewis, cook. Mapping was done principally on aerial photographs at a scale of 1:50,000. The mapping was transferred later to topographic maps at scales of 1:63,360 and 1:24,000.

Access to the township is by airplane, helicopter, or tracked vehicle from the Arctic coast. Satisfactory natural airstrips for summer use are limited to river bars and some ridgetops. During high water the river bars are covered, but float-equipped aircraft can operate on the Kukpowruk River. Surface transportation during the summer months is slow and difficult using any type of equipment, and the movement of heavy equipment is more easily accomplished during the winter. Transportation would be the most significant problem in the development of the coal resources.

GENERAL GEOLOGY

The township lies in the central part of the Utukok-Corwin region as defined by Chapman and Sable (1960). The region is underlain by sedimentary rocks ranging in age from Jurassic(?) through Upper Cretaceous and by Pleistocene and Holocene surficial deposits. Chapman and Sable divided the region into two structural provinces: a western province characterized by northwest-striking thrust faults and an eastern province containing west- to northwest-trending folds. The eastern province is subdivided into two structural belts, one in the southern foothills physiographic section and another in the northern foothills section and the Arctic Coastal Plain physiographic province. The southern foothills section is more tightly and complexly folded than the northern belt. The northern belt is characterized by broad simple synclines and basins lying between more complex anticlines, some of which are faulted (Chapman and Sable, 1960, p. 132-134). The axis of one of the synclines, the Howard syncline (fig. 2 of pl. 1), trends approximately through the center of T. 1 S., R. 44 W.

Cretaceous Rocks

Five Cretaceous formations crop out in the eastern structural province. These are the Fortress Mountain, Torok, and Kukpowruk Formations of Early Cretaceous age, the Corwin Formation of Early (late Albian) to Late (early Cenomanian) Cretaceous age, and the Prince Creek Formation of Late Cretaceous age.

Fortress Mountain Formation

The Fortress Mountain Formation is exposed only in the southernmost part of the southern foothills section and may be absent at depth in the township. Where exposed, the formation consists of interbedded shale, claystone, siltstone, sandstone, and conglomerate; the argillaceous rocks make up 50-70 percent of the formation. The total thickness of the formation in the Utukok-Corwin region is estimated at 5,000 feet but it may vary due to facies changes (Chapman and Sable, 1960, p. 72). The contact between the Fortress Mountain Formation and the overlying Torok Formation is exposed in continuous outcrops along the boundary between the southern and northern foothills belt and in the axial zones of a number of anticlines in the northern foothills section. It is exposed on the Kukpowruk River in the Archimedes Ridge anticline about 5 miles southwest of the southern boundary of the township. It is also present on the Kokolik River in the Snowbank anticline, which extends westward to cross the Kukpowruk River about 1½ miles north of the township's north boundary; however, the formation does not crop out in the Snowbank anticline at this place.

Torok Formation

The Torok Formation probably underlies the township at depths ranging from 3,000 to 7,000 feet. It is made up dominantly of clay shale, claystone, and silty shale. The rocks include 10-15 percent siltstone and a lesser amount of sandstone, mainly in the middle and upper parts of the formation. The shale and claystone are interbedded and are mainly medium to dark gray, poorly to moderately well indurated, and mostly noncalcareous, though some of the rocks are moderately calcareous.

Siltstone is interbedded with shale in beds from less than 6 inches to as much as 2 feet thick and in sets of beds as much as 20 feet thick. The rocks are light to dark gray and yellowish gray, weathering to pale yellowish brown or olive gray. The siltstone is moderately well to well indurated and slightly calcareous to noncalcareous.

The sandstone is similar in appearance to the siltstone; it is interbedded with shale in units ranging in thickness from a few inches to 15 feet. Sandstone is more common in the upper part of the formation and is generally fine grained, clayey, and more calcareous than the siltstone.

Because of the relatively uniform composition and lack of induration in the Torok Formation, the lowland areas underlain by the formation are generally featureless and have little relief.

The total thickness of the Torok Formation is not exposed at any one place in the Utukok-Corwin region. The top of the formation is exposed in the anticlines in the northern foothills, but the lower part is exposed only in the southern part of the region. Chapman and Sable (1960, p. 76) estimated an aggregate thickness of about 6,000 feet for the formation from the discontinuous sections exposed in the region.

In the central part of northern Alaska, east of the Utukok-Corwin region, the Torok Formation is overlain by a sequence of marine and non-marine rocks that is named the Nanushuk Group. The strata in the Nanushuk Group can be traced into the Utukok-Corwin region, but the detailed subdivisions applied to these rocks in the east cannot be used in the western area, where only two units, the marine Kukpowruk Formation and the non-marine Corwin Formation, can be distinguished.

Kukpowruk Formation

The Kukpowruk Formation contains resistant siltstone and sandstone beds that form most of the ridges, mesas, and cuestas of the northern foothills section. The ledges formed by the resistant beds can be traced on aerial photographs with apparent continuity for many miles. The outcrops in the upper part of the formation contain fewer resistant beds and the slopes are more gentle than in the outcrops of the lower part.

The Kukpowruk Formation is not exposed anywhere in T. 1 S., R. 44 W., but the contact between it and the overlying Corwin Formation can be observed on the Kukpowruk River less than one-fourth mile south of the south boundary and also in the township to the east. The formation crops out on the river in the Snowbank anticline about 1¼ miles northwest of the northwest corner of the township (Chapman and Sable, 1960, pl. 8). The formation underlies the township at depths ranging from 0 to about 4,600 feet, the maximum measured thickness of the Corwin Formation (fig. 3 of pl. 1). The Kukpowruk Formation consists dominantly of silty shale, siltstone, and sandstone. Lesser amounts of claystone, clay shale, conglomeratic sandstone, conglomerate, and carbonaceous shale are present. The rocks vary in character and abundance, both vertically and horizontally, and represent deposition in a rapidly sinking but shallow geosyncline that had a constantly shifting shoreline. The rocks are mostly of marine inshore facies, but some offshore facies and some nonmarine rocks (coastal facies) are in the upper part. The formation thins northeastward from more than 5,000 feet to about 2,000 feet with a corresponding decrease in the proportion of coarser clastic rocks. The type section of the Kukpowruk Formation is along the Kukpowruk River about 3-5 miles south-southwest of the southwest corner of the township. The base of the Kukpowruk Formation is not exposed in this section, which is about 2,865 feet thick (Chapman and Sable, 1960, p. 88). Another section was measured along the Kukpowruk River in the south limb of the Barabara syncline (north limb of Snowbank anticline), about 2 miles northwest of the northwest corner of the township by E. G. Sable (Chapman and Sable, 1960, p. 89). Here the formation is 2,567 feet thick and the bottom of the formation is not exposed. This would indicate a thickness of at least 2,500-3,000 feet underlying the township.

The upper 385 feet of the Kukpowruk Formation was measured along the Kukpowruk River on the south limb of the Howard syncline by the field party in 1967. The contact with the overlying Corwin Formation is gradational and transitional, and the section measured may be mostly within the zone of transition. The section consists of interbedded fine-grained sandstone and claystone in approximately equal proportions (fig. 4 of pl. 1). The contact arbitrarily was chosen at the base of a bed of sandstone 56 feet thick, which is at the approximate position of the contact as mapped by Chapman and Sable (1960, pl. 8). The 56-foot sandstone bed may be equivalent to the 70-foot sandstone bed overlying the Kukpowruk Formation at the type section (Chapman and Sable, 1960, p. 88). The sandstone units are generally thin and irregularly bedded and contain beds as much as 2.5 feet thick. The rock is medium to light gray, cross-laminated and crossbedded, and micaceous and contains carbonaceous laminae and carbonized plant fragments. Ripple marks, some with a wave length of 4 or 5 inches are present. Beds of sandstone commonly contain thin siltstone or claystone partings; some beds are calcareous. The claystone is dark gray to gray and commonly silty or shaly and in places is interbedded with black carbonaceous shale.

Corwin Formation

The Corwin Formation is the youngest pre-Quaternary formation underlying the township, and the only consolidated rocks cropping out in the township belong to this formation. The Corwin is about 15,500 feet thick at its type section at Corwin Bluff along the Chukchi Sea. At that locality, Chapman and Sable (1960, p. 105) recognized seven members. No stratigraphic breaks occur between the members, which were defined for the purpose of correlation with other sections exposed in the Utukok-Corwin region. The members are, in descending order, (1) an upper sandstone 4,141 feet thick, consisting of thick sandstone beds interbedded with shale and siltstone and containing scattered coal beds as much as 2 feet thick; (2) a bentonitic clay 2,767 feet thick composed largely of interbedded shale, siltstone, and sandstone and containing many bentonite and bentonitic clay beds and coal beds as much as 9 feet thick; (3) a conglomerate unit 635 feet thick, consisting of thick beds of conglomerate and sandstone and lesser amounts of siltstone, shale, and coal beds as much as 3 feet thick; (4) a coal and sandstone sequence 1,407 feet thick composed mainly of shale and sandstone with scattered massive sandstone beds and many coal beds as much as 9 feet thick; (5) a shale 1,238 feet thick, consisting mainly of clay shale and claystone and minor amounts of sandstone and siltstone and scattered coal beds as much as 1.5 feet thick; (6) a lower sandstone 2,685 feet thick, similar to the upper sandstone member and containing some coal beds as much as 1.5 feet thick; and (7) a silty shale 2,621 feet thick, containing dominantly silty shale and thin-bedded siltstone and a few massive sandstone beds and thin coal beds (Chapman and Sable, 1960, p. 105-121).

Rocks at the type section of the Corwin Formation were continuous with those exposed inland in the Utukok-Corwin region prior to deformation, according to Chapman and Sable (1960, p. 123). The formation thins north and east of the type locality due to either a deepening of the depositional basin southwestward or to a hiatus between deposition of the Corwin Formation and the overlying Prince Creek Formation accompanied by differential erosion of the Corwin Formation. Chapman and

Sable seem to favor the first explanation because of similar thinning in the Kukpowruk Formation and because of differences in thickness of the Corwin Formation between the north and south limbs of single synclines. The formation was measured in detail only on the south limb of the Howard syncline, but rough estimates based on attitudes and horizontal distance seem to indicate that the section on the north limb is several hundred feet thinner than the sections on the south limb. However, because large parts of the formation are covered and evidence of faulting is common in the rocks exposed on both limbs and in the axial area of the syncline, this difference may be exaggerated.

A sequence 4,632 feet thick in the Corwin Formation was measured on the south limb of the Howard syncline, but a large part of the sequence is covered or partially covered. Chapman and Sable (1960, p. 123) indicated that a correlative of the silty shale member of the type section comprises the lower 1,900-2,000 feet of the formation exposed in the syncline and that this is overlain by a sandy, coaly, and bentonitic(?) sequence. They place the base of the coaly section at 3,300 feet above the base of the formation, which corresponds to the position of the 20-foot coal bed in the south limb section measured during this investigation. The base of the formation is placed at the base of the 56-foot sandstone bed described above. The lower 1,800 feet of the section above this thick sandstone consists dominantly of claystone, silty claystone or shale, and siltstone and contains interbedded very fine grained to fine grained sandstone beds as much as 30 feet thick. The thickness of sandstone beds increases upward. About 1,900 feet above the base of the formation, the sandstone beds become much thicker and more massive, and there is a slight increase in grain size. Thin coal beds occur in the lower 3,100 feet of the formation, the thickest coal bed being about 1.5 feet. The 20-foot coal bed is 3,132 feet above the base, and it is overlain by about 1,500 feet of interbedded claystone, sandstone, siltstone, and coal, in that order of abundance. Eight coal beds more than 2 feet thick occur in the upper part of the section (fig. 3 of pl. 1). Ironstone in lenticular or irregular beds and in nodules or concretions is present throughout the formation, scattered and in layers. The ironstone is more common in the coaly part of the sequence. Conglomerate or conglomeratic sandstone was observed at only one locality in T. 1 S., R. 44 W. Thin lenses of conglomeratic sandstone and scattered pebbles of quartzite or chert as much as 2 inches in diameter occur in the thick massive cross-bedded sandstone which is about 450 feet above the 20-foot coal bed.

Most of the sandstone is medium to light gray with some buff phases. The sandstone beds contain abundant mafic materials, which weather yellow, reddish brown, and orange. Plant fragments and carbonaceous laminae are common. Ripple marks occur but are not as common or as distinctive as in the Kukpowruk Formation. Large-scale crossbedding and small-scale cross-laminations are common in the sandstone and siltstone. The claystone and shale are mostly medium to dark gray, with some black carbonaceous shale associated with the coals. Yellowish and olive-gray colors also occur in the argillaceous rocks; they weather to various shades of yellow and orange. Coaly material, leaf imprints, and plant fragments, including tree trunks, are abundant throughout the formation.

Quaternary Deposits

The Cretaceous rocks in the Arctic Coastal Plain Province of the region are overlain disconformably by gravel, sand, and silt of the Pleistocene Gubik Formation, which is largely marine, and by Holocene fluviatile deposits along the present streams. No identifiable exposures of the Gubik Formation were observed within the township, but the formation probably underlies parts of the muskeg-covered area in the northern part.

Holocene and Pleistocene fluviatile deposits are present in high-level terraces, in lower terraces formed by the present streams, and in the stream flood plains. The deposits consist of gravel, sand, silt, clay, and organic matter. Much of the gravel in the higher level terraces is made up of rock types foreign to the formations underlying the township, including varicolored chert, intrusive and metamorphic rocks, and quartz.

Concretionary ironstone derived from the underlying rocks is also present. The high-level gravels are thin within the township and are mapped as part of the colluvium that includes rubble and float derived from the underlying bedrock.

Structure

The Howard syncline is a simple, open fold which plunges to the west. The syncline is symmetrical within the township. The axis of the syncline cannot be readily defined because the beds are generally flat with small open flexures over a wide area near the axis. The dip of the bedding steepens abruptly near the south and north boundaries of the township, becoming almost vertical near the axis of the Snowbank anticline to the north and as much as 40° near the Kukpowruk-Corwin contact to the south.

Slickensides were observed in massive sandstone beds at several places along the Kukpowruk River. No consistent orientation is apparent in the slickensides or in the fractures on which they occur. They are believed to be related to local strain adjustments within the individual beds due to folding rather than to large-scale faulting.

Two large vertical transverse faults were mapped on the south limb of the syncline. One of them can be observed in the left bank of the river near the center of the east line of sec. 29, where dark-gray thin-bedded siltstone and claystone is in juxtaposition with massive light-gray crossbedded sandstone. The east side is upthrown and has a vertical displacement of about 430 feet. The other fault trends north-northwest, crossing the east line of sec. 28 near its south end. The horizontal displacement is about 1,750 feet. The vertical displacement is difficult to determine because of unreliable dips, but it is estimated to be about 300 feet. Direct evidence of this fault is lacking on the ground and on aerial photographs, but its position can reasonably be inferred from the offset on the clinkered zone which overlies the 20-foot coal bed. The offset in the coal bed itself was verified by a drill hole in sec. 27.

COAL

Coal occurs throughout the Corwin Formation, and very thin beds and coaly zones are present in the zone of transition from marine to nonmarine rocks in the upper part of the Kukpowruk Formation. Only three coal beds more than 14 inches thick occur below the 20-foot coal bed, and the only beds of foreseeable economic significance occur above this coal bed. Eight coal beds more than 14 inches thick were measured above the 20-foot bed on the south limb of the Howard syncline. On the north limb eight beds were also measured, including one which crops out just north of the township boundary and probably underlies the northwestern part of the township. Correlation of coal beds between the flanks of the syncline in a distance of 5 miles is at best uncertain and has been attempted for only one bed, the uppermost exposed bed near the axis of the syncline.

The coal beds crop out only along the Kukpowruk River; they are projected into the uplands on the basis of coaly rubble and on the projection of resistant sandstone beds associated with the coal.

In secs. 27, 28, 29, and 30, sandstone and claystone have been greatly altered by combustion of an underlying coal bed. Some of the rock has been completely fused, forming clinkers. The altered rock weathers to various hues of red, reddish orange, and reddish brown. It is considerably more resistant to weathering and mechanical disintegration than the unaltered rock and forms the crests of several hills in the area. Burning seems to have occurred only in one coal bed, probably the first bed above the 20-foot coal bed.

The coal beds are designated from south to north as follows: the three beds lying below the 20-foot bed are beds A, B, and C. The 20-foot bed is No. 1, and the remaining beds more than 14 inches thick are numbered sequentially in order of their outcrop position along the river (figs. 2, 5 on pl. 1). As was noted above, only one bed (No. 9) can be correlated, somewhat doubtfully, across the axis of the syncline, so the numbers are not intended to indicate the stratigraphic position of the coal beds.

Two points of control on the 20-foot bed (bed No. 1) have been established away from the river in core holes drilled by the U.S. Bureau of Mines and in a small diameter hole drilled during the present investigation.

The Bureau of Mines drilled four core holes (DH-2, 3, 4, 5, fig. 2 on pl. 1) in the NE¼SW¼ sec. 29 in the summer of 1966. The holes were alined approximately normal to the strike of the bed, spaced from 165 to about 210 feet apart, and ranged in depth from 81 to 212 feet. The purpose of the drilling was to obtain samples to determine whether with depth there is any change in coking quality of the coal. The coking characteristics of the 20-foot coal bed had been established in 1954 from samples obtained in the tunnel by Robbins' party for the Morgan Coal Co. and from surface samples obtained by the Bureau of Mines in a trenching program conducted in 1962 and 1963 (Warfield and others, 1966).

A small diameter (7/8 in.) diamond drill hole (DH-1) was drilled in 1967 during the present investigation to a depth of 30 feet in the NE¼SW¼ sec. 27, about 1½ miles east of the outcrop of the bed on the east side of the river. Core recovery was negligible due to the small size of the hole, but cuttings and the drilling rate gave a fair indication of the thickness of coal.

Channel samples were taken from outcropping coal beds 1 (three samples), 4, 5, 6, 7, 8, 9 (two samples), 10 (two samples), and 14. The coal is of high volatile A and B bituminous rank (table 1). Of the 12 samples, 10 show some coking characteristics, and the lower exposed part of bed 1 (sample C-1) has a free-swelling index of 6. The Bureau of Mines has done extensive coking tests on bed 1, in various combinations of parts of the bed and on the whole bed, and on blends of bed 1 coal with two West Virginia blending coals. The blends produced coke judged "to approach metallurgical quality" (Warfield and others, 1966, p. 59). The Bureau also sampled and tested bed 4 and found it to be noncoking. Core samples of bed 1 from the 1966 drilling program of the Bureau of Mines show no improvement of coking quality of the coal with depth. Bed 2, a 2.5-foot bed encountered in the core holes, had approximately

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TABLE 1.--Analyses of surface samples from outcrops along the Kukpowruk River in T. 1 S., R. 44 W., Umiat principal meridian, Alaska.

[Samples collected by A. A. Wanek, 1966. Form of analysis: A, as-received; B, moisture-free; C, moisture- and ash-free.]

Coal bed	Thickness (in.)	Location	Bureau Mines Lab. No.	Sample No.	Form of analysis	Analyses, in percent: Proximate: Moisture	Volatile matter	Fixed carbon	Ash	Ultimate: Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Ash	Heating value (Btu)	Free swelling index	Remarks
1	60	SW¼NW¼	I-59804	C-1	A	2.5	42.3	52.1	3.1	5.6	77.5	1.4	12.2	0.2	3.1	13,720	6	Lower 5 ft exposed, includes
		sec. 28			B	---	43.3	53.5	3.2	5.4	79.5	1.5	10.2	0.2	3.2	14,080		1½ in. clay in two partings.
					C	---	44.8	55.2	---	5.6	82.1	1.5	10.6	0.2	---	14,540		
1	60	--do---	I-59805	C-2	A	2.6	36.1	53.8	7.5	4.9	73.1	1.2	13.2	0.1	7.5	12,640	2½	Middle 5 ft exposed.
					B	---	37.0	55.3	7.7	4.7	75.1	1.2	11.1	0.2	7.7	12,980		
					C	---	40.1	59.9	---	5.1	81.3	1.3	12.1	0.2	---	14,060		
1	60	--do---	I-59806	C-3	A	2.9	31.3	62.0	3.8	4.8	78.2	1.2	11.8	0.2	3.8	13,560	1½	Upper 5 ft exposed, includes
					B	---	32.2	63.9	3.9	4.6	80.5	1.3	9.5	0.2	3.9	13,960		1 in. bone.
					C	---	33.5	66.5	---	4.8	83.7	1.3	10.0	0.2	---	14,530		
4	48	NE¼NW¼	I-59807	C-4	A	2.7	35.4	51.3	10.6	5.1	71.3	1.3	11.4	0.3	10.6	12,690	1½	Includes 2 in. clay parting,
		sec. 28			B	---	36.3	52.8	10.9	5.0	73.3	1.4	9.1	0.3	10.9	13,040		4 in. bone.
					C	---	40.8	59.2	---	5.6	82.3	1.5	10.3	0.3	---	14,630		
5	35	SE¼SE¼	I-59808	C-5	A	4.4	32.6	53.1	9.0	5.0	70.4	1.2	13.1	0.4	9.9	12,300	½	Includes 2 in. clay parting.
		sec. 20			B	---	34.1	55.5	10.4	4.7	73.6	1.3	9.5	0.5	10.4	12,860		
					C	---	38.0	62.0	---	5.3	82.1	1.4	10.7	0.5	---	14,350		
6	43	--do---	I-59809	C-6	A	3.8	30.2	46.7	19.3	4.5	62.1	1.2	12.6	0.3	19.3	10,850	½	Upper part of 85.6-in. bed
					B	---	31.4	48.6	20.0	4.3	64.6	1.2	9.6	0.3	20.0	11,280		includes two 1 in. clay
					C	---	39.2	60.8	---	5.3	80.7	1.5	12.2	0.3	---	14,110		partings.
7	42	--do---	I-59810	C-7	A	5.9	32.1	51.0	11.0	5.0	67.3	1.2	15.1	0.4	11.0	11,750	½	--------------------------
					B	---	34.1	54.2	11.7	4.6	71.5	1.3	10.5	0.4	11.7	12,490		
					C	---	38.6	61.4	---	5.2	81.0	1.5	11.9	0.4	---	14,140		
9	40	NE¼SE¼	I-59811	C-8	A	3.2	34.7	50.2	11.9	5.0	69.4	1.4	12.0	0.3	11.9	12,240	2	--------------------------
		sec. 17			B	---	35.8	51.9	12.3	4.8	71.7	1.5	9.3	0.4	12.3	12,650		
					C	---	40.9	59.1	---	5.5	81.8	1.7	10.6	0.4	---	14,430		
9	63	SW¼SE¼	I-59812	C-9	A	4.9	36.2	56.0	2.9	5.4	75.4	1.6	14.4	0.3	2.9	13,220	2	--------------------------
		sec. 8			B	---	38.0	59.0	3.0	5.1	79.3	1.6	10.7	0.3	3.0	13,910		
					C	---	39.2	60.8	---	5.2	81.8	1.7	11.0	0.3	---	14,340		
10	67	SE¼NW¼	I-59813	C-10	A	5.3	36.0	52.7	6.0	5.3	71.8	1.6	15.0	0.3	6.0	12,250	2	Includes 1 in. clay parting.
		sec. 8			B	---	38.0	55.7	6.3	5.0	75.7	1.7	10.9	0.3	6.3	13,220		
					C	---	40.5	59.5	---	5.3	80.8	1.8	11.7	0.4	---	14,110		
10	62	--do---	I-59814	C-11	A	6.2	35.2	54.6	4.0	5.3	72.1	1.5	16.7	0.4	4.0	12,460	0	Sampled downstream from above.
					B	---	37.5	58.2	4.3	4.9	76.9	1.6	11.9	0.4	4.3	13,280		
					C	---	39.2	60.8	---	5.2	80.3	1.7	12.4	0.4	---	13,880		
14	109	SE¼SW¼	I-59815	C-12	A	5.8	28.9	45.7	19.6	4.5	58.5	1.0	16.1	0.3	19.6	10,160	0	Includes 2 in. silt parting.
		sec. 6			B	---	30.7	48.4	20.9	4.1	62.1	1.1	11.5	0.3	20.9	10,790		
					C	---	38.7	61.3	---	5.2	78.5	1.4	14.6	0.3	---	13,630		

the same coking characteristics as bed 1. It is noteworthy that a 9-foot coal bed sampled at the surface and also by core drilling near Cape Beaufort showed no coking characteristics in the surface sample but had "significant coking properties" in the core sample (R. S. Warfield, written commun., Feb. 1968). This could indicate that at least some of the beds in the township other than beds 1 and 2 may have more promising coking possibilities at depth.

Coal reserves were calculated on the following basis: measurable coal is assumed to extend back from the outcrop (downdip and laterally) for half a mile; indicated coal extends from the outer limits of measured coal to 1½ miles from the outcrop; inferred coal lies outside the limits of indicated coal and extends to a depth of 3,000 feet, to the axis of the syncline, or to 3 miles from the outcrop, whichever is closer to the outcrop.

The 20-foot bed (bed 1) comprises 45 percent of the total reserves in all categories in the township and about 50 percent of measured reserves (table 2). This assumes an average thickness of 20 feet. The total thickness in the large outcrop in the east bank of the river is 21.6 feet (Warfield and others, 1966). Robbins measured 23 feet 8.5 inches in the tunnel in 1954. About 22 feet of coal was encountered in the small diameter hole drilled during the present investigation. The thickness in the Bureau of Mines' holes west of the Kukpowruk River ranges from 18.0 to 19.4 feet.

On the basis of 10 feet of overburden to 1 foot of coal stripping ratio, strippable reserves in the township are estimated to be 19,932,000 tons of which 14,066,000 tons are in bed 1. It is assumed that the part of bed 2 overlying the strippable part of bed 1 would be recovered in mining bed 1. Other beds containing strippable reserves are beds 6 and 7, if mined together; bed 9, assuming that it rises beneath the terrace gravels east of the river as suggested by attitudes measured at the river; and beds 13 and 14, if mined together. The tonnage of strippable reserves for each bed is as follows:

TABLE 2.--Coal reserves of T. 1 S., R. 44 W., Umiat principal meridian, Kukpowruk coal field, Alaska (in thousands of short tons).

Coal bed	Overburden (ft)	Measured 1.2-2.3 ft (14-28 in.)	Measured 2.3-3.5 ft (28-42 in.)	Measured >3.5 ft (>42 in.)	Indicated 1.2-2.3 ft (14-28 in.)	Indicated 2.3-3.5 ft (28-42 in.)	Indicated >3.5 ft (>42 in.)	Inferred 1.2-2.3 ft (14-28 in.)	Inferred 2.3-3.5 ft (28-42 in.)	Inferred >3.5 ft (>42 in.)	Total reserves--all categories 1.2-2.3 ft (14-28 in.)	Total reserves--all categories 2.3-3.5 ft (28-42 in.)	Total reserves--all categories >3.5 ft (>42 in.)	Total
A	0-1,000	366	--------	--------	689	--------	--------	819	--------	--------	1,874	--------	--------	1,874
	1,000-2,000	68	--------	--------	1,410	--------	--------	2,025	--------	--------	3,503	--------	--------	3,503
	2,000-3,000	0	--------	--------	590	--------	--------	2,947	--------	--------	3,537	--------	--------	3,537
B	0-1,000	561	--------	--------	820	--------	--------	1,064	--------	--------	2,445	--------	--------	2,445
	1,000-2,000	0	--------	--------	1,710	--------	--------	1,906	--------	--------	3,616	--------	--------	3,616
	2,000-3,000	0	--------	--------	330	--------	--------	2,830	--------	--------	3,160	--------	--------	3,160
C	0-1,000	754	--------	--------	1,523	--------	--------	0	--------	--------	2,277	--------	--------	2,277
	1,000-2,000	0	--------	--------	2,172	--------	--------	3,590	--------	--------	5,762	--------	--------	5,762
1 (20-ft	0-1,000	--------	--------	36,108	--------	--------	55,690	--------	--------	57,440	--------	--------	149,238	149,238
bed)	1,000-2,000	--------	--------	0	--------	--------	35,920	--------	--------	46,600	--------	--------	82,520	82,520
2	0-1,000	--------	1,720	--------	--------	2,145	--------	--------	0	--------	--------	3,865	--------	3,865
	1,000-2,000	--------	0	--------	--------	4,495	--------	--------	5,890	--------	--------	10,385	--------	10,385
3	0-1,000	--------	2,480	--------	--------	7,194	--------	--------	3,124	--------	--------	12,798	--------	12,798
	1,000-2,000	--------	0	--------	--------	3,642	--------	--------	7,055	--------	--------	10,697	--------	10,697
4	0-1,000	--------	--------	1,920	--------	--------	6,520	--------	--------	15,520	--------	--------	23,960	23,960
5	0-1,000	--------	1,126	--------	--------	2,890	--------	--------	7,210	--------	--------	11,226	--------	11,226
6	0-1,000	--------	--------	2,301	--------	--------	5,700	--------	--------	13,300	--------	--------	21,301	21,301
7	0-1,000	--------	--------	1,801	--------	--------	4,340	--------	--------	9,600	--------	--------	15,741	15,741
8	0-1,000	1,025	--------	--------	5,010	--------	--------	1,014	--------	--------	7,049	--------	--------	7,049
9a (3.2 ft)	0-1,000	--------	2,550	--------	--------	4,465	--------	--------	1,360	--------	--------	8,375	--------	8,375
9b (5.2 ft)	0-1,000	--------	--------	4,820	--------	--------	7,360	--------	--------	1,050	--------	--------	13,230	13,230
10	0-1,000	--------	--------	6,260	--------	--------	10,890	--------	--------	0	--------	--------	17,150	17,150
11	0-1,000	885	--------	--------	4,430	--------	--------	3,325	--------	--------	8,640	--------	--------	8,640
12	0-1,000	--------	1,098	--------	--------	2,990	--------	--------	3,970	--------	--------	8,058	--------	8,058
	1,000-2,000	--------	--------	--------	--------	2,710	--------	--------	2,660	--------	--------	5,370	--------	5,370
13	0-1,000	--------	1,095	--------	--------	2,925	--------	--------	1,120	--------	--------	5,140	--------	5,140
	1,000-2,000	--------	0	--------	--------	2,855	--------	--------	2,900	--------	--------	5,755	--------	5,755
14	0-1,000	--------	--------	3,465	--------	--------	9,270	--------	--------	3,560	--------	--------	16,295	16,295
	1,000-2,000	--------	--------	0	--------	--------	9,070	--------	--------	9,200	--------	--------	18,270	18,270
15	0-1,000	569	--------	--------	1,420	--------	--------	640	--------	--------	2,629	--------	--------	2,629
	1,000-2,000	0	--------	--------	1,390	--------	--------	1,870	--------	--------	3,260	--------	--------	3,260
16	0-1,000	--------	1,036	--------	--------	3,210	--------	--------	950	--------	--------	5,196	--------	5,196
	1,000-2,000	--------	0	--------	--------	3,800	--------	--------	10,140	--------	--------	13,940	--------	13,940
	2,000-3,000	--------	0	--------	--------	0	--------	--------	6,690	--------	--------	6,690	--------	6,690
Total, township	0-1,000	4,160	11,105	56,675	13,892	25,819	99,770	6,862	17,734	100,470	24,914	54,658	256,915	336,487
	1,000-2,000	68	0	0	6,682	17,502	44,990	9,391	28,645	55,800	16,141	46,147	100,790	163,078
	2,000-3,000	0	0	0	920	0	0	5,777	6,690	0	6,697	6,690	0	13,387
Grand total		4,228	11,105	56,675	21,494	43,321	144,760	22,030	53,069	156,270	47,752	107,495	357,705	512,952

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Bed		Tons
1	------------------	14,066,000
2	------------------	661,000
6	------------------	679,000
7	------------------	291,000
9	------------------	2,540,000
13 and 14	------------------	1,695,000
	Total -----	19,932,000

The remaining beds are not thick enough and dip too steeply to be economically recoverable by stripping.

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