UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

GEOLOGY AND COAL RESOURCES OF T. 6 S., R. 51 W., UNSURVEYED, UMIAT PRINCIPAL MERIDIAN, IN THE CAPE BEAUFORT COAL FIELD, NORTHWESTERN ALASKA

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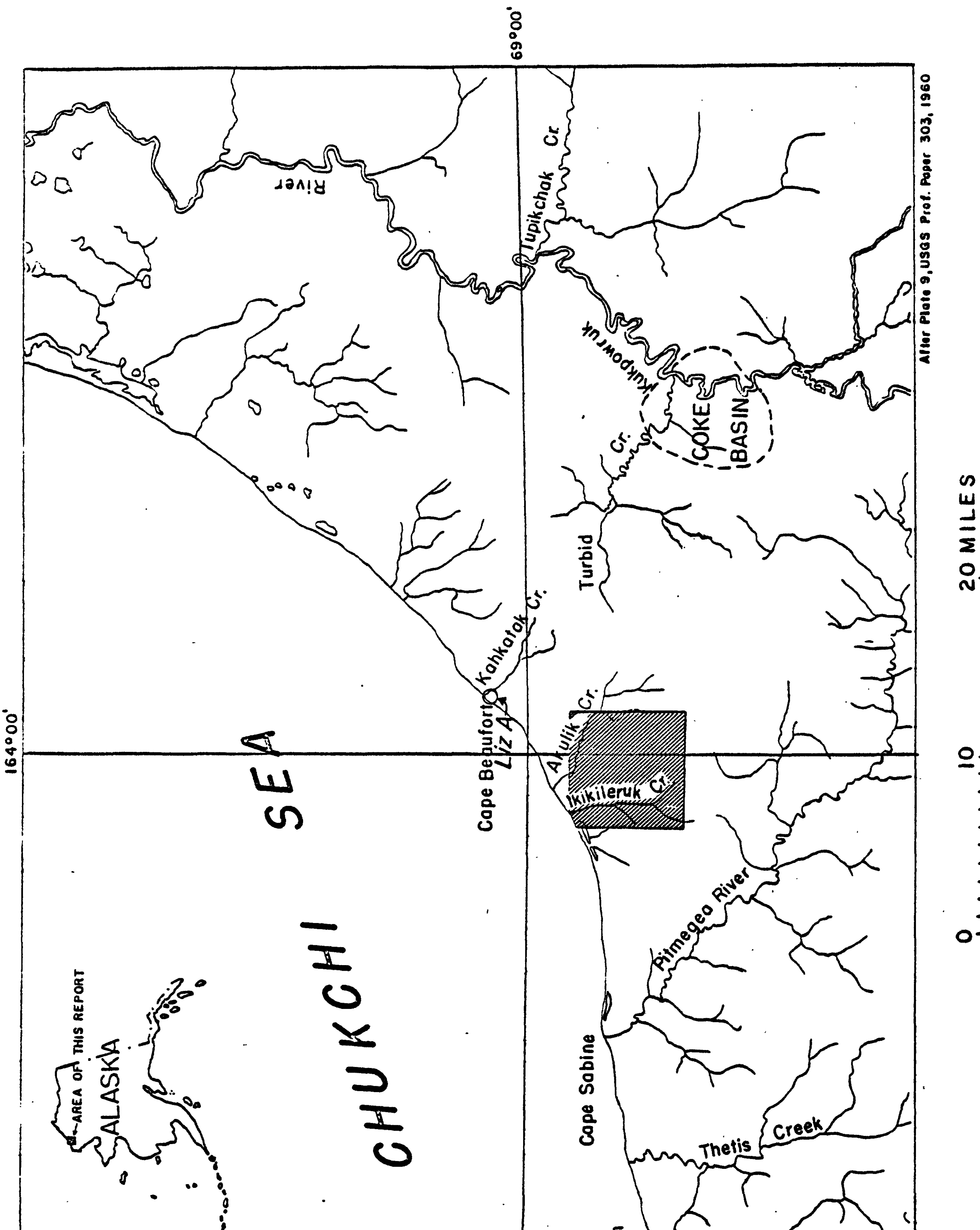
INTRODUCTION

Surface geologic mapping was done during the summer of 1969 in T. 6 S., R. 51 W., Umiat principal meridian, along the coast of the Chukchi Sea from about 6 miles north to 10 miles south of Cape Beaufort, Alaska. The northeast corner of T. 6 S. is 5 miles southwest of the abandoned Liz A DEWline site at Cape Beaufort (fig. 1) and about 10 miles south-southwest of Point Lay, the nearest permanently inhabited community. The township lies within the northern section of the Arctic Foothills physiographic province (Wahrhaftig, 1965).

The area mapped consists of the onshore portion of a northeast-trending double-plunging closed syncline, informally named the Liz A syncline. Mapping was concentrated mainly on the area underlain by the coal-bearing Corwin Formation of Cretaceous age. Bedrock is poorly exposed, especially in the northern part of the area, and drilling will be required to satisfactorily evaluate the coal resources of the syncline. The coal-bearing rocks are exposed sufficiently well at three localities in the southern part of the Liz A syncline to permit a reasonably accurate estimate of coal resources within the northern third of T. 6 S.

The land surface, which rises gradually from sea level in the northwest corner of the township to an altitude of 600 or 700 feet across the central part, reflects the more resistant character of sandstone of the Kukpowruk Formation relative to the overlying less resistant coal-bearing Corwin Formation. The general southeasterly rise of the land surface is interrupted by a broad eastward-trending belt of country underlain by the Torok Formation which is composed mainly of soft claystones and siltstones. South of this belt the terrain rises fairly abruptly to altitudes of 900-1,300 feet in areas underlain by the sandstones of the Kukpowruk Formation.

Akulik Creek, a relatively large stream with a drainage area of more than 40 square miles, flows west and northwest across the northeastern part of the township. Ikikileruk Creek flows north through the western third of the township and has a drainage area of less than 20 square miles. The lower courses of both streams are braided, and low



69°00'
164°00'
CHUKCHI SEA
AREA OF THIS REPORT
ALASKA
River
Iupikchak Cr.
Kukpowruk
COKE BASIN
Turbid Cr.
Kahkatak Cr.
Cape Beaufort
Liz A
Akulik Cr.
Ikikileruk Cr.
Pitmegea River
Cape Sabine
Thetis Creek
Corwin Bluff
0 10 20 MILES
After Plate 9, USGS Prof. Paper 303, 1960

stream terraces, generally less than 5 feet above water level, are present along both streams. Low beach terraces are present near the coast in the northwesternmost part of the township. These terraces exhibit the development of polygonal ground which is characteristic of flat poorly drained areas underlain by permafrost.

PREVIOUS INVESTIGATIONS

Coal was first reported in the Cape Beaufort area by A. J. Collier of the Beechey Expedition of 1826 and 1827 (Collier, 1906, p. 6). Whaling ships used coal from the Corwin Bluff, which is on the coast about 32 miles southwest of Cape Beaufort, during the latter part of the 19th century, and an attempt was made to develop a mine in that locality about 1884. Some coal was mined at Corwin Bluff and shipped to Nome in 1900 and 1901. Schrader (1904) of the U.S. Geological Survey visited Corwin Bluff in 1901. Collier (1906) mapped the geology along the coast and investigated the coal resources, including those at Cape Beaufort, in 1904. Between 1923 and 1926, mapping was done along the Kukpowruk, Kokolik, and Utukok Rivers northeast of Cape Beaufort (Paige and others, 1925; Smith and Mertie, 1930). In 1947 and 1949-53 the Geological Survey mapped a large area extending from Corwin Bluff to the Utukok River. The mapping consisted of boat traverses down the major rivers and foot traverses along the coast. Inland areas between the rivers were mapped on photographs. The type section of the Corwin Formation at Corwin Bluff was measured during that investigation (Chapman and Sable, 1960).

In recent years, investigations have been concentrated mainly on the coal deposits along the Kukpowruk River, about 40 miles northeast of T. 6 S., R. 51 W. The main interest has been in a 20-foot coal bed of proven coking quality. The U.S. Bureau of Mines drilled and trenched this thick bed on the Kukpowruk River (Warfield and others, 1966; Warfield and Boley, 1969). In addition, the Bureau of Mines trenched and sampled coal beds along Kahkatak Creek, southeast of Cape Beaufort, about 3-4 miles northwest of T. 6 S. One of the coal beds, approximately 2 miles above the mouth of Kahkatak Creek, was drilled to obtain unweathered samples for comparison with the trench sample. The Geological Survey did surface mapping along the Kukpowruk River in T. 1 S., R. 44 W., Umiat principal meridian, during 1966 and 1967 and made reconnaissance investigations in the two adjoining townships to the east (Callahan and others, 1969). Smiley (1969) made a comprehensive investigation of the flora of the Cretaceous rocks of the western Arctic Slope of Alaska.

GENERAL GEOLOGY

The mapped area is near the trough line of the Colville geosyncline, a depositional basin that persisted from early Mesozoic through Late Cretaceous time (Miller and others, 1959). Sedimentary rocks exposed in the region range in age from Jurassic to Late Cretaceous and are unconformably overlain by Pleistocene and Holocene surficial deposits of marine and nonmarine origin. Structurally, the region is characterized by isolated broad synclines separated by persistent tightly folded or faulted anticlines. The synclines have strong relief due to the resistant nature of the Kukpowruk and Corwin Formations. The axial areas of the anticlines are generally breached to the Torok Formation, which produces little or no surface relief. T. 6 S. is bisected by the Sea View anticline, which separates the Liz A syncline from the Sea View syncline. The axis of the Liz A syncline crosses the northwest corner of the township; the axis of the Sea View syncline lies along the south boundary of the township. The geology of the southern part of the township is from Chapman and Sable (1960, pl. 8) with modifications based on limited field observations and improved topographic coverage. The coal-bearing rocks in the Sea View syncline were removed by erosion.

Stratigraphy

The Mesozoic rocks exposed in T. 6 S. are the Torok and Kukpowruk Formations of Early Cretaceous age and the Corwin Formation of Early and Late Cretaceous age. The Kukpowruk and the Corwin represent the Nanushuk Group in the western part of northern Alaska.

Smiley (1969, p. 2083-2084) subdivided the Corwin Formation at the type locality into three parts on the basis of floral record. The lower part is generally equivalent to the Torok Formation. The middle part is correlated with the Kukpowruk Formation and the lower part of the Corwin Formation on the Kukpowruk River. The upper part correlates with the middle part of the Corwin on the Kukpowruk River. In T. 6 S. thick sandstone beds mapped as Kukpowruk Formation by Chapman and Sable (1960) appear to shale out to the west, possibly in a transition to the shale member of the Corwin to which it is partly equivalent. The type locality of the Corwin Formation at Corwin Bluff is separated from T. 6 S. by an area of complex structure. It is impossible to trace the various members of the formation directly into the mapped area. Possible correlations discussed below are based on lithologic similarity.

Torok Formation

The type section of the Torok Formation is at Torok Creek and on the Chandler River about 300 miles east of T. 6 S. The formation underlies a continuous lowland belt south of the township that extends from the Pitmegea River on the west to the Utukok River on the east. The Torok also is present in many of the breached anticlines in the region, including the Sea View anticline in T. 6 S.

The Torok Formation is composed of clay shale and claystone, 10-15 percent siltstone, and small amounts of sandstone (Chapman and Sable, 1960, p. 73). The beds of shale and claystone are poorly to moderately indurated and are mostly medium gray to dark gray; they are generally noncalcareous. The siltstone beds are interbedded with shale. The beds are generally less than 6 inches thick, but some beds are as much as 2 feet thick and sequences of beds are as much as 20 feet thick. The sandstone, which is interbedded with shale and siltstone, is generally very fine grained, dirty, and moderately to well indurated. The relatively resistant sandstone and siltstone units in the Torok Formation are lenticular (Chapman and Sable, 1960, p. 74-75).

The full thickness of the Torok Formation is not exposed in the region near T. 6 S. Approximate thicknesses were computed by Chapman and Sable (1960, p. 75-76) from incompletely exposed sections. They computed the maximum and minimum thicknesses as 7,200 feet and 4,800 feet. The upper contact of the Torok with the Kukpowruk Formation is gradational and intertonguing.

The Torok Formation is equivalent in age to the silty shale and lower sandstone members of the Corwin Formation at Corwin Bluff (Smiley, 1969, p. 2084-2085). The upper part of the rocks mapped as the Torok Formation in the central part of the township are believed to be equivalent and transitional to the silty shale member.

Within the general region of the report, diagnostic megafossils are lacking, and most of the microfossils identified are also found in the overlying Kukpowruk Formation. However, the stratigraphic position of the Torok Formation, between the Fortress Mountain and Kukpowruk Formations, indicates a late Early Cretaceous age (Chapman and Sable, 1960, p. 77-82).

Kukpowruk Formation

The type section of the Kukpowruk Formation is on the Kukpowruk River about 40 miles northeast of T. 6 S. The formation crops out in the township along the north and south flanks of the Sea View anticline. The sandstone and siltstone beds of the Kukpowruk Formation are well indurated and form resistant ledges that on aerial photographs show as distinct features, many of which are traceable for several miles.

The Kukpowruk was deposited mainly under marine inshore conditions. Some rocks of a marine offshore facies are present, and in the upper part of the formation the rocks are transitional to a nonmarine coastal facies that reached its full development in the lower members of the Corwin Formation (Chapman and Sable, 1960, p. 84). Part of this transition appears to take place laterally from the south and east toward the north and west in the area of T. 6 S. Resistant sandstone beds typical of the Kukpowruk are present in the north limb of the Sea View anticline in the extreme eastern part of the township, but they seem to become more fine grained westward across the center of the township.

The formation is made up of 65-80 percent interbedded shale and claystone and 20-35 percent thick interbeds of sandstone, conglomeratic sandstone, and siltstone. Exposures of the formation within T. 6 S. are limited. A sequence of rocks representative of the transitional zone is exposed along a small lagoon about 1¼ miles west of the township. These were mapped as Kukpowruk Formation by Chapman and Sable (1960, pl. 8), but they contain numerous plant remains, including a florule described by Smiley (1969, p. 2083) as being correlative with basal Corwin florules on the Kukpowruk River. This sequence is composed of 30-40 percent fine- to medium-grained sandstone interbedded with 60-70 percent dark-gray siltstones. The sandstone is light brownish gray in the upper part of the sequence and becomes darker in the lower part. The sandstone is even bedded; individual beds range in thickness from ½ inch to 1½ inches in units as much as 30 or 40 feet thick. The siltstone weathers to a subdued light gray. Other exposures along the east flank of the Liz A syncline are lithologically similar to that described above. The siltstone, shale, and claystone beds generally have a brownish- or olive-gray hue; beds higher in the Corwin Formation are light gray and weather buff. The sandstone beds in the Kukpowruk Formation and the transitional zone are darker and weather to less vivid colors than the sandstone beds in the Corwin Formation. Current ripple marks are characteristic in the sandstone beds in the upper part of the Kukpowruk.

The thickness of the Kukpowruk Formation is variable throughout the region. The thickness is estimated to be about 4,600 feet in the eastern part of the township; possible maximum and minimum thicknesses are 5,000 and 3,700 feet. There is a progressive stratigraphic rise northeasterly at the base of the formation because of intertonguing with the upper part of the Torok Formation. Although the thickness varies locally, regionally there is a northeastward thinning of the formation from more than 5,000 feet in the Coke Basin, 20 miles southeast of the township, to about 2,000 feet on the Utukok River, about 100 miles east-northeast of the township (Chapman and Sable, 1960, p. 96).

A conspicuous sandstone that is traceable on the aerial photographs marks the base of the overlying Corwin Formation along the south flanks of the Liz A syncline to the northeast of T. 6 S. This sandstone trace disappears in sec. 12, but the projection of the base of the Corwin at this approximate stratigraphic position is carried through by reference to more continuous sandstone traces in the Corwin Formation.

On the basis of correlations of marine faunal assemblages in the Kukpowruk Formation with those from other areas of northern Alaska and Canada, the formation is considered to be no older than late Early Cretaceous (middle and upper? Albian) by Chapman and Sable (1960, p. 98). Smiley (1969, p. 2085) assigned a middle Albian age to the Kukpowruk and its equivalent, the shale member and the coal and sandstone member of the Corwin Formation.

Corwin Formation

Schrader (1904, p. 72) applied the name Corwin series to coal-bearing rocks exposed along the coast from Wainwright to Cape Lisburne. He assigned the rocks a Jurassic to Cretaceous age. Collier (1906, p. 27, 29) renamed the sequence near Corwin Bluff the Corwin Formation, and it was assigned to the Jurassic. The Corwin Formation as defined by Collier apparently included rocks of the Kukpowruk Formation of recent usage in the Corwin Bluff-Cape Beaufort region. Chapman and Sable (1960, p. 101) redefined the Corwin Formation to include only the nonmarine Mesozoic rocks of the western Arctic Slope and assigned it an Early and Late Cretaceous age.

The type section of the Corwin Formation extends along the shoreline of the Chukchi Sea for about 5 miles in each direction from Corwin Bluff, which is 25 miles west of T. 6 S. The sandstone beds in the Corwin Formation are less resistant to weathering than those in the Kukpowruk and result in somewhat gentler relief in outcrops. However, rubble derived from the sandstone beds shows continuous well-defined traces on aerial photographs. The areas underlain by less resistant rocks are generally covered by tundra, but frost heaving has locally caused bare areas of soil derived from claystone. Due to variations in color, the underlying strata can be traced through many of these soil areas.

Chapman and Sable (1960, p. 105) divided the Corwin Formation at the type locality into seven lithologic members that, in descending order, are: (1) upper sandstone member, 4,141 feet thick; (2) bentonitic clay member, 2,767 feet thick; (3) conglomerate member, 635 feet thick; (4) coal and sandstone member, 1,407 feet thick; (5) shale member, 1,238 feet thick; (6) lower sandstone member, 2,685 feet thick; and (7) silty shale member, 2,621 feet thick. The members of the formation described at Corwin Bluff cannot all be recognized elsewhere in northwestern Alaska. However, Smiley (1969, p. 2081-2083) presented floral evidence that the upper sandstone member is a duplication of parts of the lower sandstone, shale, and coal and sandstone members. Smiley also shows structural and lithologic evidence for a repetition of these parts of the section.

The proportion of claystone, shale, and thin-bedded siltstone seems to increase northward from Corwin Bluff, and the proportion of sandstone, conglomeratic sandstone, conglomerate, and thick-bedded siltstone decreases (Chapman and Sable, 1960, p. 102).

The total thickness of the formation is 15,494 feet. Measured sections of the Corwin Formation at inland localities north and east of the type locality indicate an eastward and northward thinning of the formation. This thinning is similar to the thinning in the Kukpowruk Formation. Evidence of regional thinning of the Corwin is not well established because most of the measured sections are incomplete. The maximum thickness of the Corwin outcropping on the south limb of the Liz A syncline could be as much as 10,000 feet onshore, and an even greater thickness is possible offshore. Between 6,000 and 7,500 feet of the formation is present in T. 6 S.

A partial stratigraphic section (stratigraphic sections, pl. 1) of rocks almost continuously exposed was measured along the south shore of the lagoon in sec. 6. The rocks on Akulik Creek in secs. 2 and 3 were partly measured; some thicknesses were inferred from mapped positions of key sandstone and coal beds. A third stratigraphic section is constructed from the mapped positions of isolated exposures on Ikikileruk Creek, mainly to support the correlation between the lagoon and Akulik Creek sections. The sandstone associated with lagoon coal bed I is traceable to the sandstone overlying the 8.5-foot bed on Ikikileruk

Creek, and by projection parallel to other sandstone traces it appears to carry through to the sandstone overlying the lowermost thick coal (7.2 ft) in the Akulik Creek section.

Above lagoon coal bed I, the stratigraphic sections at the lagoon and on Akulik Creek can be correlated reasonably well, particularly the two coal zones comprised of lagoon beds A through E and F through O, which appear to be equivalent to the upper four and lower six beds on Akulik Creek, respectively. The almost identical coal analyses of the upper thick bed on Akulik Creek and lagoon bed B (table 1) constitute additional evidence for this correlation.

The lagoon stratigraphic section and the correlative section on Akulik Creek may be thickened equivalents of the coal and sandstone member of the Corwin type section, although the coal beds at these two localities are thicker and more numerous than shown for this part of the type section (Chapman and Sable, 1960, pl. 17). Below the Akulik Creek section, discontinuous exposures along Akulik Creek are composed of dark-gray to gray claystone, silty claystone, carbonaceous shale, siltstone, thin-bedded lenticular coal beds, and coaly streaks in shale. These rocks occupy a stratigraphic interval of about 2,400 feet above the sandstone chosen as the base of the Corwin Formation in sec. 12, and they are possibly equivalent to the shale member of the Corwin Formation at the type locality.

The stratigraphic section at the lagoon is comprised of about 62 percent claystone and silty claystone, 30 percent very fine grained and fine-grained sandstone, 5 percent siltstone, and about 3 percent coal. The sandstone is massive to thin bedded and generally light gray to medium gray and weathers light buff to bright orange. Crossbedding is common. A small percentage of the sandstone grades from fine grained to medium grained. Conglomerate rubble was observed locally south of the middle part of the section. Plant fragments, scattered carbonaceous particles, and carbonaceous laminae are common in the sandstone. The claystone in the lagoon section is generally medium gray to dark gray. The claystone is poorly indurated and generally very soft and sticky (bentonitic?) where associated with coal beds.

In the lower part of the formation (shale? member) along Akulik Creek, the claystone and silty clay is better indurated than in the coal-bearing unit. Hackly to nodular weathering is common, and brownish- and olive-gray colors predominate. The claystone is interbedded with thin-bedded fine-grained to very fine grained gray sandstone and medium-gray siltstone. Ironstone nodules and plant fragments are common in all exposures of this part of the formation.

Quaternary deposits

Collier (1906, p. 32-34) described unconsolidated deposits of probable Pleistocene age along the coast east of Thetis Creek. The deposits consist of silt and ground ice overlain by peat and tundra vegetation. Similar deposits occur discontinuously along the shore southwest of Cape Beaufort, underlying terraces from 5 to 50 feet above sea level. The terraces extend back from the shoreline as much as three-fourths of a mile, and the deposits are well exposed in sea cliffs between Cape Beaufort and the mouth of Akulik Creek. The cliffs are not present along the shoreline in T. 6 S.; however, the broad flat area northeast of the lagoon in sec. 5 is poorly drained and contains frost polygons, indicating the probable presence of frozen silt and ground ice.

Most of the area mapped as bedrock has a thin cover of surficial material consisting of sandstone rubble along the ridges and frozen silty soil between the ridges. Rounded pebbles and cobbles of chert were observed along the top of the ridge in sec. 1. These may be remnants of gravel which form high-level terraces elsewhere in the region (Chapman and Sable, 1960, p. 128). The areas in which this material was observed are small and isolated and display no recognizable topographic expression.

The lower courses of Akulik and Ikikileruk Creeks are braided and contain coarse sand to cobble-size material derived from the underlying consolidated rocks. The gravels are angular to subround. The beach deposits are subangular to round and range from medium sand to small cobble size. They include a variety of rock types derived from sources outside the Utukok-Corwin region.

Structure

The Sea View and Liz A synclines are typical of the broad open synclines occurring in the Cretaceous rocks of northwest Alaska from T. 6 S. eastward as far as the Colville River. West of the township the structure is more complex, involving major northwest-trending thrust faults and associated small folds. The steep dips and the abrupt change in strike of beds of the Corwin Formation in secs. 6 and 7 are probably related to this complex structure.

The Sea View syncline was not mapped in the field. Photogeologic interpretation by Chapman and Sable (1960, pl. 8) indicates that the syncline is a broad open fold and dips do not exceed 20° on either limb. Resistant sandstone beds of the Kukpowruk Formation form a mesalike topographic expression in the syncline.

The Sea View anticline is asymmetrical, as indicated by the wide disparity in dips between the north limb of the Sea View syncline and the south limb of the Liz A syncline, where dips are as much as 53° N. The axial area of the anticline is low lying and featureless due to the lack of resistant beds in the Torok Formation.

Dips on the south limb of the Liz A syncline increase from north to south, resulting in a narrowing of the outcrop belt of the Corwin Formation to the southwest. Dips across the strike are variable in the northeastern part of the syncline, but within T. 6 S. they appear to fall within a fairly narrow range of from 40° to 53°. West of the abrupt change in strike in sec. 7, the beds dip from 80° to vertical. Slickensides are common in the sandstone exposed along the lagoon. The evidence suggests that the rocks of the Corwin Formation in secs. 6 and 7 were deformed by thrusting from the west and that folding in the Cape Beaufort area was contemporaneous with the thrusting or that the thrusting could have slightly postdated the folding within the same period of orogeny (Chapman and Sable, 1960, p. 44).

COAL

Coal occurs throughout the Corwin Formation, but the thickest and greatest number of beds are in the lower sandstone, coal and sandstone, and bentonitic clay members, as indicated at the type locality.

In the Liz A syncline, all the significant coal beds appear to lie 2,000 or more feet above the base of the formation, above the probable equivalent of the shale member. Coal beds occur throughout the remainder of the Corwin section exposed in the Liz A syncline. Many of the beds were mapped over considerable distances on the basis of coal bloom; actual measurable exposures are rare, and only in the southwestern part of the syncline could thicknesses be established at more than one point on a bed.

Coal beds are exposed or were trenched at three localities within T. 6 S. (measured outcrop sections, pl. 1). Twelve beds were mapped along the shore of the lagoon in sec. 6. These are designated lagoon A through lagoon L. The outcrops of lagoon beds M, N, and O are just outside the township boundary, but the beds trend into the township.

Three coal beds were trenched on Ikikileruk Creek. The lowermost of these appears to correlate with lagoon bed I.

Ten beds were mapped on Akulik Creek in secs. 2 and 3. The coal occurs in an upper group of four beds and a lower group of six beds that correlate with lagoon beds A through E and lagoon beds F through O, respectively.

The upper exposed 4.4-foot bed on Ikikileruk Creek falls in a stratigraphic position that lies between the lagoon and Akulik Creek coal groups. No coal was found in this position in either of the last two localities.

The coal beds at the lagoon range in thickness from 16 inches to 10½ feet, with a total thickness of 58.9 feet including clay partings. All the beds have similar physical characteristics--platy or splintery fracture, irregular cleat, and generally bright luster. Surface coal samples from nine of the beds were analyzed by the U.S. Bureau of Mines. Lagoon beds E, J, L, and M are lignitic. The remainder are of subbituminous C rank (table 1).

In addition to the conventional analyses made by the Bureau of Mines, a petrographic study of the samples was made by Dr. P. D. Rao of the Mineral Industry Research Laboratory of the University of Alaska. Vitrinite in coal is the major coke-forming material. The rank of the vitrinite governs the development of the required plasticity during the coking process, and the rank of the material is defined by the percent reflectance in reflected light. The upper and lower limits of reflectance of vitrinite for the formation of coke are about 0.8 percent and 1.5 percent, respectively (Hankinson, 1965, p. 2). The percentage reflectance of vitrinite in polished sections of the coal samples from the lagoon are given in table 1. The figures represent an average of 50 readings of percent reflectance measured in oil. According to the limits set by Dr. Rao, the lagoon coals have a reflectance rank of subbituminous or high volatile C bituminous (R_o = 0.6 percent) to high volatile B bituminous (R_o = 0.6-0.8 percent).

Most of the coal beds contain thin partings and are overlain and underlain by sticky clay. Obvious partings were eliminated from the samples except where noted, but where the ground was frozen, partings were difficult to distinguish and the samples may include partings not noted. Additional clay may have been included from the clay beds overlying or underlying the beds because the coal-clay contacts in frozen ground are gradational.

The appearance and the quality of the three coal beds sampled on Ikikileruk Creek are similar to those of the lagoon beds, and the analyses of the lower two beds are comparable. The reflectance values are slightly higher, indicating a probable eastward increase in the quality of unweathered coal in the lower group of beds. Eight samples from the Akulik Creek section were analyzed by the Bureau of Mines, and percent reflectance of vitrinite was measured for these beds by Dr. Rao. The lower group of coal beds on Akulik Creek are of noticeably higher quality than the lagoon beds or those on Ikikileruk Creek even though the samples were taken from exposures subject to similar weathering conditions. The thick bed near the top of the stratigraphic section on Akulik Creek was sampled at two places about half a mile apart (samples 17 and 28). The analyses of the two samples are almost identical and are comparable within a percentage point on all components with the (air-dried) analysis of lagoon bed B, with which this bed appears to correlate.

The Bureau of Mines' analyses included coking tests; all the samples were found to be noncoking. Dr. Rao (written commun., Mar. 4, 1970) found sample 20 (table 1) to be the only one to be agglomerating, with a free-swelling index of 2. However, he stated that, on the basis of petrographic studies, unweathered coal from the Cape Beaufort area should have a minimum free-swelling index of 2. A sampling by the Bureau of Mines tends to support Rao's conclusion that some of the coals would have slight to moderate coking properties in the unweathered condition. In 1964 the Bureau of Mines sampled a 10.1-foot bed at the surface on Kahkatak Creek, about 6 miles northeast of the township. The bed contains bony coal and clay partings that leave a net coal thickness of 7.8 feet. None of the surface samples from the bed have coking properties. In 1966 a core sample of the same bed was taken from a drill hole at a depth of about 200 feet (Warfield and Boley, 1969, p. 40). The thickness of the bed in the hole is 10.7 feet with a 2.6-foot parting of bony coal and shale separating the coal. An upper part of the coal 1.5 feet thick has a free-swelling index of 1½, and a lower part 5.6 feet thick has a free-swelling index of 4½. In addition to the 10-foot bed, a 1.8-foot bed in the same drill hole was sampled at a depth of about 95 feet. This sample has a free-swelling index of 2. This bed was not sampled at the surface. A comparison of the chemical analyses of the lower six beds on Akulik Creek with the analyses of the two beds on Kahkatak Creek (Warfield and Boley, 1969, p. 54, 56) indicates a strong probability that these six beds will coke in the unweathered condition.

Coal resources

The coal resources (table 2) of T. 6 S. were computed using the following methods. Resources were not computed for beds less than 2½ feet thick because the thinner beds occur in association with beds of subbituminous or lower rank coals and are assumed to be of the same rank. Measured coal is considered to extend back from the outcrop and along strike for one-fourth mile from the point of measurement. Indicated coal is considered to extend from the outer limits of measured coal to a distance of 1½ miles from the outcrop except where correlation strongly suggests continuity over greater distance, as between the two coal zones on Akulik Creek and the lagoon in sec. 6. In this case, indicated coal is considered to extend toward the lagoon from Akulik Creek from the outer limits of measured coal to a distance of 2 miles from the outcrop and downdip to a depth of 3,000 feet. Conversely, if the continuity is doubtful, as it is on all beds northeastward from Akulik Creek, the indicated resources are limited to the extent of actual surface indications (bloom) of coal for the particular bed or group of beds. Inferred resources are considered to extend from the outer limit of indicated resources to a distance of 3 miles from the outcrop and downdip to a depth of 3,000 feet, except in the case where continuity is doubtful. Northeast of Akulik Creek, inferred resources are extended only half a mile beyond the last surface indication of coal for each bed or group of beds. For the purpose of resource calculation, the northward-dipping beds are considered to terminate at the southward projection of the vertical beds at the lagoon, and the vertical beds are considered to terminate at the subsurface projection of the northward-dipping beds. The thicknesses of the lower two beds on Ikikileruk Creek were averaged with that of the probable equivalent beds on Akulik Creek.

Estimated resources of strippable coal for each bed are shown in table 3. A stripping ratio of 10 feet of overburden for each foot of coal thickness was used in the computation.

Table 2 shows total resources in all categories. The recoverable resources would depend on the method of mining. A 50-percent recovery has been considered reasonable for underground mining in the past, and a 90-percent recovery is possible with strip mining. However, recent developments in techniques and equipment for underground mining have resulted in a much higher percentage of recovery in some areas.

The measured resources in table 2 are accurate within 20 percent. The inferred and indicated resources are probably conservative. The strippable coal resources shown in table 3 are for all beds with no consideration of workability. It is possible that strip mining on any of the coal beds in the township would not be economical because of the steep dips.

TABLE 3 - Coal resources, in thousands of short tons, of coal with less than 10:1 stripping ratio, T. 6 S., R. 51 W., U.P.M., Alaska

Coal bed	Measured			Indicated			Inferred			Total, all categories		
	2.5-5.0'	5.0-10.0'	Over 10'	2.5-5.0'	5.0-10.0'	Over 10'	2.5-5.0'	5.0-10.0'	Over 10'	2.5-5.0'	5.0-10.0'	Over 10'
Lagoon B 10.5'	----	----	106	----	----	45	----	----	----	----	----	151
Lagoon C 3.9	15	----	----	6	----	----	----	----	----	21	----	----
Lagoon E 2.9'	8	----	----	3	----	----	----	----	----	11	----	----
Lagoon F 2.9'	7	----	----	8	----	----	----	----	----	15	----	----
Lagoon G 4.7'	20	----	----	22	----	----	----	----	----	42	----	----
Lagoon H 2.9'	7	----	----	8	----	----	----	----	----	15	----	----
Lagoon I 8.9'	----	72	----	----	89	----	----	----	----	----	161	----
Lagoon J 2.8'	7	----	----	7	----	----	----	----	----	14	----	----
Lagoon L 4.7'	20	----	----	19	----	----	----	----	----	39	----	----
Lagoon M. 3.7'	3	----	----	11	----	----	----	----	----	14	----	----
Ikikileruk Creek 4.4'	23	----	----	128	----	----	95	----	----	246	----	----
Ikikileruk Creek 3.5'	14	----	----	8	----	----	----	----	----	22	----	----
Ikikileruk Creek 8.6'	----	75	----	----	510	----	----	----	----	----	585	----
Akulik Creek 8.0'	----	145	----	----	845	----	----	----	----	----	990	----
Akulik Creek 5.0	----	30	----	----	20	----	----	----	----	----	152	----
Akulik Creek 2.9'	10	----	----	61	----	----	45	----	----	116	----	----
Akulik Creek 6.9'	----	54	----	----	424	----	----	325	----	----	803	----
Akulik Creek 6.6'	----	50	----	----	386	----	----	285	----	----	721	----
Akulik Creek 4.3'	21	----	----	167	----	----	128	----	----	316	----	----
Akulik Creek 4.5'	25	----	----	150	----	----	----	----	----	175	----	----
Akulik Creek 7.2'	----	59	----	----	371	----	----	----	----	----	430	----
	180	485	106	598	2,645	45	268	712	----	1,046	3,842	151
TOTAL												5,039

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