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THE STRATIGRAPHY AND STRUCTURE OF THE OKPIKRURAK AND KIRUKTAGIAK RIVER AREAS, ALASKA

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By

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November 1949

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OF THE

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INTRODUCTION

Navy Oil Unit Party No. 4, during the summer field season of 1949, examined the surface geology of the area of the Okpikrurak and Kiruktagiak Rivers. The party consisted of six men: two geologists, two field assistants, a weasel mechanic, and a cook. Three weasels were used for transporation in the field.

The area covered is bounded on the west by the Okpikrurak River, on the east by the Chandler River, and on the south by the north front of the Brooks Range. Tuktu Bluff on the Chandler River and its westward extension forms the northern boundary. The area is drained by the Chandler, Kiruktagiak, Ayiyak, Okokmilaga, and Okpikrurak Rivers.

The objective of this summer's work was the geologic mapping and stratigraphic study of the rocks that crop out in this area. All outcrops were visited and the geology was plotted on vertical and tri-metrogon oblique aerial photographs. Altitudes were established by an altimeter traverse.

Parts of this area had been investigated previously by members of the Navy Oil Unit. During the summer of 1945 George Gryc, E. J. Webber, and Karl Stefansson visited outcrops along the Chandler and Kiruktagiak Rivers and in the vicinity of Castle Mountain.

In the same year L. A. Warner and C. E. Kirschner examined outcrops along the Okpikrurak River in conjunction with their survey of the Killik and Colville Rivers. R. L. Detterman included detailed stratigraphic studies of cut banks near the confluence of the Kiruktagiak and Chandler Rivers in his geological mapping ofthe lower Chandler during the summer of 1948.

TOPOGRAPHY

The Okpikrurak-Kiruktagiak River area lies wholly within the southern foothills section of the Arctic Foothills Province. The area can be divided into three physiographic belts that extend east-west across the area.

A high south-facing escarpment extends from Tuktu Bluff on the Chandler River across the northern margin of the area. Immediately south of this escarpment is a featureless lowland, 6 to 10 miles wide, broken only by a few low ridges adjacent to the scarp. The belt is underlain by the finer-grained, nonresistant members of the Torok unit, and outcrops are limited to cut banks.

To the south is a belt, five to ten miles wide, of long, east-trending, rubble-covered, hogback ridges, flat-topped bluffs; small, irregularly shaped buttes and knobs; and two massive mesalike synclinal mountains, Castle Mountain and Fortress Mountain. These features are topographic expressions of the infolded coarse clastic facies of the Torok unit, and of mafic igneous intrusives and Triassic cherts. The best outcrops in the Okpikruak-Kiruktagiak River area are in this belt which is referred to below as the Castle Mountain-Fortress Mountain infolded belt.

A gravel pediment of Late Tertiary or Pleistocene age lies between the infolded belt and the north front of the Brooks Range. Bedrock outcrops are limited to the valleys of incised rivers and a small dissected area south of Fortress Mountain.

The area has a maximum relief of approximately 1,400 feet; the highest point is the top of Castle Mountain, at an altitude of 3,726 feet.

GEOLOGY

Stratigraphy

The sedimentary rocks that crop out in the Okpikruak-Kiruktagiak River area are the Mississippian Lisburne limestone, the upper Triassic Shublik formation, and the Lower Cretaceous Killik group and the Lower Cretaceous part of the Nanushuk group.

Aside from gathering lithologic and faunal data, a concerted effort was made to determine the thicknesses and stratigraphic relationships of these lithologic units. The results of this work are set forth in the form of a composite stratigraphic column (Plates 2 and 3). It should be emphasized that, except for the Lisburne limestone, all thicknesses given are approximate. A large percentage of the rocks of the Killik group and Shublik formation are nonresistant and therefore not well exposed anywhere in the area. The complicated structure throughout most of the area made reliable thickness measurements on many of the better-exposed sections impossible.

The stratigraphic column presented is an assemblage of incomplete sections logged at various localities. Correlation between these sections was made on the basis of structure, gross lithologic features, maximum-minimum thickness measurements, and fossils. In view of the facies changes that occur, particularly in the Killik group, the column is not specifically applicable to any one locality.

Mississippian Rocks

Lisburne Limestone

The bulk of the Lisburne limestone is well-exposed long the north front of the Brooks Range. In the Okpikruruak-Kiruktagiak River area, however, exposures are limited to small isolated outcrops on the crests of breached anticlines.

The most extensively exposed section is about 1 mile north of the Range on the Kiruktagiak River and Monotis Creek, where 370 feet of Lisburne is exposed from the center of a breached anticline to the base of the overlying Triassic shales (Plate 2).

The lower 150 feet of this section is predominately a massive, gray-buff, crystalline, bioclastic limestone. This sequence is capped by an 8-foot bed of dark, bituminous or carbonaceous chert. On the basis of the lithologic characteristics and a scant fauna, A. L. Bowsher 1/ believes that this lower 150 feet can be tentatively correlated with the Alapah member of the Lisburne at Kanayut Lake which he described.

The upper 220 feet of this section consists of black, bituminous (?), phosphatic, cherty, and shaly limestones that carry a distinctive upper Mississippian fauna. No corresponding section has yet been recognized in the Brooks Range, although Bowsher 1/ reports finding a few phosphatic beds near the top of the Lisburne at Chandler Lake. Over much of the Range, erosion may have stripped away these less resistant beds. It is proposed on the basis of the distinct lithologic characteristics to call this unit the Kiruktagiak member of the Lisburne limestone. The stratigraphic position of this member with reference to the overlying Shublik formation and the underlying massive limestone (Alapah (?)) lead the writers to believe that it is younger than the Alapah member as described by Bowsher.

The bottom 40 feet of the Kiruktagiak member is poorly exposed and consists of gray-black phosphatic and bituminous (?) limestones and shaly limestones. Black, dense, ammonite-bearing calcareous concretions as much as 3 feet in diameter occur locally. These beds overlie the 8 foot chert bed of the lower massive Alapah member with no apparent discordance. The phosphatic zone is overlain by 175 feet of dark, cherty, bituminous (?) limestone, shaly limestone, and shale. This is capped by 5 to 6 feet of fossiliferous, pyritic, black shale. The contact with the overlying red and green shales of the Shublik formation is not exposed but there is no apparent discordance in dips between the two sections over the 30-to 100-foot covered interval which separates them.

A narrow belt of limestone crosses the Kiruktagiak Valley at The Notch where the Lisburne is exposed along the crest of an anticline. The exact stratigraphic sequence of the beds could not be deciphered because of structural complications, but several horizons of the Kiruktagiak member were recognized. Black phosphatic or bituminous (?) shales with hard, calcareous concretions were found to carry the same well-preserved small ammonite as occurred at the type locality. The shales appear to be overlain by dark, bituminous (?), cherty limestones.

Two narrow belts of Lisburne limestone extend east-west between the East and Middle Forks of the Okpikruruak River. They are marked by a series of sharp jagged ridges of black, bituminous (?) cherts and limestones. Although there are no exposures between the East Fork of the Okpikruruak and the Okokmilaga Rivers, outcrops of similar rocks on the Okokmilaga Valley indicate that these belts are probably continuous across the divide. The

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1/ Bowsher, A. L., personal communication.

fossils and lithology strongly suggest that these rocks belong to the Kiruktagiak member.

Numerous small exposures of Lisburne limestone crop out throughout the Okpikrurak-Kiruktagiak River area. Practically all, however, have been reduced to rubble and not enough data could be gathered to correlate them with known sections in the Brooks Range and on the upper Kiruktagiak River.

Upper Triassic Rocks

Shublik Formation

Triassic rocks are widespread south of the Castle Mountain-Fortress Mountain infolded belt, but exposures are limited to disconnected cut banks along the major streams or to scattered rubble ridges and low knobs in this belt of close folding. Isolated outcrops indicate another band of Triassic strata 1 to 3 miles north of Castle Mountain and Fortress Mountain.

Parts of the Triassic section are excellently exposed along the Middle Fork of the Okpikrurak River and also along Monotis Creek near the front of the Range. A composite section (Plate 2) established from these outcrops represents, as far as determinable, the minimum thickness of the Shublik formation in the Okpikrurak-Kiruktagiak River area. For descriptive purposes, the Shublik can be subdivided into two units on the basis of gross lithology: the lower unit of shales, cherts, and minor coarser clastics; and the upper unit of interbedded shales and siltstones.

The lower 310 feet of this section is composed of several varieties of shale. In stratigraphic order they are: 1) Basal, green, red, and dark-colored silt-clay shales and siltstones, 150 feet thick. 2) Black fissile shales with a zone of olive-drab bedded chert near the top, 80 feet thick. 3) Carbonaceous or bituminous shales, locally woody oil shales, calcareous paper shales, and minor fossiliferous limestone beds and lenses, 80 feet thick. The succeeding 150 feet of this lower section is dominantly a black, medium-bedded chert. Carbonaceous shale partings and thin interbeds are abundant. A 25-foot carbonaceous-calcareous shale break occurs in the upper part. Forty-five feet above the base of this chert sequence are two thin, persistent limestone beds that mark the first appearance of Pseudomonotis. A 20-foot zone of interbedded, dark- to medium-gray, finely crystalline limestones, cherty limestones, and oil shales cap this section.

Triassic rocks are exposed in numerous cut banks on the Middle Fork of the Okpikrurak River. A complete sequence from the top of the Lisburne to basal Killik is partly exposed on the north flank of an overturned anticline, $3\frac{1}{2}$ miles south of the junctions of the Forks. Here, the maximum possible thickness for the Triassic was computed to be 3,280 feet, of which the upper 450 feet is covered. Within this sequence, an outcrop of the Pseudomonotis-bearing limestone zone lies 480 feet above the top of the Lisburne and 520 below dark shales and siltstones of the upper unit. Thus, the thickness of the lower cherty unit of the Shublik formation is limited to 1,000 feet.

Parts of this section are exposed farther south along the Middle Fork. The sequence from older to younger is: (1) Black bedded cherts with minor carbonaceous or bituminous limestone beds; only the uppermost part of this sequence is well exposed. (2) A zone of limestone similar to the top beds described on Monotis Creek. (3) A 175-foot thickness of well-indurated, medium-gray to medium-green, locally calcareous siltstones, shales, and sandstones which are not readily distinguishable from basal Killik rocks. (4) A 250-foot section of green to medium gray, somewhat glassy, bedded cherts with a red shaly chert zone near the top.

Eighteen hundred feet of the upper unit of the Shublik is exposed on the limb of the anticline on the Middle Fork. Nearly the same thickness crops out along Ohkonagoon Creek. In both places the sections consist of an alternating series of well-indurated, hackly, dark, commonly purple or green shales; dark gray, purple-banded siltstones; and, locally, light gray to white, very fine grained sandstones. In the basal part the rocks are coarser, darker, and contain scattered carbonaceous fragments. The siltstones generally have rippled bedding surfaces and abundant scour casts. No fossils were found in either section. Several outcrops of these beds elsewhere are darker red and green, probably because of more intensive weathering. These rocks of the upper unit may be differentiated from younger rocks by their greater degree of induration, the lighter color, the cleaner character of the coarser facies and the scarcity of carbonaceous material.

Although the fossils collected from below the Pseudomonotis-bearing limestone zone in the cherty unit have not yet been identified, the strata of this lower unit have been assigned, on the basis of the upper Triassic age of the Pseudomonotis-bearing beds, to the Shublik formation. The general stratigraphic relationships of the upper unit are not certain because, apparently, these shale-siltstones have a restricted occurrence as a result of pre-Killik erosion. But in the localized area of exposure, no break in the depositional sequence from the lower to the upper units was recognized. Therefore, the upper shale-siltstone unit has been included with the lower cherty unit in the Shublik formation. Later microfossil and laboratory studies may furnish more conclusive evidence as to relationships of these beds.

Lower Cretaceous Rocks

Killik Group.

The rocks of Lower Cretaceous age in northern Alaska have been assigned to the Killik group and to the lower part of the Nanushuk group. To date, the stratigraphic studies of Lower Cretaceous rocks by the Navy Oil Unit have been confined largely to the Nanushuk group. This group has been subdivided into formations, members, and tongues and into time-rock units (zones A, B, C, etc.). The Killik, on the other hand, has never been satisfactorily subdivided in smaller mappable units.

As a result of their summer's work, the writers believe that the Killik can be broken down into three mappable units, at least, in the Okpikrurak-Kiruktagiak River area. These units are: the Aucella unit, the Shale unit, and the Torok unit. The classification is based on field studies alone. Subsequent laboratory studies of macro- and microfossils, heavy minerals and lithologic specimens may necessitate some modifications. Therefore it is not now feasible to assign formational or member status to these units.

In 1949, the zone A (Torok shales), formally part of the Killik group, was assigned to the Nanushuk group. Studies in the Okpikrurak-Kiruktagiak River area this summer indicate that it more logically belongs in the Killik group. The reasons for this change will be explained later.

Aucella Unit.

In the Okpikrurak-Kiruktagiak River area the Aucella unit crops out south of the Castle Mountain-Fortress Mountain infolded belt and in several places on the flanks of the Castle Mountain syncline. The unit most commonly crops out as long, low, rubble ridges but is best exposed in two cut banks on the Okpikrurak River and one on a tributary of the Kiruktagiak River.

The characteristics which distinguish the Aucella unit from the Shale and Torok units are: (1) the abundance of Aucella crassicolis Keyserling; (2) the cleaner, more quartzose character of the sandstones; (3) the scarcity of carbonaceous matter above the basal sandstones and conglomerates; (4) ripple and scour marks on the sandstones and siltstones; (5) iron-rich sandy limestone lenses and concretions which weather rusty brown; (6) the monotonous repetition of interbedded fine-grained sandstones, calcareous sandstones, siltstones, and shales throughout most of the sequence. On aerial photographs, outcrops of this unit cannot readily be distinguished from the overlying Torok unit.

In a cut bank on the Okpikrurak River a 2,000-foot section of the Aucella unit is chiefly a series of interbedded fine-grained, green, argillaceous sandstones, dark calcareous sandstones, and dark shales (Plate 3). The sandstones and calcareous sandstones make up about 60 percent of the section. Aucella occurs throughout. At the bottom of this sequence is 20 feet of coarse sandstone and chert-granule conglomerate. A 500- to 600-foot covered interval separates these beds from Shublik cherts. Thus, provided there is no major faulting, the Aucella unit here has a maximum thickness of 2,500 feet and a minimum thickness of 2,000 feet. Parts of the same section are exposed several miles to the south on the Middle Fork of the Okpikrurak where the maximum thickness was calculated to be 2,500 feet. Again the basal 500 feet are not exposed.

One mile south of Fortress Mountain, Shublik cherts are directly overlain by a 300-foot sequence of fine-grained, green and gray argillaceous sandstone with lenses of chert-pebble conglomerate and a 100-foot section of dark clay shale (Plate 3). The conglomerate consists of angular to subangular chert fragments, rounded oil shale pebbles, and scattered carbonized plant fragments in a fine-grained sandy matrix. Four specimens of Aucella were found in a conglomerate lens. This sequence is separated from Shublik cherts by a covered interval of 30 feet. At numerous other places south of the Castle Mountain-Fortress Mountain infolded belt, these basal sandstones have been infolded with Shublik shales and cherts. In addition to chert and oil shale, several of the conglomerates contain pebbles of crinoidal limestone (Lisburne), green, fine- to medium-grained mafic igneous rock, and green quartzite. Four miles south of Fortress Mountain, a zone of boulder conglomerate 20 feet thick rests directly on an irregular surface of Shublik chert. Although the relationships there are partly obscured, no great angular discordance is apparent.

In a cut bank on a tributary of the Kiruktagiak, about a mile north of The Notch, a 950-foot section of the Aucella unit is exposed (Plate 3). In this series of Aucella-bearing green argillaceous sandstone, calcareous sandstones, shales and siltstones, the proportion of shale is considerably greater than in the Okpikrurak section.

Based on the occurrence of Aucella crassicolis, the Aucella unit is assigned to Neocomian (lower Lower Cretaceous).

Shale Unit.

The Shale unit crops out on the flanks of the Castle Mountain and Fortress Mountain synclines and in a band 3 to 4 miles wide north of the Castle Mountain-Fortress Mountain infolded belt. Exposures are limited to cut banks of which the most extensive are along the Kiruktagiak and Chandler Rivers.

The unit is predominantly dark clay and silt shales. These shales cannot be readily distinguished from shales of the Torok unit or Aucella unit, but in the area studied it is a mappable unit because of its stratigraphic position between the underlying Aucella unit or Shublik formation and the overlying basal sandstones and conglomerates of the Torok unit.

Practically everywhere the shales have been intricately folded and, therefore, thickness measurements are difficult to obtain. On the Kiruktagiak River, west of Castle Mountain, however, a relatively uncomplicated section overlies Shublik cherts and shales and underlies basal Torok conglomerates and sandstones (Plate 3). Here the unit measured 1,750 feet in thickness and is composed of dark clay and silt shales with silty, somewhat septate, ellipsoidal concretions. Thin beds of fine-grained, green, argillaceous sandstones are scattered through the section; carbonaceous material and fossil wood are abundant.

In the band of Shale unit north of the Castle Mountain-Fortress Mountain infolded belt, lenses and concretions of limy siltstone that weather bright yellow-red are common.

A fossil fish skeleton of the Aspidorhynchidae family was found in an exposure of Shale unit on Torok Creek.

Torok Unit (Probable Killik Group).

The bulk of the Killik group rocks have been assigned to the Torok unit. More study, however, may reveal that a further breakdown of this great thickness is possible. The Torok unit is exposed in the Castle Mountain-Fortress Mountain infolded belt and just south of the Tuktu escarpment.

Briefly, the Torok unit consists of a thick series of dark shales, siltstones, graywackes 1/, and graywacke conglomerates that were deposited in a marine environment. The coarse clastic facies are concentrated along the southern margin of the Castle Mountain-Fortress Mountain infolded belt, but grade out into shales a short distance to the north. There are also appreciable facies changes in an east-west direction. No reliable stratigraphic horizon could be traced throughout the area. Fossils are scarce generally and nonexistent through much of the unit.

The only unbroken section of the Torok unit is at Castle Mountain. From the basal graywackes and conglomerates overlying the Shale unit to the top of the conglomerates which cap Castle Mountain, the section is 8,460 feet thick (Plate 3).

The basal graywackes and graywacke conglomerates at Castle Mountain were deposited on a scoured surface of the Shale unit. The basal section is approximately 650 feet thick and consists of medium- to coarse-grained, green graywackes with irregular lenses of chert-pebble and granule conglomerate. The section grades upward into shales. Carbonized plant fragments and oil shale pebbles are abundant. Inoceramus sp. was present locally.

In the Fortress Mountain area, the basal coarse clastic facies crops out on the Canoe Hills. Here the section consists of interbedded shales, graywackes, and graywacke conglomerates. In addition to chert these conglomerates contain cobbles and pebbles of gray, crystalline, bioclastic limestone, green diabase, green quartzite, black bituminous limestone, and wood fragments. These are imbedded in a highly argillaceous, poorly consolidated matrix which locally has shaly partings. At several horizons, large, subangular chunks of shales and siltstones are imbedded in the matrix.

1/ The graywackes are sandstone which contain, besides quartz, significant amounts of angular and subangular fragments of both non-resistant and resistant rocks and minerals set in a dark, highly argillaceous, and often calcareous, matrix. They are typically poorly sorted.

To the west on Okok Creek the basal coarse clastics are even more erratic. Angular chunks of graywacke, chert, and carbonized wood fragments are scattered at random through an irregularly bedded silt, shale, and graywacke matrix.

Outcrops of the same horizon occur on the Okokmilaga and Okpikruak Rivers. Lemuroceras was found at the latter locality.

In the Castle Mountain area, the basal conglomeratic section is overlain by a monotonous sequence, several thousand feet thick, of dark silt and clay shales with some fine-grained, green graywackes and siltstones. Aucellina was found in these shales at several localities on the Kiruktagiak River. This shale section is overlain by 900 feet of fine-grained graywackes with lenses of chert-granule and chert-pebble conglomerate. These beds are well exposed on Castle Creek but apparently grade into shales rather abruptly, as they were not recognized on the north side of Castle Mountain.

At least 3,000 feet of dark shales separate these coarse clastics from those which cap Castle Mountain. The few thin beds of graywacke and conglomerate scattered through these shales on the south side of Castle Mountain are not present on the north side.

On the southeast face of Castle Mountain the 3,000-foot sequence of shale is capped by 1,300 feet of coarse green graywacke and graywacke conglomerate. These conglomerates, like those below, are composed chiefly of subround chert pebbles in a graywacke matrix. Carbonaceous matter is abundant. Gray bioclastic limestone, black bituminous limestone, green quartzite, and pink, gneissic granite pebbles are common in the upper 800 feet. No white vein quartz pebbles were found.

A 1,500-foot section of the upper Torok unit was also measured three quarters of a mile to the north at the center of the Castle Mountain syncline. The upper part of this section differs little from the 1,300-foot section to the south. The lower part, however, is essentially dark shale. When the two sections are correlated by the direct tracing of beds, it is apparent that the lower 800 feet of the conglomerate in the southern section grades into shale within three quarters of a mile (Plate 3).

The Torok unit is also exposed in a belt, 3 to 4 miles wide, that extends east-west across the northern part of the area. The best outcrops are along the Chandler River where, in 1948, R. L. Detterman measured a sequence 4,160 feet thick between the underlying Shale unit and the overlying Tuktu sandstone (Plate 3). The 500 feet of green to gray graywacke and chert-granule conglomerate at the base of this section is believed to be correlative with the basal coarse clastics of the Torok unit at Castle Mountain. Several species of Lemuroceras and one Beudanticeras were found in these beds on the Chandler River by the writers. Between these graywackes and the Tuktu sandstones is about 3,000 feet of clay and silt shale with lenses and concretions of dark silty limestone.

The presence of Lemuroceras, Beudanticeras, and Aucellina in the Torok indicates an age of Albian (upper Lower Cretaceous).

Lower Part of Nanushuk Group.

Tuktu Sandstone Unit.

The Tuktu sandstone crops out along the northern boundary of the Okpikrurak-Kiruktagiak River area. As this unit has been studied in detail by several parties in the past, it was given only a cursory examination in 1949. On the Chandler River Detterman found it to be 1,040 feet of a fine- to medium-grained, argillaceous, locally fossiliferous, green sandstone. A few pebbles of white vein quartz appear in the upper half, and near the top are a narrow lens of quartz and chert-pebble conglomerate, coal, and several beds of yellow-red sandstone.

The Tuktu sandstone overlies the Torok unit. Everywhere a covered interval of from 50 yards to a half mile separates the two units. Near the contact the sandstones dip from 10° to 20° to the north, but the crenulated Torok shales dip on the average of 30° to 50° to the north. This discrepancy may indicate an angular unconformity or may have resulted from the relative competency of the sandstones and shales.

Igneous Rocks

The only igneous rock found in the Okpikrurak-Kiruktagiak area is fine-grained. With the exception of two large masses at Horseshoe Mountain and on the west side of the Kiruktagiak River 7 miles south of Horseshoe Mountain, the rock generally occurs as small scattered outcrops within the areas of Shublik exposures. Many exposures are small, pluglike bodies elongated parallel to the strike of the host strata. In several places, these separated exposures are alined, which probably indicates discontinuous intrusion along linear zones of weakness parallel to the regional trends. In numerous other places, sill-like relationships were were evident in the outcrop and areal plan: thin layers of the igneous rock alternate with thin beds of chert; tabular bodies, 20 to 50 feet thick and up to one-half mile long, parallel the strike of the country rock. The thicker masses, with the exception of Horseshoe Mountain, show similar elongation in the direction of regional trend.

No microscopic study of this season's collection has been made, but previous work has shown the rock to have a gabbro-basalt composition. Megascopically, the rock has a fine- to medium-grained, even texture and is dark green. Minor variations in texture and color were noted over the area, but there were no great differences in composition. Local changes in appearance are probably due to assimilation of country rock.

The outcrops of the igneous rock are deeply weathered because the feldspar breaks down readily, but they stand in slight relief because the rock as a whole resists erosion. The alteration of the feldspars to calcite and the subsequent leaching of the calcite commonly produce a porous texture.

The effect of the intrusive rock upon its host was generally slight, particularly in the cherts, shales, and sandstones. At The Notch, a tabular body 350 feet thick was intruded along the contact of Lisburne limestone and Shublik chert. The limestone near the contact has been recrystallized, silicified, and impregnated with veinlets of calcite.

The rocks appear to be intrusive everywhere except at Horseshoe Mountain, where some fine-grained and amygdaloidal textures are suggestive of extrusion. Thin-section studies are necessary before conclusions as to the relationships at Horseshoe Mountain can be made.

Nowhere was it established that the igneous rock is intrusive into Killik or younger strata. Pebbles and cobbles of mafic igneous rocks are present in the basal conglomerates of the Aucella and Torok units. On the evidence now available, the age of the intrusive activity would fall between post-Shublik and pre-Lower Cretaceous.

Structure

Orogenic movements associated with deformation of the east-trending Brooks Range are reflected in the Okpikrurak-Kiruktagiak River section of the foothills region by a complex series of folds, generally paralleling the strike of the mountain front. In contrast to the thrusting prevalent in the front of the Range, compressional stresses were here relieved more by folding than by faulting. The folding diminishes northward from the Range. A regional dip to the north prevails.

Between the front of the Brooks Range and the Castle Mountain-Fortress Mountain infolded belt, pre-Torok strata have been compressed into a myriad of short, sharp, overturned folds. The outcrop pattern resulting from this close folding is well-developed south of Fortress Mountain (Plate 1).

Several larger folds are exposed along the Kiruktagiak River and between the Middle and East Forks of the Okpikrurak. They could not be related across the interstream areas because of cover. The smaller folds appear to be secondary on these larger structures.

In the infolded belt, the Torok and Shale units have been warped into a broad syncline. Attitudes on the upper beds of the Torok unit, which occur at the top of Castle Mountain, are gentle and regular. Attitudes on older Torok strata west of Castle Mountain, however, show greater deformation, even across the center of the major syncline. In the area surrounding Castle Mountain, some basal Torok beds have been overturned and faulted. As there is no apparent major angular break within the Torok sequence, folding must have been progressive and, also, contemporaneous with deposition.

The general east trend of the large syncline is interrupted at several localities along the infolded belt. In each case, the western segment has been displaced northward relative to the segment east of the break in continuity. Over a distance of 15 miles, the cumulative effect of these offsets has been to displace the major synclinal axis at the Okpikrurak River 4 to 5 miles north of its position at Castle Mountain. Several major streams cross the infolded belt along lines that mark these offsets. Projections of the lines or zones that terminate the Fortress Mountain segment coincide with zones of north-south structures in the close-folded belt south of Fortress Mountain. The above evidence suggests that north-south zones of strong disturbances are present.

Two major faults are associated with the Castle Mountain of the infolded belt. South of Castle Mountain, the strike of basal Torok strata is discordant with the Triassic-Cretaceous contact. This discordance can be traced from the pediment gravel cover near the headwaters of Torok Creek westward to the lower reaches of Castle Creek and may be continuous to the Kiruktagiak-Ayiyak divide. South of Fortress Mountain, Torok directly overlies Shublik with no apparent discordance. South of Fortress Mountain, Torok conglomerates directly overlie Aucella and Shublik beds. Here, however, the unconformity beneath the Torok conglomerates at the west and northeast ends of Fortress Mountain is thought to account for the missing beds. As evidence is inconclusive, it is possible that these beds have been faulted out.

A narrow band of Triassic underlying the Torok and Shale units is exposed on the north limb of the major syncline in the Castle and Fortress Mountain segments. These cherts have been thrust against south-dipping Torok and Shale units to the north. Apparently, the fault does not extend to the Chandler River on the east nor to Fortress Creek on the west.

The lowland between the infolded mountains and the Tuktu escarpment is largely underlain by deformed strata of the Shale unit that were brought up on the crest of a broad anticlinorium. Crenulations and drag folds, broken by minor faults, in the incompetent shales have variable intensity and orientation. In general, their orientation is parallel to the regional east trends, with south dips steeper south of the axial trace and north dips steeper north of the axial trace.

That the large anticline has appreciable asymmetry is shown by the narrower exposure width of the Shale unit north of the fold axis. Although the beds are badly crenulated, over-all dips on the north flank are between 35° and 45°, and those on the north flank are between 40° and 55°. Either fold intensity diminishes rapidly north of this anticline or else an angular unconformity exists under the Tuktu unit, because, over a mile distance, dips decrease from 40° in the Torok to a prevailing 10° in the Tuktu.

Interpretations

Killik Group Rocks

The characteristics of the sediments of the Torok and Shale units indicate that they were deposited during a period of active earth movements.

The graywackes and graywacke conglomerates of the Torok are a heterogeneous accumulation of poorly sorted and slightly rounded, resistant and nonresistant rocks and minerals of several varieties. Their nature suggests that at the time of deposition a nearby rising land mass was being rapidly eroded and the detritus was being dumped into an actively sinking marine basin.

As already pointed out, the sediments in the Shale unit and in the lower part of the Torok unit are more deformed than those above. These rocks must have been subjected to active compressional stresses even during deposition.

Under these conditions of sedimentation, it might be expected that numerous small unconformities would develop. Several such breaks were observed in the Okpikrurak-Kiruktagiak area. North of Fortress Mountain, conglomerates of the Torok unit crop out very close to Shublik cherts. Apparently some of the Shale unit has been eroded away. On the west side of Fortress Mountain, conglomerates of the Torok lie unconformably on dark shales. A similar situation exists west of Castle Mountain. None of these unconformities could be traced very far.

No outcrops of the Shale unit or Torok unit were found south of the Castle Mountain-Fortress Mountain infolded belt. The concentration of coarse clastics along the southern margin of the infolded belt and the abrupt wedge out of these clastic members into shale proves that the source area and shoreline, during the time of deposition, were very close. It is doubtful that these marine sediments ever existed as far south as the Brooks Range. The Castle Mountain-Fortress Mountain infold may mark the location of a rapidly sinking offshore marine trough during upper Lower Cretaceous time. The infold, as it is now known, was in the process of formation during the time of deposition of Torok and Shale unit sediments.

The occurrence of Aucella unit strata a mile north of the Brooks Range indicates that the source for these sediments lay at least as far south as the present range.

As noted above there apparently was a break in deposition and a period of erosion following Aucella time. Based on fossil evidence, the extent of this break would be from Neocomian to Albian.

No such extensive break was noted between the Shale unit and the Torok unit. Minor unconformities between these two units were observed in several places, but from the base of the Shale unit to the top of the Torok the series is essentially continuous.

If further work on rocks of the Killik group proves that the Aucella unit-Shale unit unconformity is widely persistent in the Arctic Foothills Province, then the Killik group should be reclassified to give the Aucella unit an independent formational status.

Killik Group-Nanushuk Group Contact

The basal graywackes and conglomerates of the Torok unit at Castle Mountain have been correlated with the basal coarse clastics of the 4,160-foot section which R. L. Detterman measured at Tuktu Bluffs below the Tuktu sandstone. The two sections could not be correlated directly above the basal members.

White quartz pebbles occur in the upper half of the Tuktu sandstone, but no quartz pebbles were found in any of the conglomerates at Castle Mountain. It is assumed, therefore, that the top beds of the Torok unit at Castle Mountain are older than the upper half of the Tuktu sandstone and are probably older than the entire Tuktu. If this reasoning is valid, it would appear that the 1,460 feet of the Torok unit at Castle Mountain has thinned to less than 5,000 feet 13 miles to the north. This is not surprising in view of the abrupt northward wedge out of the coarse clastics at Castle Mountain. An unconformity at the base of the Tuktu sandstone unit would also account for the thinning.

In 1949 1/ the 4,160 feet of graywackes and shales that underlie the Tuktu sandstones at Tuktu Bluffs were included in the Nanushuk group as Zone A. In the same report the graywackes, graywacke conglomerates and shales in the lower part of the Torok unit in the Castle Mountain-Fortress Mountain infolded belt were described as Killik group rocks, and typical of "flysch" deposits as contrasted to the Nanushuk "molasse" type. Because the field studies in 1949 revealed that the shales and graywackes of the 4,160-foot section at Tuktu Bluff are correlative with typical "flysch"-type deposits, this section is distinct from the "molasse"-type of the Nanushuk group. Therefore this section should be included in the Killik group.

Significant Petroleum Features

1. Much of the dark, bituminous(?) limestone in the Kiruktagiak member of the Lisburne limestone has what is described as an "oil shale" odor. It is particularly noticeable on a freshly broken surface.

2. Oil shales are present in the lower cherty section of the Shublik formation. A 15-foot zone on Monotis Creek is the thickest section exposed.

3. Asphaltic material generally associated with vein calcite is common as fracture-fillings in both the Shale and Torok units. On Fortress Mountain, a Torok conglomerate bed consists of angular chert granules cemented by asphaltic material.

4. No good reservoir sandstones were recognized on field inspection. The cleanest sands appear to be those at the base of the Aucella unit.

1/ Payne, T. G., Geology of the Arctic Slope of Alaska; Oil and Gas Investigations Map 106; U. S. Geol. Survey, 1949.

SUMMARY

1. A 220 foot-section of dark, bituminous (?), cherty limestone and shale overlies the Alapah member of the Lisburne limestone. This section differs markedly from the Lisburne limestone below and, therefore, is named the Kiruktagiak member.

2. The upper Triassic Shublik formation is 3,280 feet thick; the age of the lower 1,000 feet of cherts, and shales is well established by fossils. The upper 2,280 feet of nonfossiliferous shales and siltstones is exposed in only one place. It appears to overlie conformably the lower 1,000 feet and therefore has been tentatively assigned to the Shublik formation.

3. In the area studied the Lower Cretaceous Killik group can be subdivided into three mappable units: the Aucella, the Shale, and the Torok. The Aucella unit is about 2,400 feet thick and consists of shale and of argillaceous sandstones and siltstones which differ in a few respects from those in the overlying units. The fossil Aucella is common. The unit appears to be separated from the overlying Shale unit by an erosional break. The Shale unit is about 1,750 feet thick and consists predominately of dark shales which do not differ from the shales of the over- and underlying units. The unit is mappable because of its stratigraphic position. The Torok unit is 8,460 feet thick at Castle Mountain and there consists of shales and of graywackes and conglomerates that wedge out northward into shales. Thirteen miles to the north the Torok unit is not more than 5,000 feet thick; except for 500 feet of graywackes and conglomerates at the base, it is composed chiefly of shale. There is no widespread unconformity between the Torok and the Shale unit.

4. The presence or absence of an unconformity at the base of the Tuktu sandstone cannot be established.