Stratigraphy and Structure of the Ekokpuk Creek Area, North-Central Brooks Range, Alaska

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U.S. GEOLOGICAL SURVEY BULLETIN 1848

DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, Jr., Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1990

For sale by the
Books and Open-File Reports Section
U.S. Geological Survey
Federal Center, Box 25425
Denver, CO 80225

Library of Congress Cataloging-in-Publication Data

Nelson, Willis H. (Willis Howard), 1920–
Stratigraphy and structure of the Ekokpuk Creek area, north-central Brooks Range, Alaska / by Willis H. Nelson and Béla Csejtey, Jr.
p. cm. — (U.S. Geological Survey bulletin ; 1848)
Includes bibliographical references.
Supt. of Docs. no.: I 19.3:1848
1. Geology, Stratigraphic—Mississippian. 2. Geology—Alaska—Ekokpuk Creek Region. 3. Geology, Structural—Alaska—Ekokpuk Creek Region. 4. Chert—Alaska—Ekokpuk Creek Region. 5. Limestone—Alaska—Ekokpuk Creek Region. I. Csejtey, Béla, 1934– . II. Title. III. Series.
QE75.B9 no. 1848 557.3 s—dc20 89–600289
[QE672] [551.7'51'097987] CIP

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FIGURES

Stratigraphy and Structure of the Ekokpuk Creek Area, North-Central Brooks Range, Alaska

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Abstract

Sedimentary rocks of Devonian to Cretaceous age in the vicinity of Ekokpuk Creek in the north-central Brooks Range are deformed and displaced northward by northward-verging tight folds and thrust faults. Here the proximity of black chert to limestone, both of the Lisburne Group of Mississippian age, is probably the result of original deposition rather than the result of tectonic juxtaposition as has been previously postulated.

INTRODUCTION

A small area along Ekokpuk Creek in the north-central Brooks Range of northern Alaska, in the southwest corner of the Chandler Lake 1:250,000 quadrangle (fig. 1), is of particular interest because it contains two contrasting coeval facies of the Mississippian Lisburne Group—black chert and limestone—adjacent to one another. The proximity of these two facies has been attributed to tectonic juxtaposition by displacement along low-angle northward-directed thrust faults, which are common in the area. However, the distribution of these two facies as shown by our mapping a short distance south of the high point along cross section *A–A'* (fig. 2) strongly suggests that these two facies were originally deposited close to each other. The Ekokpuk Creek area is also of interest because it contains the southernmost known exposures of Cretaceous rocks in the central Brooks Range and because these Cretaceous rocks are the youngest rocks known to be involved in the low-angle imbricate faulting common in the area.

Fieldwork in the 35-km^2 study area (fig. 2) was done during June 1985 and included 13 days of foot traverses with limited helicopter support. The work was part of the U.S. Geological Survey's assessment of the mineral resource potential of the Chandler Lake and Killik River 1:250,000-scale quadrangles.

Manuscript approved for publication, August 9, 1989.

Acknowledgments

Oxygen isotope data cited in this report were determined by Teresa Presser in the laboratory of Ivan Barnes (U.S. Geological Survey). J. Thomas Dutro, Jr. (U.S. Geological Survey), accompanied us in the field for four days and helped with geologic mapping and identified fossils from limestones of the Mississippian Lisburne Group and from shell-rich beds of Cretaceous age; also, Katherine M. Reed (U.S. Geological Survey) identified radiolarians from the Otuk Formation.

DESCRIPTION AND INTERPRETATION OF STRATIGRAPHIC UNITS

Kanayut Conglomerate

In the Ekokpuk Creek area, the Kanayut Conglomerate consists mostly of fine- to medium-grained quartzite with subordinate interbedded shale and siltstone. The quartzite beds are faintly laminated and several centimeters thick and are composed of monocrystalline quartz fragments (80–85 percent), chert fragments (15–20 percent), and small amounts of detrital siltstone and argillaceous rock. The originally irregular boundaries between quartz grains have been flattened by local transfer of silica so that the grains now form a mosaic with only a small amount of intervening matrix. Although phantom grain boundaries are common in quartzite, none were recognized in thin sections that we examined.

The mechanism and environment of deposition of the Kanayut were studied by Moore and Nilsen (1984), who concluded that these rocks represent dominantly fluvial deposition. They also reported that this unit is Late Devonian and Early Mississippian(?) in overall age (Nilsen and Moore, 1984).

The Kanayut Conglomerate was named by Bowsher and Dutro (1957); they reported that the formation is approximately 670 m thick about 75 km east-northeast of the area of figure 2.

Kayak Shale

The Kayak Shale is mostly very dark gray silty shale, siltstone, and impure sandstone, in decreasing order of abundance. In the Ekokpuk Creek area, the formation also contains a few layers of limestone, each of which is a few to several tens of meters thick. Some of these layers, which are described below, are integral parts of the formation. Others are slivers of limestone of the Lisburne Group that have been interlayered with Kayak strata by faulting; the layer of light-gray limestone that crosses the ridge near the north end of cross section *C–C′* is such a sliver.

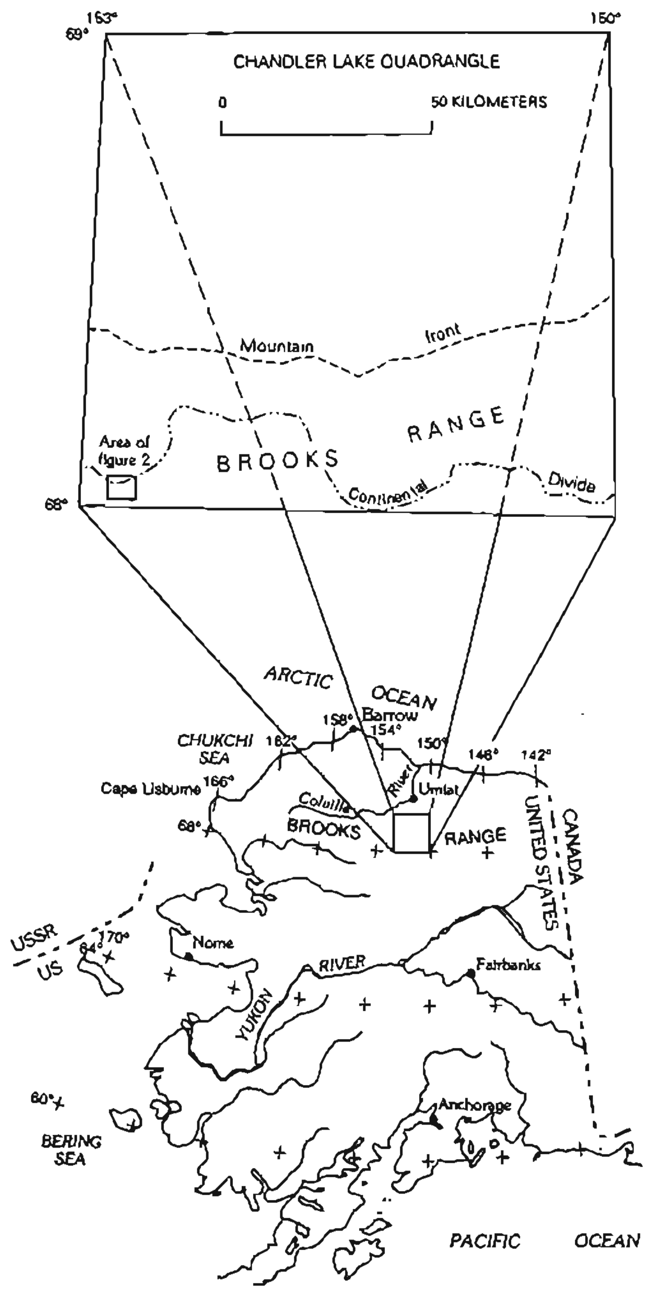


Figure 1. Index map to Chandler Lake 1° by 3° quadrangle and location of study area (area of fig. 2).

The basal part of the formation in the vicinity of Ekokpuk Creek is mostly fine-grained, impure, iron-stained argillaceous sandstone. Some of these rocks contain scattered carbonized plant debris. Beds in the basal part of the formation range from a few millimeters to a few centimeters in thickness. Much of the bedding in this part of the formation is irregular, apparently the result of small-scale scour-and-fill action during deposition.

The middle two-thirds of the formation is dominantly very dark gray fissile shale that locally is somewhat silty.

The upper one-fifth of the formation is very dark to dark-gray shale, silty shale, siltstone, and fine-grained sandstone. This part of the formation includes a few layers of limestone, which are a meter to a few meters in thickness. This limestone is composed mostly of crinoid columnals along with other fossil detritus. It is medium gray when fresh and weathers to a yellowish brown due to iron oxide, which is confined largely to the matrix.

No definitive fossils were found in the Kayak Shale in the Ekokpuk Creek area; however, Nilsen and Moore (1984, p. 62) reported that elsewhere the Kayak contains a varied assemblage of fossils of Early Mississippian (late Kinderhookian) age.

It was not possible to determine the thickness of the formation because of poor exposures and intense folding and faulting. The cross sections (fig. 2) suggest that the Kayak Shale is 150 to 400 m thick; at its type locality, about 75 km east-northeast of Ekokpuk Creek, the Kayak is about 290 m thick (Bowsher and Dutro, 1957).

Lisburne Group

Most of the Lisburne Group in the Ekokpuk Creek area is composed of black chert of the Kuna Formation, with a small amount of medium-gray bioclastic carbonate rock of the undivided Wachsmuth and Alapah(?) Limestones.

Kuna Formation

The Kuna Formation in the Ekokpuk Creek area is almost entirely very dark gray, nearly black, vitreous chert. White quartz veins of variable trend and thickness are spaced every few centimeters throughout the chert. These veins are as much as a centimeter thick and clearly seem to be fractures that have been filled by quartz derived from the chert. In addition to chert, the formation includes a few layers of very dark to dark-gray argillaceous siltstone and a subordinate amount of medium-gray, fine-grained limestone. Most of the limestone occurs as scattered discontinuous blebs in the chert. The short axes of these blebs are parallel to one another and normal to bedding, in the few places where faint bedding can be recognized. Individual blebs are as much as 2 cm in their short dimension and as much as several centimeters in their other dimensions.

Although some of the chert of the Kuna Formation at Ekokpuk Creek was probably limestone that was replaced by silica, we believe that most of the chert in the Kuna at Ekokpuk Creek was deposited as primary chert. This is in accord with Armstrong and Mamet's interpretation (1978, p. 356 and 358) that the chert-rich part of the section at Till Creek, about 27 km southeast of Ekokpuk Creek, are starved-basin deep-water deposits. Also, oxygen isotope compositions indicate that most of the chert is primary. The $\delta^{18}O$ values for four specimens of chert (sample localities N6, N25A–C, fig. 1) from this unit were determined to be +27.5, +29.5, +28.0, and +26.8 per mil; these compositions fall within the range +24 to +34 per mil that Savin (1973) cited as being characteristic of deep-water cherts.

The Kuna Formation was named by Mull and others (1982) for a sequence of black carbonaceous shale, black chert, and fine-grained limestone and dolomite that many previous workers had informally called the "black Lisburne." The designated type section is about 200 km east of Ekokpuk Creek along the upper Kuna River in the Howard Pass quadrangle. Mull and others (1982) designated the section of black chert that we describe here to be a reference section for the formation.

Another section, along Till Creek and described by Armstrong and Mamet (1978), as well as the type section (Mull and others, 1982) includes more carbonate and argillaceous rocks than the section at Ekokpuk Creek. Till Creek is about 25 km east-southeast of the area of figure 2, in the Wiseman quadrangle. Armstrong and Mamet (1978, p. 338–339 and fig. 7) show all the above-mentioned sections separated from one another by faults, thus obscuring their original spatial relations.

Wachsmuth and Alapah(?) Limestones, Undivided

The rocks that are herein identified as the undivided Wachsmuth and Alapah(?) Limestones of the Lisburne Group in the vicinity of Ekokpuk Creek are coarse-grained, medium-gray echinoderm-bryozoan-brachiopod packstones, which have indistinct irregular bedding with individual layers that range from a few tens to several tens of centimeters in thickness. Bands of these limestones occur at two places in association with rocks of the Kayak Shale within the area of figure 2.

One of these bands of limestone that is several tens of meters thick occurs near the contact between the Kayak Shale and Kuna Formation along the line of cross section *A–A'*, figure 2. The undivided Wachsmuth and Alapah(?) Limestones are lateral equivalents of the Kuna Formation, and we believe that this band of calcareous rocks at the Kayak-Kuna contact is a tongue of limestone of the undivided Lisburne Group and that it was deposited as a wedge in the basal part of the Kuna Formation.

The other band of limestone, which is about 20 m wide, crops out within the area underlain by the Kayak Shale near the north end of cross section *C–C'* (fig. 2). We believe that this was emplaced in the Kayak by faulting.

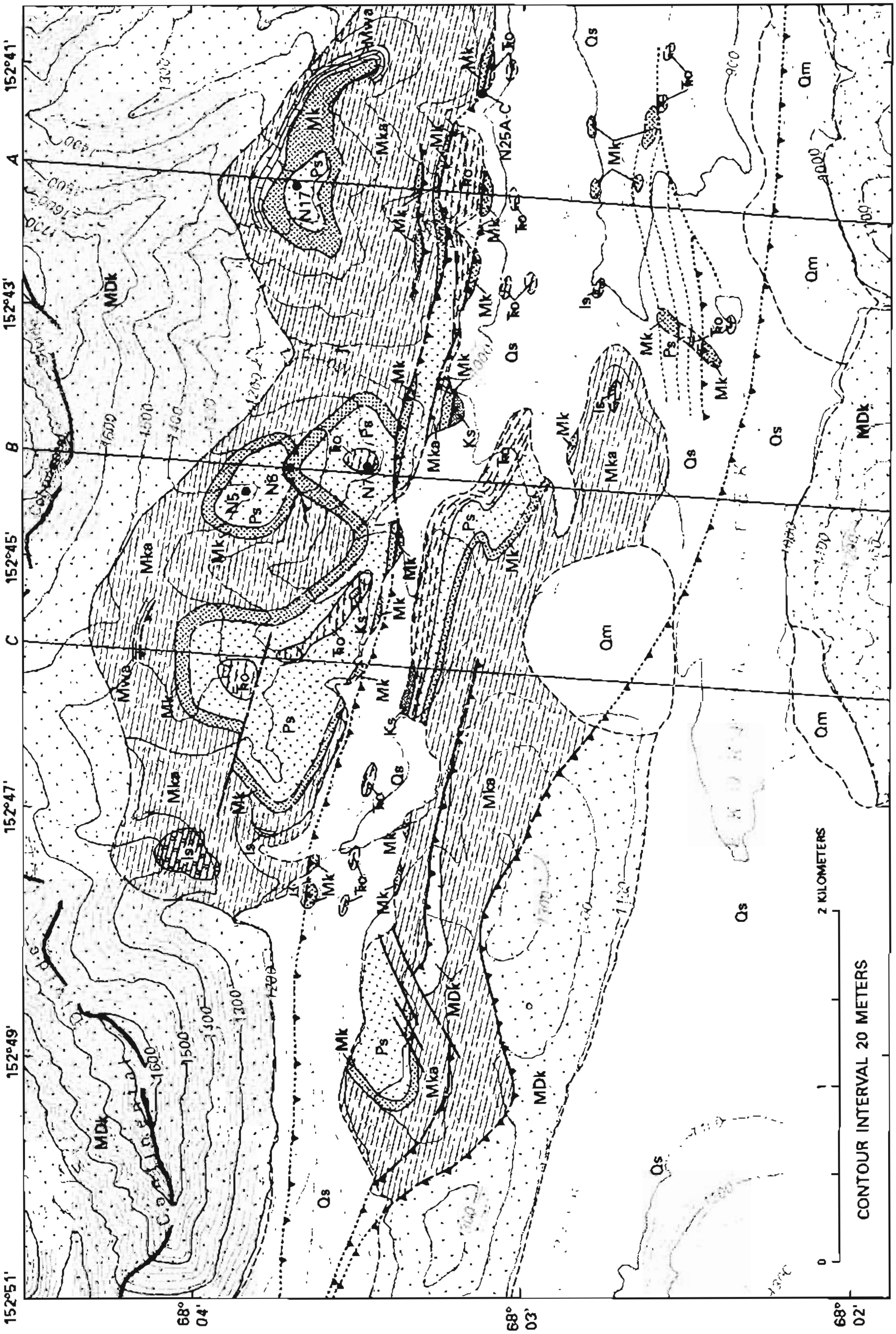
J.T. Dutro, Jr. (oral commun., 1984), identified the spirifer genera *Brachythyris* sp. and *Logani* sp. or *Ovatia* sp. in the field from the band of calcareous rocks along cross section *A–A'*. These fossils are indicative of Early Mississippian age and identify these rocks as the Wachsmuth Limestone of the Lisburne Group. Armstrong and Mamet (1978) interpreted the rocks of these formations north of Ekokpuk Creek to be shallow-marine and slope-facies limestones.

Siksikpuk Formation

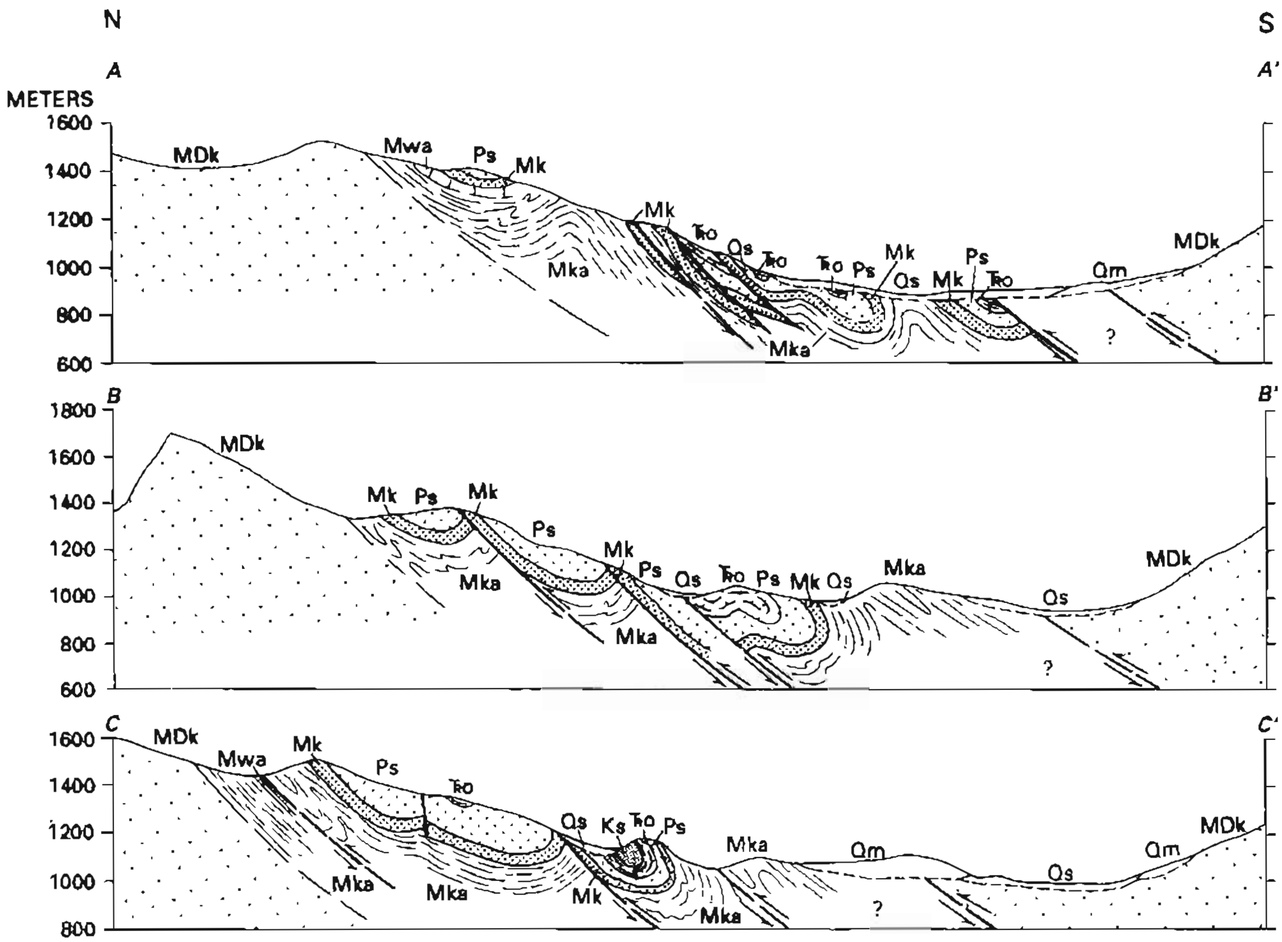
The Siksikpuk Formation in the vicinity of Ekokpuk Creek consists predominantly of uniformly fine-grained, faintly laminated siltstone. Although mostly light-neutral-gray, locally this siltstone is dark to very dark gray, and some of it is brown. The siltstone's typical color and texture give it the appearance of fine-grained, felsic pyroclastic rocks. However, oxygen isotope data suggest that this siltstone was deposited in deep cold water. Oxygen isotope, $\delta^{18}O$, values from two siltstones (sample localities N5 and N17, fig 2) are +22.31 and +24.6 per mil. These values are less than or barely overlap the range of $\delta^{18}O$ values cited by Savin (1973) as characteristic of marine cherts (+24 to +34 per mil), are greater than the range of values cited for pelagic sediments (+16 to +18 per mil), and are much greater than the range cited as typical of igneous rocks (+9 to +10 per mil). Savin and Epstein (1970) report oxygen isotope ratios between +11.5 and +28.5 per mil for carbonate-free fractions of 27 ocean core samples.

Although atypical of the Siksikpuk Formation, the siltstone near Ekokpuk Creek has herein been assigned to that formation on the basis of its stratigraphic position between the Kuna and Otuk Formations and its resemblance to some of the rocks that make up a minor part of the Siksikpuk Formation along the mountain front to the north.

In the Ekokpuk Creek area, the Siksikpuk is about 100 m thick as determined by using the average dip across outcrop bands whose widths were scaled from the map (fig. 2). This approximation may differ by as much as 10 m from the true thickness because the topography on the base map (fig. 2) is not detailed enough to determine an accurate outcrop width and because the exposures are



152°51'
152°49'
152°47'
152°45'
152°43'
152°41'
68° 04'
68° 03'
68° 02'
A
A'
B
B'
C
C'
CONTOUR INTERVAL 20 METERS
0
1
2 KILOMETERS
Geology mapped in 1985
MDk
Mka
Mk
Ps
Qs
Qm
Ks
N17
N25A-C
N5
N6



EXPLANATION

Qs — Surficial deposits (Quaternary)

Qm — Morainal deposits (Quaternary)

Ks — Sedimentary rocks (Cretaceous)

Ꞧo — Otuk Formation (Triassic)

Ps — Siksikpuk Formation (Permian)

Lisburne Group (Mississippian)—In this area consists of:

Mk — Kuna Formation

Mwa — Wachsmuth and Alapah(?) Limestones, undivided

Mka, ls — Kayak Shale (Mississippian)—Locally includes limestone (ls)

MDk — Kanayut Conglomerate (Lower Mississippian? and Upper Devonian)

Contact—Long dashed where approximately located; short dashed where more indefinite; dotted where concealed

Fault—Dashed where approximately located; dotted where concealed

Thrust fault—Dashed where approximately located; dotted where concealed. On map, sawteeth on upper plate; in cross sections, arrows indicate direction of relative movement

NS — Sample locality cited in text

Figure 2. Geologic map and cross sections of part of Ekokpuk Creek area. Base from U.S. Geological Survey, 1:63,360, Chandler Lake (A-5), 1986. Queries on cross sections indicate unknown unit.

too scattered to accurately determine variations in dip that result from internal structure.

The Siksikpuk Formation was named by Patton (1957, p. 41) for exposures along Tiglukpuk Creek, a tributary of the Siksikpuk River about 33 km northeast of Ekokpuk Creek. Helen Duncan and J. Thomas Dutro, Jr. (see Brosgé and others, 1962, p. 2194), reported that fossils collected by Patton and Tailleur (1964, p. 429–430) at the type locality were of definite Permian, probable Early Permian, age. Mull and others (1982, p. 356–357) gave a brief description of the formation.

Otuk Formation

The Otuk Formation is very distinctive and easily recognized. It is made up of evenly bedded, fine-grained limestone, siltstone, mudstone, and minor chert. Most of the rock is dark to very dark neutral gray where fresh and generally somewhat lighter colored where weathered. Some of the weathered rock is neutral gray but most of it is a characteristic yellow and locally orange of varying intensity. Pelecypod fossils of the genera *Monotis* and *Halobia* are characteristic of the Otuk and abundant on many of the bedding planes: Few sections of the formation that are more than a few meters thick are devoid of bedding planes bearing these fossils. The formation is estimated to be several tens of meters in thickness, on the basis of cross section *C–C'* (fig. 2).

Radiolarians from chert of the Otuk Formation (station N7, just east of cross section *B–B'*, fig. 2), identified as *Staurodoras* (Eliluvia) sp. cf. *cocholeata* (Nakaseko and Nishimura, 1979), and *Pseudostylosphaera* (*Archaeospongoprunum*) sp. cf. *helicata* (Nakaseko and Nishimura, 1979), are indicative of an early Late Triassic (Karnian) age.

The Otuk Formation was named by Mull and others (1982) for exposures along Otuk Creek within the area of the Killik River 1° by 3° quadrangle about 145 km west-northwest of Ekokpuk Creek.

Sedimentary Rocks of Cretaceous Age

The rocks of Early Cretaceous age within the map area (fig. 2) are dark-gray shale, shaly siltstone, sandstone, and a few thin, possibly discontinuous beds of limestone composed predominantly of fossil debris. These rocks are exposed only in small, widely scattered outcrops. Bedding is obscure but can locally be discerned by differences in the abundance of fine-sand and silt fractions from layer to layer. Where they can be distinguished, beds range from a few millimeters to a few centimeters in thickness. Much of the observed bedding is parallel and rhythmic, which suggests that the sediments were deposited in fairly deep water.

The thin-bedded limestone is the most distinctive of the Cretaceous sedimentary rocks that form this unit; it is composed largely of clam shells cemented by calcareous algae. Considerable reddish-brown, interstitial argillaceous material gives this limestone its distinctive color. These shell-rich beds were termed "coquinoid limestone" by Patton (1956), who first described such rocks from the Tiglukpuk Creek area at the mountain front about 40 km northeast of the area of figure 2. Patton (1956, p. 215) proposed the name Tiglukpuk Formation for an assemblage of rocks that includes the shell-rich beds. This formation name was abandoned after Imlay and Detterman (1973, p. 14) determined that the rocks at the type locality were disrupted by faulting.

J.T. Dutro, Jr. (oral commun., 1984), identified the clam *Buchia sublaevis* of Cretaceous age in the field as a dominant component of the shell-rich beds in this unit. These rocks seem to be virtually identical to those at the Tiglukpuk Creek locality from which Jones and Grantz (1964) collected *Buchia sublaevis* of Early Cretaceous (Valanginian) age.

Quaternary Deposits

Unconsolidated sand, gravel, silt, and clay cover much of the area of figure 2. In the valleys, most of the unconsolidated surficial deposits consist of alluvium and alluvial outwash. The steeper slopes are mantled with colluvium. Moraines are shown separately from the other surficial deposits on the map (fig. 2).

STRUCTURE

Because of the relatively small size of the Ekokpuk Creek study area, it is useful to view the structures of that area within the context of the surrounding Brooks Range. According to most interpretations of the regional structure of the Brooks Range, considerable shortening has taken place as a result of imbricate thrusting and associated folding (see, for instance, Chapman and others, 1964; Brosgé and others, 1979; Kelley, 1984; and Mayfield and others, 1984). Detailed mapping of the structure of the area around Ekokpuk Creek is sparse; Porter (1966) reported low-angle faults and overturned folds in the vicinity of Anaktuvuk Pass, about 40 km east of the Ekokpuk Creek area. The authors, accompanied by John Kelley of the U.S. Geological Survey, have seen as many as three repetitions of limestone strata of the Lisburne Group in imbricated fault slices along the front of the Brooks Range north of Ekokpuk Creek.

The structure of the Ekokpuk Creek area (fig. 2) is characterized by a central east-west-trending band of deformed rocks sandwiched between thrust slices of rocks of Devonian age. The deformation evident in this central band of rocks can be attributed to relative northward movement of the overthrust mass of the Kanayut

Conglomerate in the southern part of the Ekokpuk Creek area. Although stratigraphically the oldest rocks in the map area, the Devonian and Mississippian(?) strata of the Kanayut to the north of the area of figure 2 structurally overlie other Devonian rocks owing to thrust faulting. Still farther north, thrust slices of the Kanayut overlie rocks of Mississippian age.

The amount of displacement between the two major masses of the Kanayut Conglomerate cannot be determined. Much of the resulting deformation is represented by crumpling and thrust faulting within the Kayak Shale; evidence of this includes locally exposed tight folds, pencil-shaped prisms of rock (formed by the intersection of bedding- and axial-plane cleavage), and fault slivers of both younger and older formations within the Kayak Shale. These fault slices, in the northern and western parts of the map area (fig. 2), include a sliver of limestone of the Lisburne Group and several slivers of quartzite of the Kanayut Conglomerate.

Although the Kayak Shale near the north edge of the map area (fig. 2) is in normal stratigraphic position above the Kanayut Conglomerate, faulting is likely to have occurred at or near their mutual contact. Even though this contact can be located to within a few meters along most of its length within the map area, whether or not it is a fault contact unfortunately could not be determined because the rocks along it are extensively broken by frost action. However, the strong deformation of the Kayak Shale here and the notable contrast in competence between the Kanayut Conglomerate and the Kayak Shale suggest that this is a fault zone.

Thin sections of four specimens of quartzite of the Kanayut Conglomerate from the northern part of the area of figure 2 show no evidence of small-scale deformation such as strain shadows in quartz. This absence of evidence of deformation suggests that the quartzite in the Kanayut was so competent that deformation in it was confined to narrow zones or was transferred to the nearby, less competent rocks of the Kayak Shale.

The general structure of the area between the bands of the Kanayut Conglomerate is characterized by asymmetrical folds disrupted by reverse faults. The faults and axial planes of the folds trend east-west and dip steeply to the south. Several closely spaced faults trend east-west through the middle of the area of figure 2; weaknesses along these faults probably localized the valley along which they lie. Most of these faults juxtapose older rocks over younger rocks, which is a common relationship along overthrust faults. It is noteworthy that along at least two of these faults younger rocks overlie older rocks. The superposition of younger over older rock along overthrust faults can be explained in a number of ways. An explanation that we favor is that before faulting ceased the rocks were folded in such a way that younger rocks in what was to become the upper plate were in positions to be cut and transported upward along the fault to positions adjacent to older rocks in the lower plate. An example of these relations is near the center of cross section *A–A′* (fig. 2), where the Otuk Formation overlies the Kuna Formation. Another explanation is that normal movement along some of the overthrust faults or newly developed faults parallel to the overthrust faults downdropped younger, upper plate rocks until they were adjacent to older rocks of lower plates; such faulting could have occurred during an episode of tension after relaxation of the compression that had led to the overthrusting. The normal fault that seems to offset the rocks of the Siksikpuk Formation a few meters near the north end of cross section *C–C′* probably was formed in this way. A third explanation for overthrust faults that juxtapose younger rocks over older rocks is that they are simply bedding-plane detachment faults. Because such faults do not disturb the normal stratigraphic sequence, they are difficult to detect.

In the north half of the area of figure 2, several synclines are delineated by the chert of the Kuna Formation. This folding may be the result of drag along several northward-verging faults that separate the synclines. These folds plunge gently to the west, with the result that the southernmost of the two folds at the north end of cross section *B–B′* projects above the surface along cross section *A–A′*. To the west along the line of cross section *C–C′* the two folds north of Ekokpuk Creek merge to form a single, broad synclinal fold with a small anticline in the middle.

A recumbent syncline occurs in the low ridge near the middle of line of cross section *B–B′* (fig. 2). The core of this syncline is composed of rocks of the Otuk Formation, which crop out sporadically. This syncline continues westward to the middle of the line of cross section *C–C′*; for about half of the distance westward from the line of cross section *B–B′* toward cross section *C–C′*, the south limb of this syncline is delineated by an obscure band of chert of the Kuna Formation. This syncline can be traced west of cross section *C–C′* by discontinuous outcrops of chert of the Kuna Formation along its south limb to its continuation in the center of the western quarter of the area of figure 2. This syncline is interpreted to continue eastward beneath surficial deposits to the area along the line of cross section *A–A′*.

Outcrops in the southeastern quadrant of the area of figure 2 are so small and scattered that no unique interpretation of the structure there is possible. However, folds and faults similar to those north of Ekokpuk Creek could explain the distribution of the rocks exposed there; the structural interpretations shown along the south half of the line of cross section *A–A′* are based on analogies with the structure in the north half of the area of figure 2.

Rocks of the Kanayut Conglomerate at the south edge of the area of figure 2 seem to be thrust over the rocks to the north. The thrust contact is concealed by surficial deposits over most of its length within the map area. It can be located to within a few meters along about 3 km of its length in the western part of the area of figure 2; however, even here most of the outcrops are frost riven and no outcrops of the actual contact were found.

We believe that most of the faults in the area are south-dipping thrusts that become less steeply dipping downward and merge with a major sole fault. This basal thrust has not been recognized in the field, but we believe that it comes to the surface in the north band of the Kayak Shale at or near its contact with the quartzite of the Kanayut Conglomerate.

Another interesting aspect of the geology of the Ekokpuk Creek area is the presence of Lower Cretaceous rocks, which, according to C.G. Mull (written commun., 1986), are not only the most southerly Cretaceous rocks that are known to occur in fault slices in the north-central Brooks Range but also the youngest rocks known to be involved in thrusting in the Brooks Range.

CONCLUSIONS

The pattern of northward-verging tight folds and thrust faults in the Ekokpuk Creek area is in harmony with the structural style in nearby parts of the north-central Brooks Range. The close proximity of Mississippian chert in the Ekokpuk Creek area to coeval limestone in adjacent areas has been suggested to be the result of large-scale differential lateral tectonic transport of rocks from contrasting sedimentary environments. However, our mapping suggests that this proximity is due to the two facies' being deposited close to each other. Cretaceous rocks are the youngest rocks involved in the deformation in this part of the Brooks Range, and the Cretaceous rocks at Ekokpuk Creek are the most southerly Cretaceous rocks known to be involved in the deformation there.

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☆ U.S. GOVERNMENT PRINTING OFFICE: 1990—785-048/3034