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STRATIGRAPHY AND STRUCTURAL SETTING OF THE PICNIC CREEK ALLOCHTHON, KILLIK RIVER QUADRANGLE, CENTRAL BROOKS RANGE, ALASKA: A SUMMARY

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ABSTRACT

Recent geologic mapping in the Killik River Quadrangle of the central Brooks Range indicates that large areas of the mountains and foothills disturbed belt are composed of rocks that are characteristic of two of the major allochthons found in the western Brooks Range. In ascending order, these are the Endicott Mountains (Brooks Range) allochthon and the Picnic Creek allochthon. Strata typical of the Ipnavik River allochthon are also present as well as an unusual association of strata typical of the Nuka Ridge and Copter Peak allochthons.

The Endicott Mountains allochthon forms the main range crest and front of the Endicott Mountains; it is the structurally lowest allochthon in the area. Major rock units on the allochthon include: Hunt Fork Shale (Upper Devonian), Noatak Sandstone (Upper Devonian), Kanayut Conglomerate (Upper Devonian-Lower Mississippian), and Kayak Shale (Mississippian) of the Endicott Group; the Wachsmuth Limestone, Alapah Limestone and Kuna Formation of the Lisburne Group (Mississippian and Pennsylvanian), and the Siksikpuk Formation (Permian) and Otuk Formation (Triassic-Jurassic) of the Etivluk Group. Lower Cretaceous coquinoid limestone (Valanginian) and, in some places, turbidites of the Okpikruak Formation form the stratigraphic top of the allochthon. The stratigraphic thickness of the pre-Cretaceous rocks of the Endicott Mountains allochthon is over 8,000 ft.

Rocks of the Picnic Creek allochthon are widespread in the 'disturbed belt' of the Brooks Range foothills, and structurally overlie rocks of the Endicott Mountains allochthon. Major rock units on the Picnic Creek allochthon include: Hunt Fork Shale(?) (Upper Devonian?), Kurupa Sandstone (new name) (Lower Mississippian), and Kayak Shale (Mississippian) of the Endicott Group; Akmalik Chert (new name) (Mississippian-Lower Pennsylvanian) of the Lisburne Group; and Imnaitchiak Chert (new name) (Pennsylvanian-Triassic) of the Etivluk Group. Turbidites and an olistostrome in the Lower Cretaceous Okpikruak Formation apparently form the top of the Picnic Creek allochthon although no definite depositional contacts of Okpikruak with older rocks have been mapped. The stratigraphic thickness of the pre-Cretaceous rocks of the Picnic Creek allochthon is approximately 1,400 ft.

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In a palinspastic restoration the Picnic Creek allochthon is moved to its relative position south of the Endicott Mountains allochthon. In the reconstructed basin, the Kurupa Sandstone appears to represent the distal southern end of the Kanayut-Noatak clastic wedge. The Akmalik Chert represents basinal equivalents of the Wachsmuth Limestone, Alapah Limestone, and the Kuna Formation of the Lisburne Group, and the Imnaitchiak Chert is a more basinal and distal equivalent of the Siksikpuk Formation of the Etivluk Group.

Detailed stratigraphic and paleontologic studies of the Mississippian through Triassic rocks on the Picnic Creek allochthon are in progress.

INTRODUCTION

Ongoing geologic mapping of the Killik River Quadrangle has focused on the stratigraphy and structural style of the northern flank of the Endicott Mountains and the 'disturbed belt' of intensely faulted rocks to the north. The mountains are composed dominantly of rocks of the Endicott Mountains allochthon, which in this area is the structurally lowest of the allochthons that form the northern front of the central Brooks Range (Mull, 1982; 1985). The Endicott Mountains allochthon (also known as the Brooks Range allochthon in the western Brooks Range) is overlain by the Picnic Creek allochthon and rocks of other allochthons mapped in the De Long Mountains (Mayfield and others, 1983). Regional structural and stratigraphic studies indicate that much of the telescoping of allochthons occurred during the Early Cretaceous (Neocomian to Aptian) and that regional folding of the allochthons occurred during a stage of uplift of the Brooks Range core during Albian to Late Cretaceous and Tertiary time (Mull, 1982, 1985; Mayfield and others, 1983).

The stratigraphy of the Endicott Mountains allochthon is relatively well known; therefore, this summary focuses on the little known stratigraphy and structural setting of the Picnic Creek allochthon. In the Killik River Quadrangle, the Picnic Creek allochthon is best exposed in the area from the Kurupa Hills on the west to the Killik River on the east (fig. 1). Its stratigraphy differs markedly from that of the Endicott Mountains allochthon, although there are common characteristics that show that the two allochthons represent parts of a formerly continuous sedimentary basin. On the Picnic Creek allochthon we have established a new nomenclature for some lithologically distinctive rock units that are coeval with those on the Endicott Mountains allochthon.

ENDICOTT MOUNTAINS ALLOCHTHON

The generalized stratigraphic sequence on the Endicott Mountains allochthon is illustrated in figure 2. Details of the stratigraphy on the Endicott Mountains allochthon are available in a number of reports. Reconnaissance studies by Chapman and others (1964) and Patton and Tailleur (1964) provided the regional stratigraphic and structural framework of the area. Brosgé and others (1979), Nilsen (1981), Moore and Nilsen (1984), and Nilsen and Moore (1984), mapped and described the regional stratigraphy of the Kanayut Conglomerate (Upper Devonian - Lower Mississippian) and Noatak Sandstone and Hunt Fork Shale (Upper Devonian); these are the oldest rocks

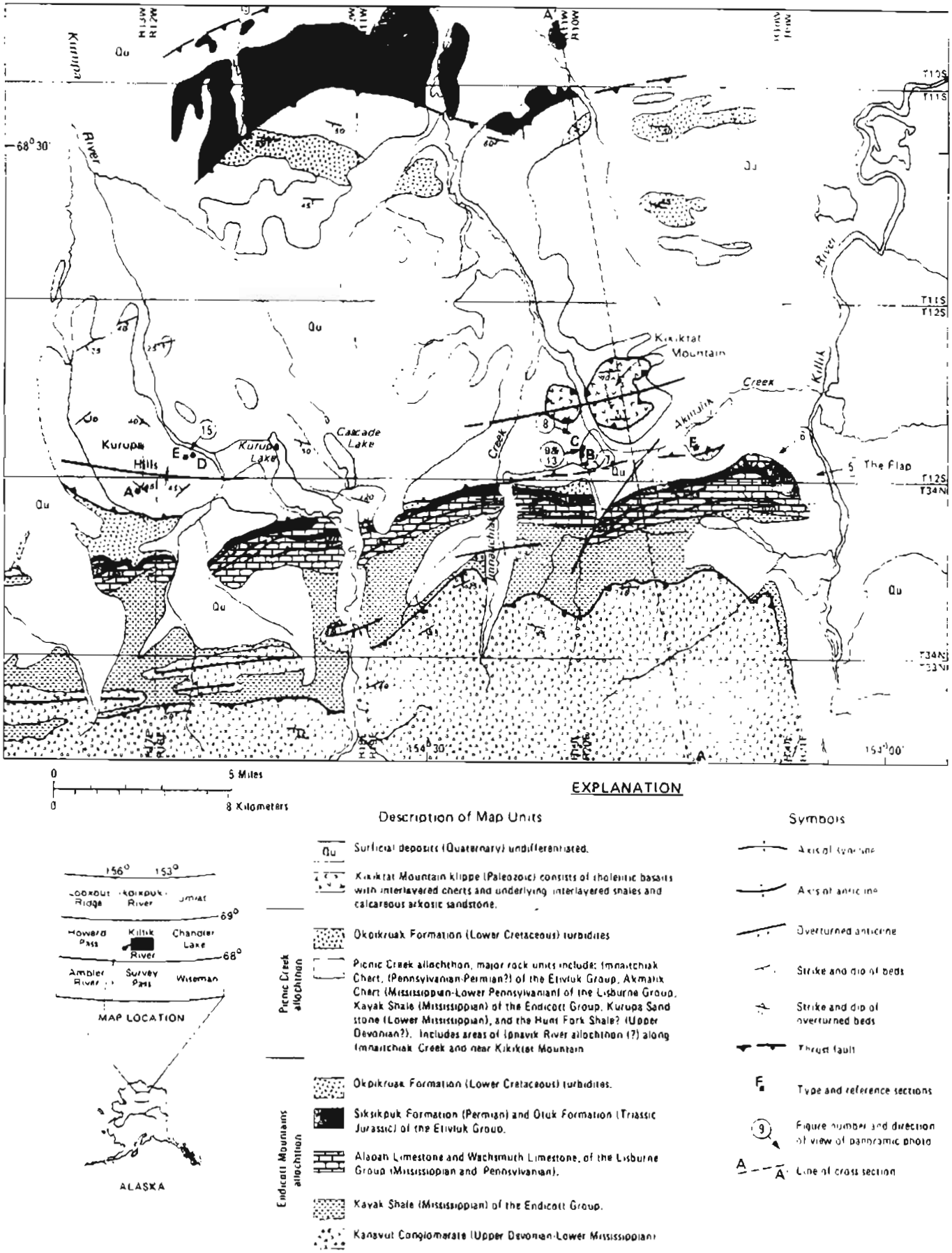

Figure 1. Generalized geologic map of the Killik River – Kurupa Hills area, showing approximate distribution of Endicott Mountains allochthon, Picnic Creek allochthon, and Kikiktat Mountain klippe. (1) Note: After these illustrations were prepared, radiolarian dates (B.L. Murchey, verbal commun.) indicate that the Imnaitchiak Chert ranges to as young as Middle or Late Triassic age.

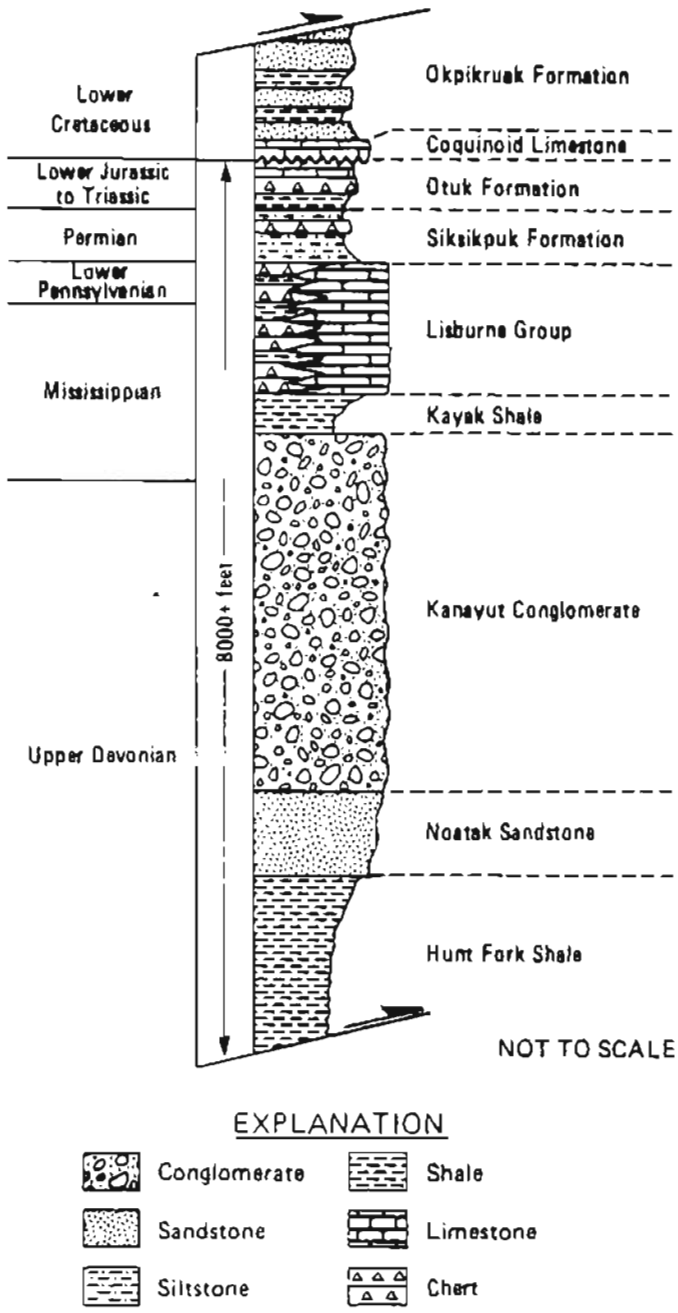

Figure 2. Generalized stratigraphic column of Endicott Mountains allochthon.

exposed in the Endicott Mountains allochthon in the Killik River Quadrangle. Formations of the Lisburne Group (Mississippian and Pennsylvanian) were named by Bowsher and Dutro (1957) and Mull and others (1982). Armstrong (1970) and Armstrong and Mamet (1977, 1978) described the carbonate rocks of the Lisburne Group in detail. The Siksikpuk Formation (Permian) and Shublik Formation (Triassic) were described in detail by Patton (1957), Bodnar (1984, 1985) and Siok (1985). Mull and others (1982) named the Otuk Formation (Triassic-Jurassic) for rocks formerly included in the Shublik Formation; and proposed the term Etivluk Group to include the Otuk and Siksikpuk Formations. The top of the stratigraphic succession on the Endicott Mountains allochthon consists of an unnamed thin (< 5 ft) distinctive Lower Cretaceous (Valanginian) coquinoid limestone (Jones and Grantz, 1964) that is exposed intermittently; in other places the top of the allochthon consists of turbidites of the Okpikruak Formation, which in some places contains an olistostrome (Mull, 1985; Crane, 1985).

PICNIC CREEK ALLOCHTHON

The Picnic Creek allochthon (Mayfield and others, 1983) is named for exposures in the Picnic Creek fenster in the eastern De Long Mountains, 120 mi west of the Killik River Quadrangle. The stratigraphic units of the Picnic Creek allochthon (fig. 3) are divided into three sequences: (1) an Upper Devonian(?) to Lower Mississippian clastic sequence, (2) a Mississippian to Permian (?) chert sequence, and (3) a Lower Cretaceous turbidite sequence. The clastic and chert sections occupy the stratigraphic positions of the Endicott, Lisburne, and Etivluk Groups on the Endicott Mountains allochthon, and have stratigraphic sequences and lithologic characteristics in common with the formations of the Endicott Mountains allochthon. The stratigraphic units on the Picnic Creek allochthon are described below.

Structural Setting

In the Killik River - Kurupa Hills area, rocks of the Picnic Creek allochthon are present in the Kikiktat syncline (fig. 4), a regional asymmetric syncline that lies north of the Endicott Mountains front and trends east-west through Kikiktat Mountain to the Kurupa Hills on the west (fig. 1). The mountain front is formed by a nearly east-west trending vertical to south dipping overturned sequence at the top of the Endicott Mountains allochthon. Although the thick carbonate rocks of the Mississippian - Pennsylvanian Lisburne Group are imbricated, the top of the sequence at the mountain front in many places consists of the Lisburne Group, Siksikpuk Formation, and Otuk Formation in an unfaulted normal depositional sequence with stratigraphic tops to the north (figs. 5 and 6). The overturned nature of the Lisburne section at the mountain front is confirmed by an abundant conodont fauna of Morrowan age (Early Pennsylvanian) (Anita Harris, written commun., 1985) obtained from the top of the Lisburne at Akmalik Creek 5 ft below the contact with the Siksikpuk Formation (Siok, 1985). These are the youngest fossils yet reported from the Lisburne in the central Brooks Range; the sample from which they were recovered clearly represents the top of the Lisburne inasmuch as most of the formation in the Endicott Mountains is Osagian, Meramecian, and Chesteran age (Early to Late Mississippian) (Armstrong, 1970; Armstrong and Mamet, 1978; Chapman and others, 1964; Patton and Tailleur, 1964). In addition, in three measured

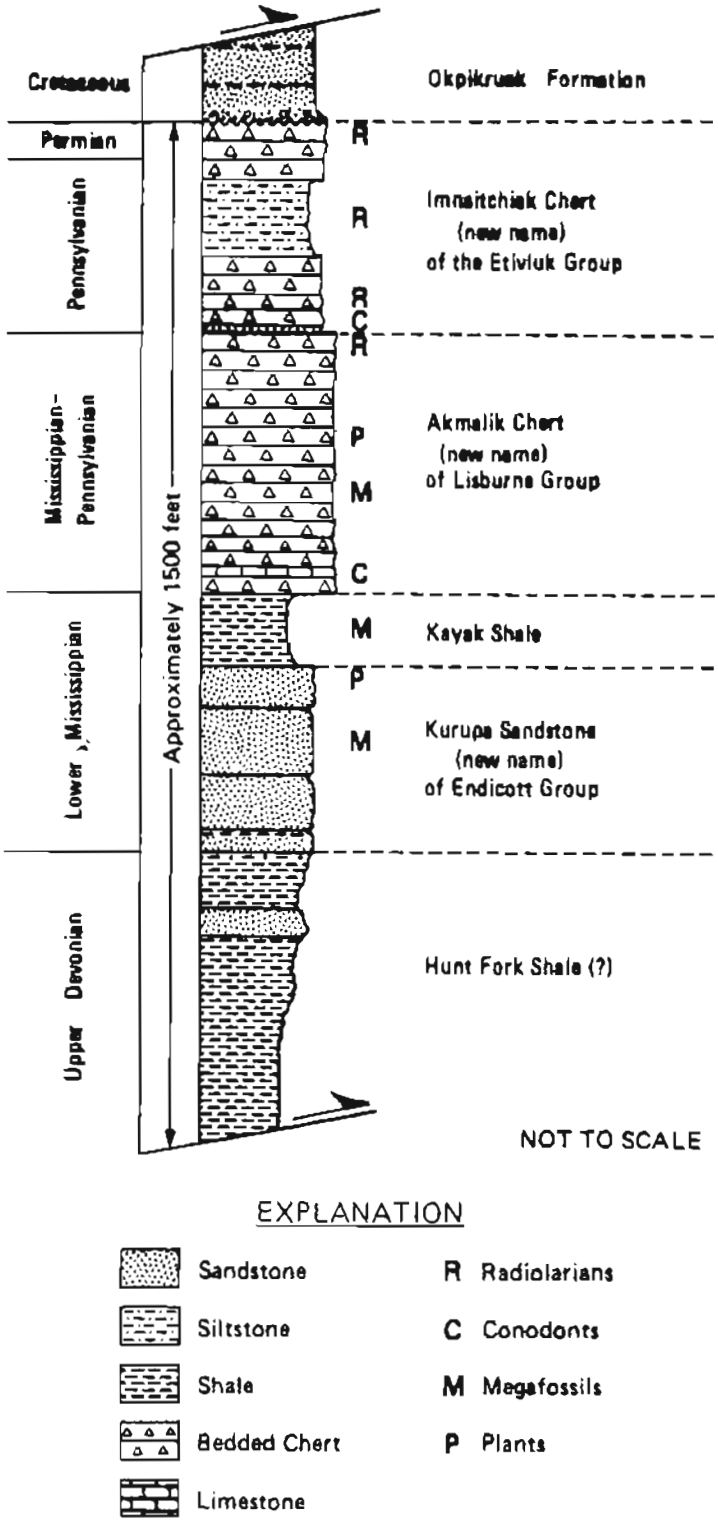

Figure 3. Generalized stratigraphic column of Picnic Creek allochthon. (1)Note: After these illustrations were prepared, radiolarian dates (B.L. Murchey, verbal commun.) indicate that the Imnaitchiak Chert ranges to as young as Middle or Late Triassic age.

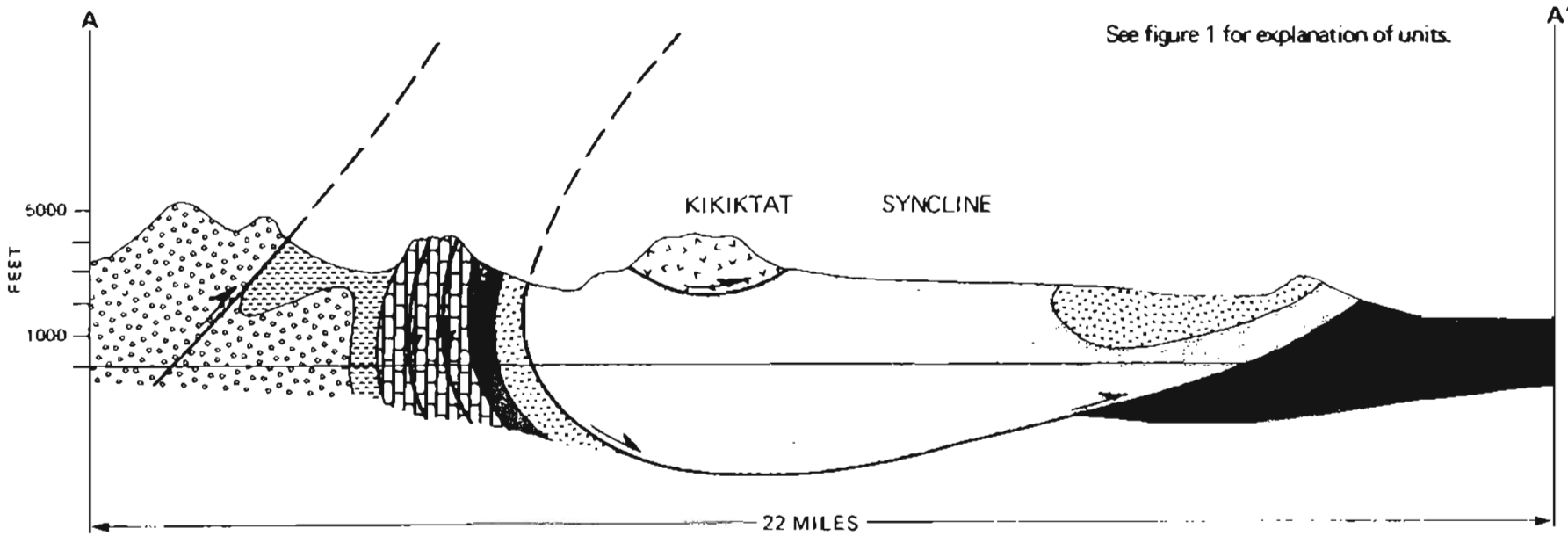

Figure 4. Generalized cross section of Endicott Mountains front and 'disturbed belt' in Killik River - Kurupa Hills area.

Figure 5. View to west to 'The Flap', an overturned synclinal sequence at the top of the Endicott Mountains allochthon. Etivluk Group (JPe) in core of 'The Flap' (A) is intensely crumpled, but to north (B) is in overturned sequence with depositional contacts beneath overturned Lisburne Group(PM1). MDk - Kanayut Conglomerate, Mk - Kayak Shale. Topographic relief on 'The Flap' is about 2,000 ft.

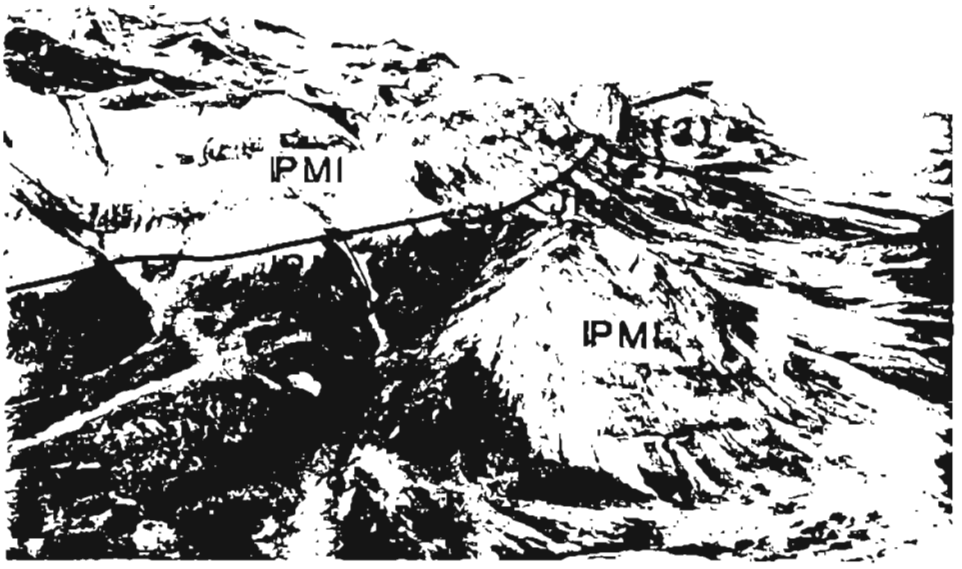

Figure 6. View to southwest along overturned south dipping sequence of Lisburne (PMl) and Etivluk Group (JPe) at top of Endicott Mountains allochthon between 'The Flap' and Akmalik Creek. Stratigraphic top of sequence is to the north (right). Measured sections of overturned Otuk and Siksikpuk formations of the Etivluk Group, and Lisburne Group are at (1), (2), and (3); formation contacts are all depositional. Height of limestone cliff is about 1,500 ft.

sections of vertical to inverted Otuk, Siksikpuk, and the top of the Lisburne located between Akmalik Creek and 'The Flap,' regionally persistent lithostratigraphic units within the Siksikpuk Formation (Siok, 1985) and Otuk Formation (Bodnar, 1984) are found in their proper stratigraphic positions with stratigraphic tops to the north (fig. 6). In two of the sections, the top of the Lisburne is exposed at a depositional contact stratigraphically beneath the Siksikpuk Formation; in the third section the contact is obscured beneath talus.

On the south flank of the Kikiktat syncline, the base of the Picnic Creek allochthon is marked by a zone that may be up to 1,000 feet thick consisting of sheared shale and mudstone that contains large sheared blocks of black, gray, and green chert (fig. 7). The blocks in this broken formation appear to have been derived entirely from formations on the Picnic Creek allochthon rather than representing exotic blocks derived from other sources. The sheared matrix in which the blocks are encased may consist of shale that forms the lower part of the Picnic Creek allochthon or may be sheared Cretaceous mudstone derived from the underlying allochthon, or may be a mixture derived from both sources. A sequence of rocks with more coherent stratigraphy overlies the broken formation (fig. 8), forming the majority of the Picnic Creek allochthon. However, throughout the allochthon, thrust faulting is pervasive.

The north flank of the Kikiktat syncline is marked by the contact of complexly deformed cherts of the Akmalik Chert and Imnaitchiak Chert of the Picnic Creek allochthon with isoclinally folded and imbricated south dipping Otuk Formation and slivers of Early Cretaceous coquinoid limestone, which mark the top of the Endicott Mountains allochthon. The Otuk Formation and overlying chert of the Picnic Creek allochthon are exposed in a series of low rubble covered ridges that extend between Imnaitchiak Creek and Heather Creek 10 to 12 mi north of the mountain front. The absence of the Hunt Fork Shale(?) and Kurupa Sandstone at the base of the Picnic Creek allochthon on the north flank of the Kikiktat syncline is probably due to upward ramping of the basal thrust of the Picnic Creek allochthon.

Around the lower slopes of Kikiktat Mountain, rocks of the Picnic Creek allochthon are structurally overlain by rocks similar to some of the Ipnavik River allochthon; these rocks are also present elsewhere in the Killik River-Kurupa River area. Kikiktat Mountain, which marks the structurally lowest point along the axis of the syncline, is a klippe composed of two imbricated sheets of pillow basalt and flows with columnar jointing. The basalt of the upper sheet, which is internally imbricated, overlies at a baked contact arkosic limestone typical of the Nuka Formation. The Kikiktat Mountain klippe, at the top of the stack of allochthons in the Killik River Quadrangle, occupies the structural position of the Copter Peak allochthon. In the western Brooks Range, the Copter Peak allochthon is part of a complex of allochthons that may be part of an obducted dismembered ophiolite (Roeder and Mull, 1978; Mull, 1982; Mayfield and others, 1983). However, the association of Nuka Formation and basalt at Kikiktat Mountain is anomalous, and except for the lithology and structural position, we lack other evidence for directly correlating Kikiktat Mountain with the Copter Peak allochthon.

Figure 7. View southwest in Akmalik Creek canyon to broken formation at base of Hunt Fork Shale(?) on Picnic Creek allochthon. Sheared blocks consist of probable Etivluk Group chert and siliceous shale in sheared mudstone groundmass. Canyon wall is about 100 ft high. High peak in distance is composed of four imbricated and south-dipping overturned sheets of Lisburne near top of Endicott Mountains allochthon.

Figure 8. View southeast to Akmalik Creek canyon and Endicott Mountains front, showing rocks on Picnic Creek allochthon, broken formation at its base, approximate trace of basal thrust-zone, and overturned top of Endicott Mountains allochthon. Picnic Creek allochthon: PMa - Akmalik Chert (type section), PMi - Imnaitchiak Chert (light colored band), (1) Mk - Kayak Shale, Mku - Kurupa Sandstone (reference section), bf - broken formation. Endicott Mountains allochthon: PMl - Lisburne Group, JPe - Etivluk Group (Siksikpuk and Otuk Formations). Measured section of overturned top of Lisburne, Siksikpuk, and Otuk is at (A). Imnaitchiak Chert reference section is on shoulder of hill at (B).

(1)Note: After these illustrations were prepared, radiolarian dates (B.L. Murchey, verbal commun.) indicate that the Imnaitchiak Chert ranges to as young as Middle or Late Triassic age.

Generalized Stratigraphy

Six stratigraphic units are mapped on the Picnic Creek allochthon. These units are, in ascending order; the Hunt Fork Shale(?) (Upper Devonian), the Kurupa Sandstone (new name) (Lower Mississippian), and the Kayak Shale (Mississippian) of the Endicott Group; the Akmalik Chert (new name) of the Lisburne Group (Upper Mississippian-Lower Pennsylvanian?); the Imnaitchiak Chert (new name) (Pennsylvanian-Triassic); and the Okpikruak Formation (Lower Cretaceous).

Hunt Fork Shale(?)

The base of the stratigraphic sequence on the Picnic Creek allochthon is composed of several hundred feet of unfossiliferous greenish-gray shale that grades up to dark-gray to black shale interbedded with thin sandstone beds. The contact with the overlying Kurupa Sandstone is gradational and interfingering; the contact is arbitrarily placed at the base of the lowest sandstone bed that is overlain by interbedded shale intervals thinner than the adjacent sandstone beds. This shale interval is provisionally assigned to the Hunt Fork Shale based on its stratigraphic position and lithologic similarity to the Hunt Fork Shale on the Endicott Mountains allochthon. The Hunt Fork Shale(?) is well exposed on the west side of the Kurupa Hills near the head of the west fork of the Kurupa River.

Kurupa Sandstone

Definition

The name Kurupa Sandstone is here applied to a resistant Lower Mississippian sandstone interval that underlies a Mississippian chert and shale section and overlies the Hunt Fork Shale(?). The Kurupa Sandstone is well exposed in a number of imbricated thrust sheets in the Kurupa Hills, 5 mi west of Kurupa Lake in the central Killik River Quadrangle. The type locality is located on the highest point in the Kurupa Hills (fig. 1, sec. A) (C, Sec. 1, T. 34 N., R. 17 E, Kateel River Meridian). A reference section is located in the canyon of Akmalik Creek (fig. 9) 2 mi southwest of Kikiktat Mountain (fig. 1, sec. B) (C, sec. 30, T. 12 S., R. 10 W., Umiat Meridian).

The Kurupa Sandstone has been mapped as a conspicuous resistant unit in a 35 mi east-west trend from the Kurupa Hills on the west to near the Middle Fork of the Okpikruak River, 20 mi east of Kikiktat Mountain. It is also exposed about 10 mi north of the mountain front, between Imnaitchiak Creek and the head of Heather Creek. West of the Kurupa Hills, the formation is less resistant, and contains thin interbedded platy sandstone and silty limestone beds. Regional structural relationships suggest that the Kurupa Sandstone is probably not present in the subsurface north of the exposed 'disturbed belt.' Thus, although the relatively clean quartzose nature of the sand suggests that the Kurupa Sandstone could have reservoir potential, the formation is probably not a hydrocarbon exploration objective.

Lithology, sedimentology, and contacts

The Kurupa Sandstone is a well-bedded succession of medium- to coarse-grained sandstone with intervening thin shale and siltstone beds (fig. 9). Preliminary petrographic studies indicate that it is composed of 80 to 85 percent quartz, 5 to 10 percent chert, 3 to 10 percent feldspar, and trace amounts of rock fragments and accessory minerals. The thickness of complete exposures average 130 ft. The Kurupa is underlain by the marine Hunt Fork Shale(?) and overlain by siltstone and shale of the Kayak Shale. Both upper and lower contacts are variably gradational. Our comments here address general depositional characteristics of the Kurupa; a more complete sedimentologic analysis will be summarized in a future paper.

The Kurupa Sandstone is dominated throughout its outcrop belt by thin to medium bedded sandstone units in which are preserved a variety of primary sedimentary structures. More than 95 percent of the Kurupa lithologies are sandstone. Minor granule and pebble conglomerate occurs rarely in some sections. Most sandstone sequences are turbidites and display variable Bouma sequences. The sequence at most outcrops shows an upward-coarsening and thickening trend which begins with thinly-interbedded sandstone-shale alternations in the upper Hunt Fork(?), and reaches its culmination near the middle of the Kurupa Sandstone. The upper few feet of the Kurupa are highly variable and range from thinly-bedded, ripple-laminated, fine-grained sandstone, to massive and apparently structureless medium-grained sandstone with minor shale interbeds. Directional analyses of numerous sole marks and other primary current-generated structures indicates a strong southeasterly component of sediment dispersal.

The lower beds of the Kurupa Sandstone are part of an imperceptable upward coarsening which begins in the Hunt Fork Shale(?). Typically, the lower Kurupa beds comprise a 20 to 60 ft section of alternating, thinly-bedded siltstone and sandstone with minor shale partings. Sandstone beds are often characterized by plane-parallel beds with ripple tops (Bouma T_{bc}). Numerous feeding traces of uncertain affinities mark bedding surfaces. Rare vertical escape burrows have been observed in a few sandstone beds. Sandstone beds of the lower Kurupa sequence thicken and become more closely-spaced upsection.

At most localities we have studied, the lower beds of the Kurupa grade upsection into a coarsening and thickening sequence which dominates the middle 60 to 75 ft of the formation (fig. 10). Sandstone beds within this sequence are medium- to coarse-grained and vary in thickness from 10 in. to more than 3 ft (fig. 11). Some sandstone units are bimodally sorted with coarse sand and granule size grains occurring within medium-grained sandstone. Many sandstone intervals are amalgamated turbidites separated by thin shale drape which show repetative Bouma T_{bc} sequences and occasionally the Bouma sequence T_{abc}. The base of most beds display well-preserved sole marks, rip-up and deformational structures and dewatering features. Shale interbeds often contain organic-rich laminae, and abundant plant debris is disseminated within some sandstone layers. Significantly, recognizable channelized intervals with erosional bases have not been observed within the Kurupa Sandstone. Individual sandstone beds are laterally continuous with very rare pinchouts visible in outcrop.

Figure 9. Kurupa Sandstone reference section and overlying Kayak Shale and Akmalik Chert, east side of Akmalik Creek canyon. Mku - Kurupa Sandstone, Mk - Kayak Shale, PMa - Akmalik Chert (type section). Canyon wall is about 250 ft high.

Figure 10. Kurupa Sandstone, Akmalik Creek. Upward coarsening and thickening megasequence within lower and middle Kurupa Sandstone. Section is gradational with underlying Hunt Fork Shale(?). Pillow and columnar basalts of Copter Peak allochthon on west peak of Kikiktat Mountain in left background. Note figure in center for scale.

Figure 11. Thick sandstone intervals characteristic of middle 60-75 ft of Kurupa sandstone. Beds are internally composed of multiple amalgamated turbidites.

The upper 15 to 50 ft of the Kurupa is highly variable. At some outcrops (e.g., Akmalik Creek), the upper Kurupa is developed as an upward-thinning and fining megasequence composed internally of numerous small-scale upward fining sequences. Sandstone-shale ratios decrease irregularly throughout the upper interval. Shale and siltstone interbeds contain abundant organic detritus and horizontal burrows of uncertain affinity. The upper contact with the Kayak Shale is a gradational transition to recessive and poorly-exposed siltstone and shale. At other localities in the Cascade Lake region, the upper Kurupa shows numerous soft-sediment deformational features and conspicuous low-angle intraformational truncation surfaces (fig. 12). Ripple-laminated beds terminate the sequence.

Age

Mississippian plant fossils have been collected from the Kurupa Sandstone at a number of localities in the central Killik River Quadrangle. Although plant debris is common throughout the formation, the largest collections of plant fossils have been found in thin platy siltstone beds near the top of the formation. The fossils have been identified as early representatives of the arborescent lycopods Tomiodendron varium (Radczenko) Meyer and Angarophloios cf alternans (Schmalhausen) Meyer of Tournaisian-Visean (Kinderhook to Meramec) age (B.A. Thomas and R.A. Spicer, Goldsmiths College, University of London, written communication, 1984). Spicer and Thomas (1985) also report that these fossils are known only from Mississippian units in eastern Siberia. Furthermore, these authors suggest that the absence of these genera in extensively collected European assemblages suggests that northern Alaska and eastern Siberia were joined during Mississippian time.

In addition to plant fossils, a few brachiopods were collected near Otuk Creek, 25 mi west of the Kurupa Hills, in a sequence of silty limestone interbedded with very fine grained, platy sandstone that contained plant debris and conspicuous flute casts similar to beds in the Kurupa Sandstone. The fossils were identified as rhynchonelloid brachiopods that may be Paraphorhynchus sp. of probable Early Mississippian age (J.T., Dutro, Jr., written commun., 1984).

Interpretation of Depositional Environments

We believe the turbidite sequences preserved within the Kurupa Sandstone were deposited as a delta-fed, low-efficiency, sand-dominant dispersal system similar in some aspects to that described by Heller and Dickenson (1985). The thinly-bedded upward coarsening sequence marking the transition between the Hunt Fork(?) and Kurupa records southerly progradation of the fringe areas of a submarine, delta-built ramp. The general upward-thickening, non-channelized organization of sandstone sequences suggests that the middle portion of the Kurupa was deposited by sheet flows which spread laterally onto a ramp surface. As progradation ensued, the density of turbid flows steadily increased and culminated by deposition of thick, amalgamated sequences which characterizes the middle Kurupa interval at most locations. The upper beds of the Kurupa record deposition in a suite of environments, ranging perhaps from prodelta slope to delta platform. Multiple intraforma-

Figure 12. Intraformational truncation surface in upper portion of Kurupa Sandstone in Kurupa Hills. Basal sandstone bed overlying the angular discordance contains sole marks, minor scour and fill structures cut into underlying strata, and rip-up clasts derived from underlying beds, attesting to a sedimentary origin of the truncation.

tional truncation surfaces and large-scale slump features may record the transition from slope to platform environments. These environments apparently developed as the distal sand-dominant dispersal systems of the major Late Devonian and Early Mississippian fluvio-deltaic complexes recorded by the Kanayut Conglomerate and related formations.

Kayak Shale

The Kurupa Sandstone is overlain by 50 to 100 ft of poorly exposed recessive siltstone and black clay shale (fig. 9) that contains scattered red-brown-weathering ironstone concretions, and grades upward into siliceous shale. On the basis of lithology and stratigraphic position, these beds are considered to represent the Kayak Shale, although the shale interval on the Picnic Creek allochthon is much thinner than the Kayak on the Endicott Mountains allochthon. The contacts with the underlying Kurupa Sandstone and overlying Akmalik Chert are gradational over a thin interval. Fossils from concretions collected at the headwaters of a tributary of Imnaitchiak Creek were identified as Mississippian by J.T. Dutro, Jr., (written commun., 1984). The collection contained Schizophoria sp., Retichonetes sp., Quadratia sp., Setigerites sp., Astartella sp., and indeterminate orthotetid brachiopods, rhynchonelloid fragments, platycrinitid columnals, and echinoderm debris.

Akmalik Chert

Definition

The name Akmalik Chert is here applied to a sequence of bedded black chert that overlies the Kayak Shale and is considered to be part of the Lisburne Group. It is extensively exposed in the Kurupa Hills and in the Imnaitchiak and Akmalik Creeks areas (fig. 13). Its type locality is in the canyon of Akmalik Creek (fig. 1, sec. C) (C, sec. 30, T. 12 S., R. 10 N., Umiat Meridian) about 2 mi southwest of Kikiktat Mountain. At this location, a shallow east-west trending syncline crosses the canyon about 100 yds downstream from the resistant Kurupa Sandstone (fig. 8); the Akmalik Chert is best exposed on the east side of the canyon, although the contact with the overlying Imnaitchiak Chert is best exposed near the top of the west side of the canyon. A reference section is located in the Kurupa Hills on the west side of the Kurupa River, about 2 mi downstream from Kurupa Lake (fig. 1, sec. D) (C, sec. 29, T. 12 S., R. 12 W., Umiat Meridian).

Tailleur and others (1966) informally designated "black Lisburne" in some sedimentary sequences near Howard Pass. This name covers many separate and mappable facies of Mississippian age rocks. One facies, the Kuna Formation, was named by Mull and others (1982). The Akmalik Chert contains other rocks previously designated "black Lisburne"; yet other facies within the "black Lisburne" are unnamed.

Lithology and contacts

The Akmalik Chert consists almost entirely of bedded black chert, with minor amounts of siliceous black mudstone and interbedded black shale. The chert typically fractures with a smooth conchoidal surface, and most beds

Figure 13. Akmalik Chert type section, east side of Akmalik Creek canyon. Note thin white weathering limestone bed near base of section. Light weathering interval near top of bluff is basal Imnaitchiak Chert. Height of bluff about 250 ft. Contact with Kayak shale is exposed out of view to right, near top of bluff.

contain finely disseminated pyrite. Near the base of the formation are two conspicuous dolomitic limestone beds up to 40 in. thick. Most of the formation is evenly bedded although beds range from 1 to 30 in. thick and are occasionally nodular to lenticular. Average bedding thickness is about 3 in. Internal structures are generally absent, with the exception of faint parallel to wispy laminations and very minor occurrences of low angle cross-bedding. Orange- and red-brown streaks stain the surface of the black chert, due to the oxidation of the pyrite, giving the unit a distinctive 'Halloween' appearance. When studied in the Killik River area, the formation is between 230 and 260 ft thick.

The base of the formation is not well exposed but is apparently gradational over a thin interval with the underlying Kayak Shale. Where well exposed, the upper contact with the Inmaitchiak Chert is sharp and marked by an abrupt change in lithology (fig. 14). The base of the overlying Imnaitchiak Chert consists of a distinctive thin (less than 30 in. thick) fine-to-medium grained glauconitic and phosphatic sandstone horizon (Siok and Mull, 1986, this volume); however, at one locality an oncolitic conglomerate with a glauconitic and phosphatic matrix overlies the Akmalik chert. In places where the exposures are poor and the sandstone or oncolite is not exposed, the contact is marked by a change in color, from black chert below to gray or green-gray chert above the contact.

The Akmalik Chert on the Picnic Creek allochthon is distinguished from the Kuna Formation of the Lisburne Group on the Endicott Mountains allochthon by a variety of features, although in poor outcrops the two formations may superficially resemble each other. In contrast to the Akmalik Chert, which consists almost entirely of bedded black chert, the Kuna Formation is predominantly sooty black shale interbedded with black chert.

In addition to the lithologic characteristics that distinguish the Akmalik Chert from the Kuna Formation, the two formations are part of distinctively different sedimentary sequences. The Kuna Formation is overlain by generally poorly exposed shaly and silty beds of the Siksikpuk Formation, whereas the Akmalik Chert is overlain by dominantly cherty rocks that even in poor exposures weather to rubble-covered hillsides. In addition, the Kuna Formation overlies thick sections of black clay shale of the Kayak Shale, which, in turn overlies thick sections of Kanayut Conglomerate; whereas, the Akmalik Chert overlies thin siliceous Kayak Shale and the relatively thin Kurupa Sandstone.

Age

At the present time, we consider the Akmalik Chert to be Mississippian to Early Pennsylvanian in age, based on a plant fossil and radiolarian and conodont dates. The plant fossil is a beautifully preserved imprint of an unnamed new genus that combines characteristics of Tomiodendron and Angarophloios (R.A. Spicer, written commun., 1984). According to Spicer, a similar specimen has been recovered from the Lower Namurian (= Chesterian, Upper Mississippian) in Russia. Radiolarians recovered from several horizons in the Akmalik Chert include Latentifistula impella, L. ruestae, L. spp., Albaillella sp., spumellarians with bipolar spines, and spongy tetrahedral

Figure 14. Top of Akmalik Chert, west side of Akmalik Creek canyon. Undulatory top of chert is overlain by 1½ ft thick fine grained glauconitic and phosphatic sandstone, which is succeeded upward by greenish gray bedded chert.

latentifistulids. This fauna suggests a Late Mississippian age and represents assemblages A and B of Murchey and others (1979), which are equivalent to the lower part of the Chesterian to Morrowan Albaillella-3 assemblage of Holdsworth and Jones (1980) (B.L. Murchey and K.M. Reed, written commun., 1984). An occurrence of spongy tetrahedral latentifistulids at the top of the Akmalik Chert near Kurupa Lake suggests a Morrowan (Early Pennsylvanian) age for the top of the black chert at that locality, however, the possibility exists that these radiolarians may range down into the Chesterian. Conodonts from the limestone horizons at the base of the Akmalik Chert are dated by Anita Harris (written commun., 1985) as Morrowan (Early Pennsylvanian); the significance of the divergent radiolarian and conodont dates has not been resolved although biostratigraphic studies are continuing.

Imnaitchiak Chert

Definition

The name Imnaitchiak Chert is here applied to a section of dominantly gray and green chert and maroon silicified shale and siltstone of the Etivluk Group overlying some formations of the Lisburne Group. In the Killik River Quadrangle, the Imnaitchiak Chert is extensively exposed on the Picnic Creek allochthon in the Imnaitchiak Creek area and in the Kurupa Hills (fig. 1). The type locality is in the Kurupa Hills on the southwest side of the Kurupa River (fig. 1, section E; fig. 15) (c, sec. 29, T. 12 S., R. 12 W., Umiat Meridian). A reference section is located on the south side of an isolated hill along lower Akmalik Creek (fig. 1, section F; fig. 8) (NE. ¼, sec. 27, T. 12 S., R. 10 W.).

The Imnaitchiak Chert contains some of the rocks that were previously known as the Siksikpuk Formation throughout the central and western Brooks Range. The Siksikpuk Formation is here recognized in its original sense in some areas of the western Brooks Range and in the north-central Brooks Range. This includes its type locality on Tiglukpuk Creek, 60 mi east of the Killik River area (Patton and Tailleur, 1964). The Siksikpuk Formation as here restricted consists dominantly of shale and siltstone and only minor chert. In the Killik River and Chandler Lake Quadrangles the Siksikpuk Formation is present only on the Endicott Mountains allochthon. In the Killik River Quadrangle Imnaitchiak Chert is present on the Picnic Creek allochthon and on the Ipnavik River allochthon, where it is poorly exposed and has not been studied in detail. To the west, in the De Long Mountains, Imnaitchiak Chert is present on the Endicott Mountains, Picnic Creek, Kelly River, Ipnavik River, and Nuka Ridge allochthons. It is also present on the Lisburne Peninsula.

Lithology and contacts

The rocks here referred to as the Imnaitchiak Chert have been described and studied in detail by Siok (1985), who recognized on the Picnic Creek allochthon six lithostratigraphic units that can be correlated throughout the Imnaitchiak Creek, Kurupa Hills, and Akmalik Creek areas. These units are distinctly different from those of the Siksikpuk Formation. The Imnaitchiak Chert consists dominantly of chert and siliceous mudstone with interbedded

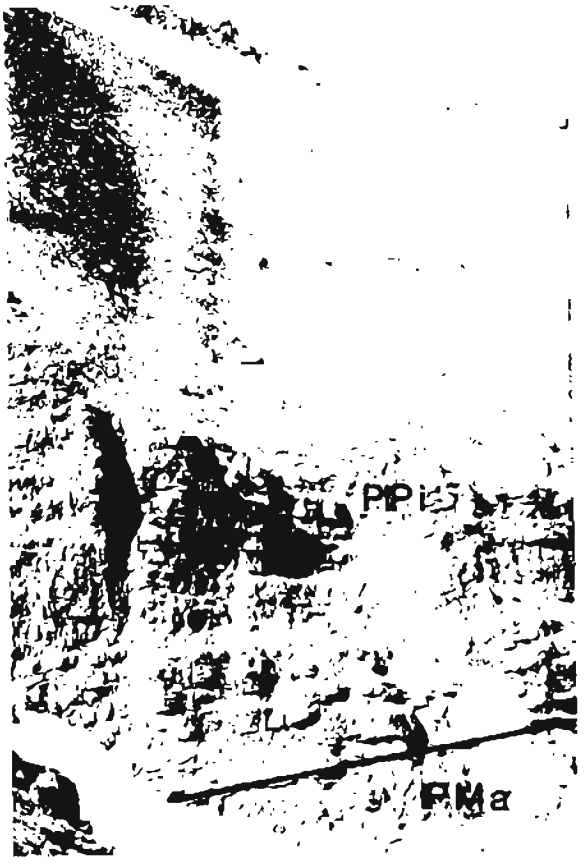

Figure 15. Lower part of Imnaitchiak Chert in Kurupa Hills; contact with Akmalik Chert is marked by 2 ft thick glauconitic and phosphatic sandstone. Lower resistant part of Imnaitchiak Chert is about 50 ft thick, has abundant orangish yellow weathering clay; upper silicified mudstone has conspicuous maroon color. Ridge top is formed by thrust sheet of Kurupa Sandstone. PMa - Akmalik Chert, PPi - Imnaitchiak Chert. (1)Note: After these illustrations were prepared, radiolarian dates (B.L. Murchey, verbal commun.) indicate that the Imnaitchiak Chert ranges to as young as Middle or Late Triassic age.

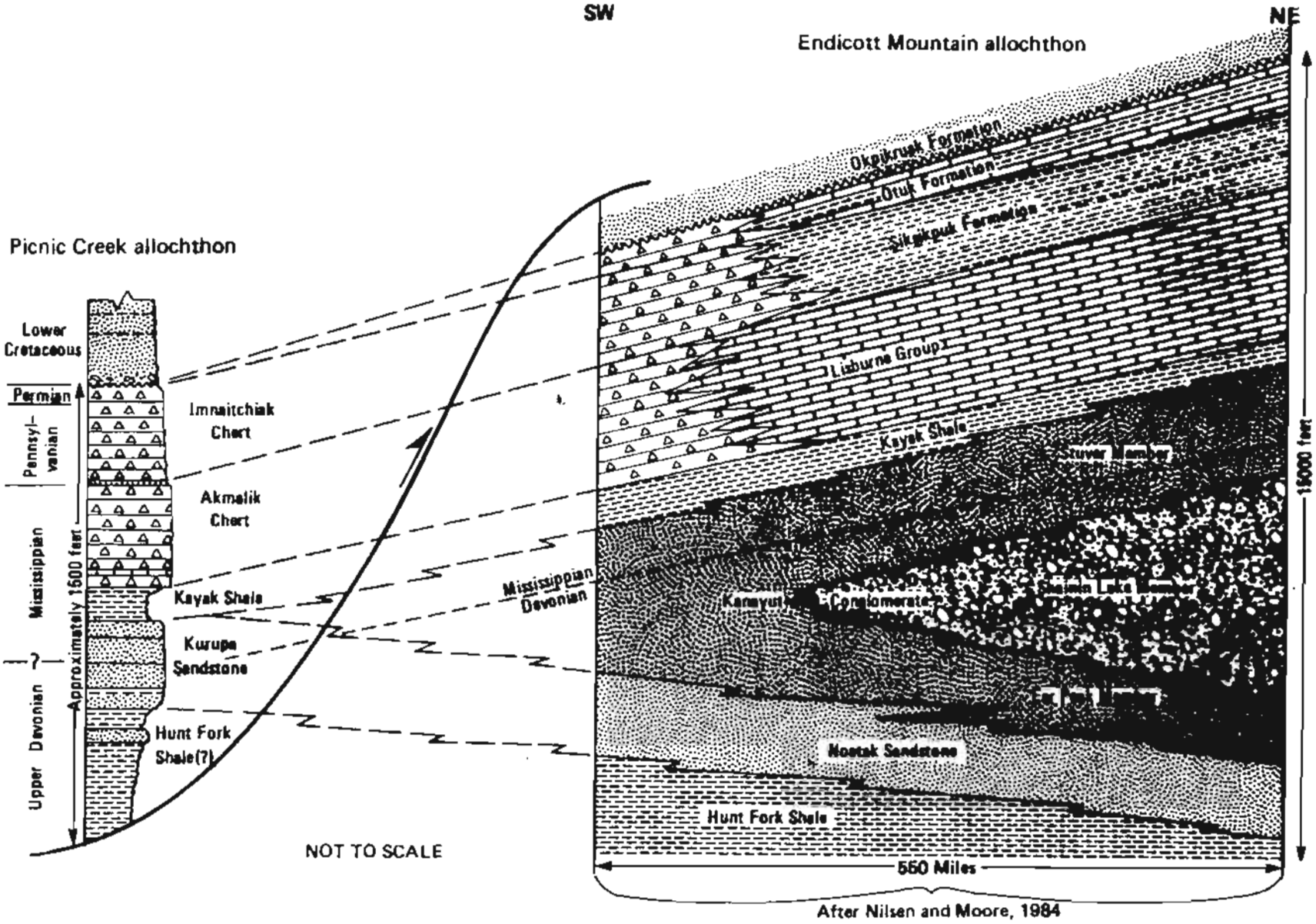

Figure 16. Schematic diagram showing correlation of Picnic Creek allochthon with schematic cross-section of Endicott Mountains allochthon. Stratigraphy of Endicott Mountains allochthon is modified from Nilsen and Moore (1984).

siliceous shale and subordinate amounts of siltstone to very fine-grained sandstone. The colors range from dominantly dark gray to greenish-gray in the lower part of the formation to dominantly red, maroon, or purple in the upper part. Yellow-orange weathering of decomposed shale is characteristic of the lower part of the formation above the bedded gray chert. Typical bedding character of rocks here recognized as Imnaitchiak Chert is illustrated by Mull and others (1982, fig. 7, p. 356).

On the Picnic Creek allochthon in the Kurupa Hills the basal contact of the Imnaitchiak Chert is a sharp disconformity. The basal 1 to 3 ft of the Imnaitchiak Chert is composed of a distinctive fine- to medium-grained glauconitic sandstone that separates the underlying black Akmalik Chert from the overlying dominantly greenish-gray Imnaitchiak Chert (Siok and Mull, 1986, this volume). At the reference section near lower Akmalik Creek, an unusual oncolitic conglomerate composed dominantly of replacement barite and a glauconitic and phosphatic matrix is present at the base of the formation. At most places, the formation is overlain by a thrust fault, although at a few localities it is overlain by graywacke of the Cretaceous Okpikruak Formation. As much as 250 ft of Imnaitchiak Chert has been measured, but most sections are incomplete and less than 150 ft thick.

Age

In the Killik River Quadrangle, the Imnaitchiak Chert was originally dated as Pennsylvanian-Early Permian(?) (Wolfcampian) on the basis of three radiolarian assemblages recovered from a number of samples (Siok, 1985). However, Triassic radiolarians have now been recovered also (B.L. Murchey, personal commun., 1987). The dates, however, are imprecise and generally range over at least two stages. The radiolarians were identified by B.L. Murchey and K.M. Reed (written commun., 1984), who correlated the assemblages with a radiolarian zonation developed by Murchey and others (1979).

The Pennsylvanian radiolarian assemblages include Latentifistula sp., Tormentum sp., Albaillella sp., and Pseudoalbaillella sp. from rocks here named the Imnaitchiak Chert, and Latentifistula impella from the underlying Akmalik Chert. In areas in which the contact between the Akmalik Chert and Imnaitchiak Chert is defined by the presence of the glauconitic sandstone or oncolite, the Latentifistula impella assemblage always occurs below the sandstone and the other three assemblages occur above it. This suggests that the glauconitic sandstone can be used as a precise chronostratigraphic correlation marker. However, locally, thin black chert has been found above the contact and thin gray chert has been found a short distance below; this suggests that the color change from black to gray chert does not represent a precise time line.

A single conodont recovered from high in the Imnaitchiak Chert was identified by Bruce Wardlaw (written commun., 1984) as a juvenile Neogondolella that is either N. clarki (Koike) of late Morrowan age or N. bisselli (Clark and Brown) of late Wolfcampian age. The Neogondollella, however, occurs above Pseudoalbaillella spp., a radiolarian that appears to have developed after the Morrowan, thus we suggest that the conodont is probably a late Wolfcampian form.

Only one megafossil has been found in the Imnaitchiak Chert on the Picnic Creek allochthon. It is an indeterminant linguloid brachiopod with no age significance (J.T. Dutro, Jr., written commun., 1984).

In the Killik River Quadrangle, most of the Imnaitchiak chert is Pennsylvanian age. However, scattered conodont and radiolarian data show that it ranges to as young as Triassic. To the west in the De Long Mountains, poorly studied cherty rocks that are lithologically similar to part of the Imnaitchiak Chert also contain Triassic fossils. On this basis we believe that future studies may show that the Imnaitchiak Chert ranges from Pennsylvanian to as young as Late Triassic.

Okpikruak Formation

In the canyon of Akmalik Creek, the Imnaitchiak Chert is overlain by black mudstone and minor graywacke of the Okpikruak Formation. In the Imnaitchiak Creek area, the Imnaitchiak Chert is overlain by lithic graywacke and chaotic conglomerate. The lithic fraction of the graywacke is dominated by fine grained sedimentary rock fragments but contains a significant percentage of volcanic grains and minor amounts of metamorphic and plutonic detritus (Wilbur and others, 1986, this volume). Clasts in the conglomerate include chert, limestone, gabbro, basalt, and granitic rocks. Some of the rounded igneous boulders range up to 9 in. in diameter, but angular limestone blocks 4 to 20 ft long have been observed; these coarse chaotic deposits are part of an olistostrome.

Two pelecypods, Buchia sublaevis Keyserling and Buchia crassicolis solida (Lahusen) have been collected from the graywacke in the Imnaitchiak Creek area and have been dated as early to late Valanginian (Early Cretaceous) (J.W. Miller, written commun., 1984).

Exposures of the Okpikruak Formation are generally poor and consist dominantly of rubble; therefore no contacts with other rock units are exposed. The basal contact is presumably an unconformity that overlies Imnaitchiak Chert. In many areas the top of the Okpikruak is a Holocene erosion surface, however, locally the Okpikruak appears to be overlain by a thrust sheet of older rocks.

REGIONAL RELATIONSHIPS

The stratigraphic sequences of the Picnic Creek and Endicott Mountains allochthons show many similarities, although the individual formations on the Picnic Creek allochthon are much thinner and are generally finer grained than than the correlative rocks on the Endicott Mountains allochthon. The clastic rocks of the Kurupa Sandstone and Hunt Fork Shale(?) are lithologically similar to and coeval with the Kanayut Conglomerate, Noatak Sandstone, and Hunt Fork shale of the Endicott Mountains allochthon; likewise the Akmalik Chert and Kayak Shale of the Picnic Creek allochthon are lithologically similar to and coeval with the Kuna Formation and Kayak Shale of the Endicott Mountains allochthon. Similarly, the Imnaitchiak Chert has some lithologic similarities to the Siksikpuk Formation, but paleontologic data suggest that its base is older than the Siksikpuk. In general, the Kayak Shale, Akmalik

Chert, and Imnaitchiak Chert are much more siliceous and thinner than their counterparts on the Endicott Mountains allochthon.

In a palinspastic restoration the northernmost rocks of the Picnic Creek allochthon are moved at least 60 mi to a position south of the Endicott Mountains allochthon. This shortening is a minimum figure that does not include shortening by imbrication and folding of rocks within each of the allochthons. The restoration is based upon regional geologic relationships in the Brooks Range that indicate north vergent deformation and thrusting in the Early Cretaceous evolution of the Brooks Range orogenic belt (Mull, 1982; Mayfield and others, 1983). On the Endicott Mountains allochthon, Nilsen and Moore (1984, fig. 8) illustrated southwestward thinning and fining of the fluvial deposits of the Kanayut, and inferred a Kanayut pinchout into marine strata to the southwest. In the reconstructed basin, the marine strata of the Kurupa Sandstone on the Picnic Creek allochthon occur in a relative position predicted by the detailed facies studies of Nilsen and Moore. In addition, stratigraphic studies of Mississippian through Triassic sequences document a southerly or southwesterly progression to more siliceous sediments on the Endicott Mountains allochthon (Mull and others, 1982; Bodnar, 1984; Siok, 1985; Adams and Mull, 1985). The relative position of the Akmalik Chert and Imnaitchiak Chert on the restored Picnic Creek allochthon is compatible with the facies progressions seen in the correlative sequences on the Endicott Mountains allochthon.

In summary, the Upper Devonian through Triassic stratigraphic sequences on the Picnic Creek allochthon appear to be distal southern or southwestern equivalents of the sequences on the Endicott Mountains allochthon.

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