Public-data File 86-86b

THIRTY-SEVEN MEASURED SECTIONS OF LOWER CRETACEOUS KEMIK SANDSTONE, NORTHEASTERN ALASKA

By
Douglas G. Knock

Alaska Division of Mining and Geology

December, 1986

794 University Avenue, Basement
Fairbanks, Alaska 99709

CONTENTS

TABLES

FIGURES

SHEETS

THIRTY-SEVEN MEAURED SECTIONS OF LOWER CRETACEOUS KEMIK SANDSTONE, NORTHEASTERN ALASKA

INTRODUCTION

Thirty-seven stratigraphic sections of Lower Cretaceous Kemik Sandstone in northeastern Alaska were measured and sampled during the 1985 and 1986 field seasons. Figure 1 is an index map of northeastern Alaska showing locations of the thirty-seven measured sections listed in Table 1. This report provides information concerning the depositional setting and lithofacies of the Kemik Sandstone.

METHODS AND EXPLANATION

All stratigraphic sections were measured with a tape or Jacob staff and Brunton compass. The sections were plotted at a vertical scale of one cm. equals one meter.

A major emphasis was placed on determining characteristics which would define individual lithofacies. Lithofacies were defined by lithology, sedimentary structures, biogenic structures, and bed thickness and contact types.

Paleocurrents shown on the sections were measured from low-angle crossbeds, current ripples, wave ripples and trough crossbeds. Current directions were corrected for regional strike and dip by using a stereonet.

Sample numbers refer to rock samples (85DK---) taken for thin sections, micropaleontologic identifications and hand samples. Megafossil

Table 1. List of Kamik measured sections, northeastern Alaska.

No.	Section Name	Location				
		Mt. Michelson Quadrangle		Section	T.	R.
1	West Side Canning River Valley 1	B-4	NW/4,NE/4	7	1N	23E
2	West Side Canning River Valley 2	B-4	S/2	6	1N	24E
3	West Side Canning River Valley 3	B-4	NE/4, SW/4	6	1N	24E
4	West Side Canning River Valley 4	B-4	E/2, NE/4	1	1N	23E
5	West Bank Canning River	B-4	SE/4, SE/4	30	2N	24E
6	Ignek Creek 1	C-4	SW/4,NW/4	19	3N	25E
7	Ignek Creek 2	C-4	S/2,NE/4	27	3N	25E
8	Ignek Creek 3	C-4	NE/4,SW/4	26	3N	25E
9	Ignek Creek 4	C-4	SE/4,SE/4	25	3N	25E
10	Hue Creek	C-4	SW/4, NE/4	6	2N	26E
11	Ignek Creek 5	C-4	SW/4,SW/4	29	3N	26E
12	Ignek Creek 6	C-4	SW/4,SW/4	29	3N	26E
13	Ignek Valley-Elevation 2220 Hogback 1	C-3	C,SW/4	27	3N	26E
14	Ignek Valley-Elevation 2220 Hogback 2	C-3	W/2,SE/4	27	3N	26E
15	Ignek Valley-Elevation 2220 Hogback 3	C-3	NE/4,SE/4	27	3N	26E
16	Ignek Valley South Of Katakturuk Canyon	C-3	SW/4,SE/4	25	3N	26E
17	Ignek Valley-Middle Fork Of Katakturuk R.	C-3	SE/4,SE/4	6	2N	27E
18	Ignek Valley-East Fork Of Katakturuk R. 1	C-3	NE/4,NE/4	4	2N	27E
19	Ignek Valley-East Fork Of Katakturuk R. 2	C-3	E/2,NW/4	3	2N	27E
20	Ignek Valley-Katakturuk R. Syncline 1	C-3	NW/4,NW/4	2	2N	27E
21	Ignek Valley-Katakturuk R. Syncline 2	C-3	SW/4,NW/4	2	2N	27E
22	Ignek Valley-Katakturuk R. Syncline 1	C-3	S/2,NW/4	2	2N	27E
23	Ignek Mesa	C-3	NE/4,SE/4	6	2N	28E
24	West Fork Marsh Creek 1	C-2	SW/4,SE/4	22	4N	29E
25	West Fork Marsh Creek 2	C-2	NE/4,NW/4	23	4N	29E
26	Marsh Creek 1	C-2	SE/4,SE/4	19	4N	30E
27	Marsh Creek 2	C-2	NW/4,NE/4	19	4N	30E
28	Marsh Creek 3	C-2	NE/4,NW/4	19	4N	30E
29	Marsh Creek 4	C-2	SE/4,SW/4	18	4N	30E
30	Marsh Creek 5	C-2	SE/4,SW/4	18	4N	30E
31	Marsh Creek 6	C-2	S/2,SW/4	18	4N	30E
32	Marsh Creek 7	C-2	NW/4,SW/4	18	4N	30E
33	Marsh Creek 8	C-2	NE/4,SE/4	13	4N	29E
34	Last Creek 1	C-1	S/2,NW/4	11	3N	31E
35	Last Creek 2	C-1	SE/4,NE/4	11	3N	31E
36	Sadlerochit River 1	C-1	N/2,NW/4	14	3N	31E
37	Sadlerochit River 2	C-1	NW/4,SW/4	14	3N	31E

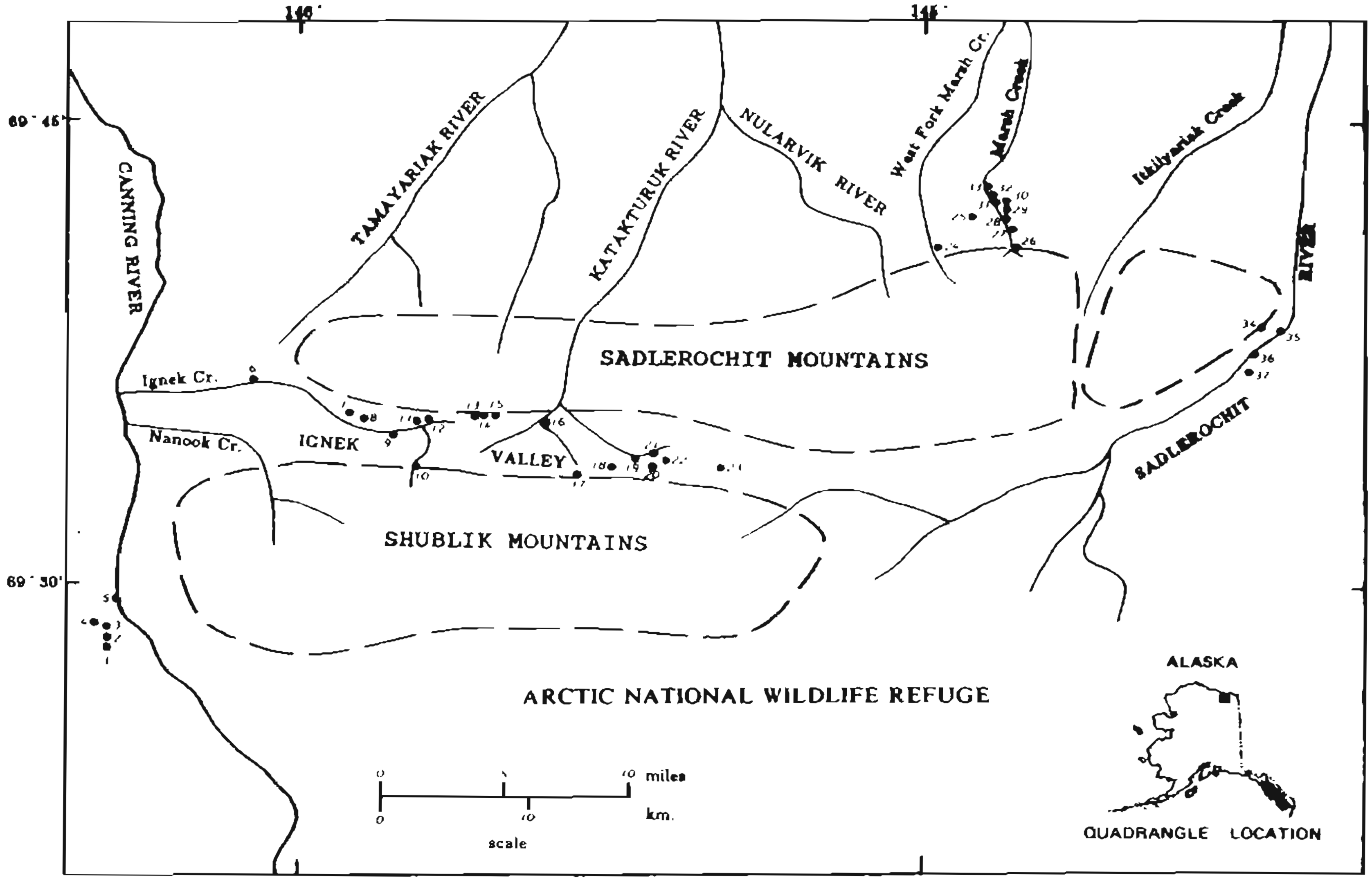

Figure 1. Index map of northeastern Alaska showing locations of Kemik measured sections.

samples are referenced by their University of Alaska Museum locality number (A---).

Megafossil identifications are by Dr. R. C. Allison of the University of Alaska-Fairbanks and Dr. J. Callomon of the University College-London.

REGIONAL GEOLOGIC SETTING

The stratigraphy of northern Alaska has been divided into depositional sequences which are separated by prominent unconformities (Lerand, 1973; Craig and others, 1985). The Franklinian sequence consists Precambrian to Devonian rocks which form the present-day basement. Late Devonian orogeny deformed and truncated these rocks creating the stable Arctic Platform. The Ellesmerian sequence is composed of Mississippian to Early Cretaceous deposits of northern provenance which were deposited on the stable platform. The Rift sequence includes all Neocomian deposits derived from uplifted blocks of Ellesmerian and Franklinian strata. The Brookian sequence is composed of Early Cretaceous and younger deposits derived from the ancestral Brooks Range to the south.

The continental margin north of Alaska is considered to be a passive (Atlantic type) continental margin (Grantz and May, 1983). Mature marine and nonmarine clastics and carbonates were deposited above a regional erosion surface on Franklinian basement rocks. Rifting during Early Cretaceous (Neocomian) time effectively removed the northern Ellesmerian source area. The Barrow Arch, a broad structural culmination located generally near the present north Alaska coastline may represent a partial remnant of the northern landmass. In northeastern Alaska, the Sadlerochit Mountains area is thought to be an emergant eastward extension of the Barrow Arch.

CRETACEOUS SETTING

The complex Cretaceous stratigraphic and tectonic setting in northeastern Alaska has been discussed by Molenaar (1983), Molenaar and others (1986) and Mull (1985; 1986). Many of the interpretations presented here are based on their ideas.

The Neocomian depositional history of northeastern Alaska records the transition from stable platform deposits of northern provenance to orogenic deposits derived from the ancestral Brooks Range to the south. In northernmost Alaska, offshore shelf deposits of the Kingak shale prograded southeastward into a deepening basin in Jurassic and earliest Cretaceous time (Craig and others, 1985). To the south, in the central and western Brooks Range, orogenic uplift and thrusting began during the Late Jurassic or early Neocomian (Grantz and May, 1982). The loading of Brooks Range thrust sheets downwarped the Ellesmerian platform, creating the east-west trending Colville foredeep (Fig. 2). During the early Neocomian, Brookian turbidites of the Okpikruak Formation were deposited along the southern flank of the Colville foredeep. Uplift and erosion of the Ellesmerian platform along the northern flank of the Colville foredeep (Barrow Arch) during mid-Neocomian time resulted in a regional unconformity which truncates progressively older formations to the north.

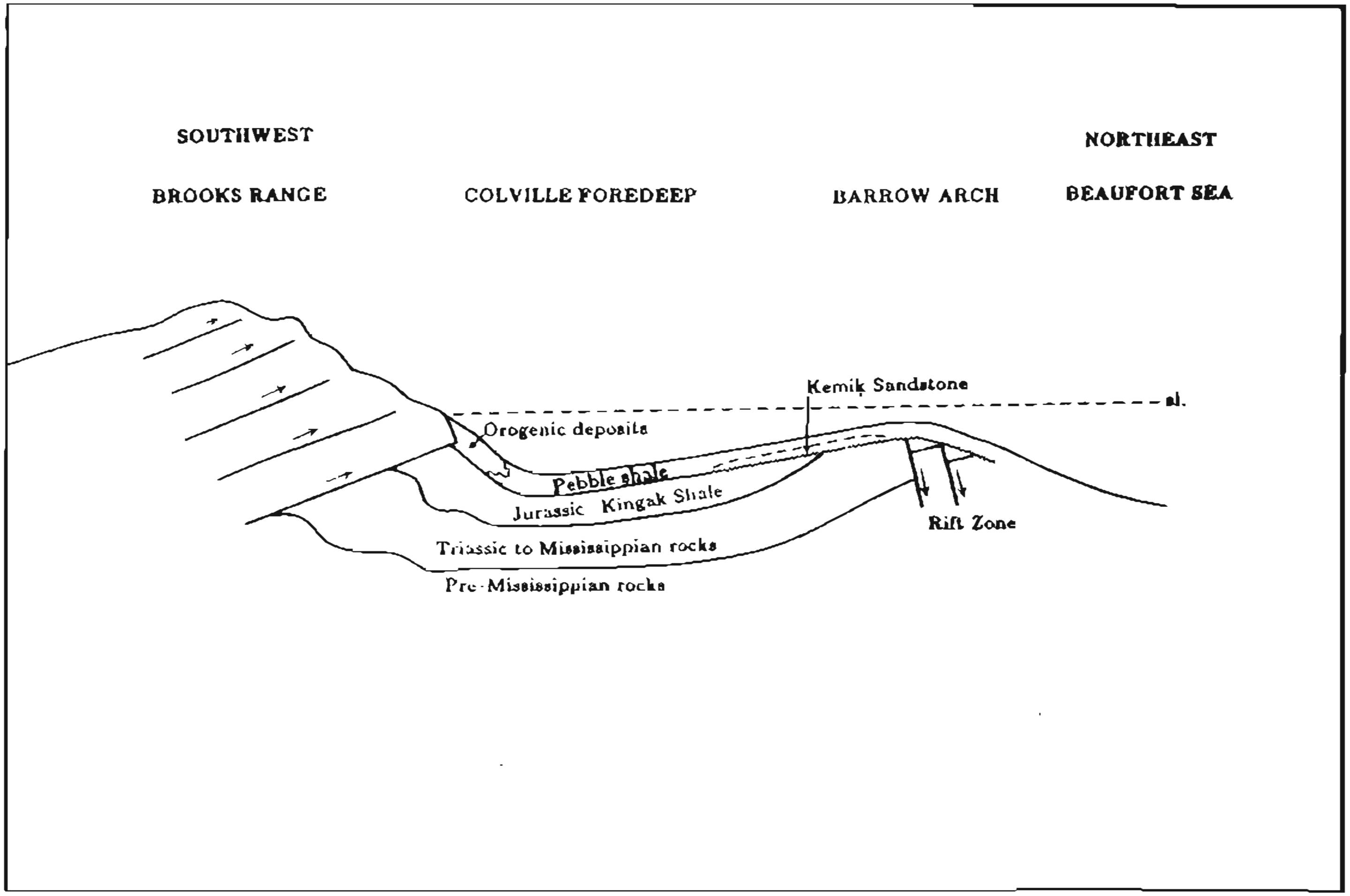

Figure 2. Generalized regional geologic setting during late Neocomian time in northeastern Alaska.

This uplift may correspond to incipient rift zone uplift prior to continental breakup (Craig and others, 1985). Rift sequence deposits of the Kemik Sandstone and the pebble shale unit were deposited above the regional mid-Neocomian unconformity along the northern flank of the Colville foredeep. To the south where Kemik was not deposited, the unconformity dies out and the pebble shale unit is conformable with the Kingak Shale. The Kemik and the pebble shale unit represent the last deposits derived from a northern source. After continental fragmentation, a thick clastic wedge of Brookian deposits prograded northward into basins along the newly formed continental margin.

STRATIGRAPHY

The Hauterivian to Barremian Kemik Sandstone is one of at least four Rift sequence sandstones in northeastern Alaska. The Put River Sandstone, Point Thomson sandstone , upper part of the Kuparuk Formation, and the Kemik Sandstone are all localized sand accumulations which directly overlie a regional mid-Neocomian unconformity (Craig and others, 1985; Mull, 1986).

In the study area, the Kemik ranges from five to fourty-five meters thick and is composed dominantely of quartzose, very fine-grained sandstone (Fig. 3). The lower contact with the Jurassic Kingak Shale, Triassic Ivishak Formation or Triassic Shublik Formation is the regional mid-Neocomian unconformity. The widespread Hauterivian to Barremian pebble shale unit conformably overlies the rift sequence sandstones in

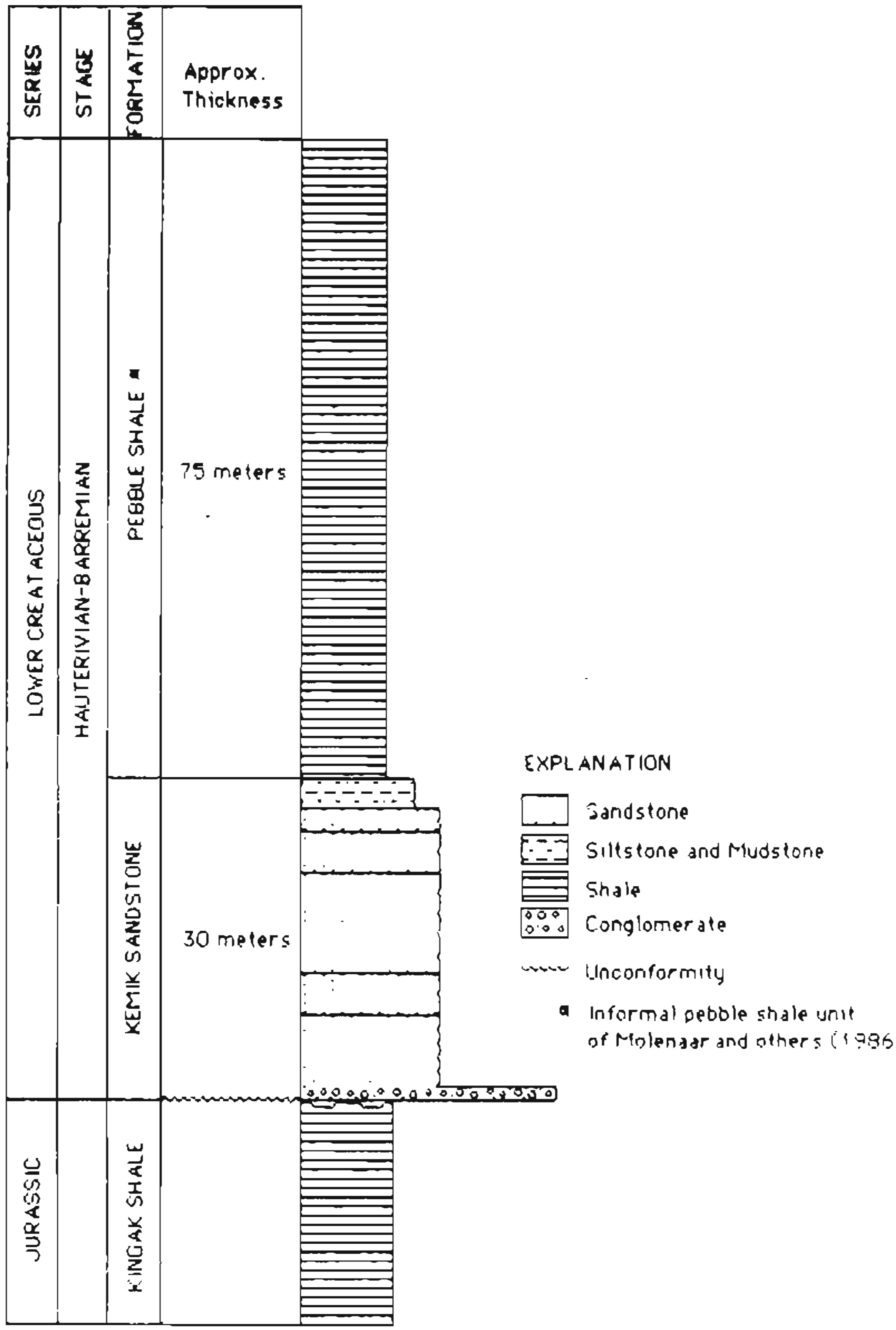

Figure 3 Generalized stratigraphic section of Kemik Sandstone and adjacent units in Ignek Valley.

northeastern Alaska A south dipping unconformity at the top of the pebble shale unit marks the top of the Rift sequence (Craig and others, 1985).

LITHOFACIES

In the study area, the Kemik Sandstone is composed of six major lithofacies: (1) basal conglomerate, (2) interbedded rippled and bioturbated sandstone, (3) burrowed sandstone, (4) crossbedded sandstone, (5) bioturbated sandstone, and (6) interbedded siltstone and mudstone. General diagnostic characteristics of each lithofacies are shown in Table 2. The lithofacies are described in ascending depositional order.

(1) Basal Conglomerate

Description

The basal conglomerate lithofacies generally defines the base of the Kemik in the study area. It is not present west of the Canning River or at Marsh Creek where Kemik lies on the Ivishak Formation. It is characterized by moderate to well sorted, matrix supported, chert pebble conglomerate. Pebbles average roughly 3 cm in diameter and range up to a maximum of 10 cm. Matrix is composed dominantely of quartzose, very fine-grained sand. The basal conglomerate ranges from 8 to 60 cm thick and appears to pinch and swell over a distance of several kilometers.

No crossbedding or burrowing were observed in the basal conglomerate lithofacies.

Table 2. Lithofacies of the Kemik Sandstone.

Lithofacies	Lithology	Sedimentary Structures	Burrowing
(6) Interbedded Siltstone and Mudstone.	Friable, muddy siltstone and mudstone. Common floating chert pebbles and clay ironstone beds.	Rare parallel lamination.	Extreme, Planolites, Skolithos.
(5) Bioturbated Sandstone	Argillaceous, mottled, VF sandstone. Some floating chert pebbbles and clay ironstone concretions	Rare parallel lamination and rippled tops. Rare hummocky cross stratification.	Abundant, Skolithos, Planolites, Zoophycos.
(4) Crossbedded Sandstone	Clean, quartzose, VF-F grained sandstone. Some muddy sandstone lenses, rare chert pebble congl stringers	Parallel lamination and low-angle crossbeds. Rare trough crossbeds, rare graded beds.	Minimal, few trace fossils present
(3) Burrowed Sandstone	Quartzose, VF-F grained sandstone. Some muddy sandstone lenses and clay drapes, rare chert pebble congl stringers	Structureless or parallel laminated. Rare low angle and trough crossbeds.	Moderate, Skolithos, Arenicolites
(2) Interbedded Rippled and Bioturbated Sandstone	Argillaceous, VF grained sandstone and quartzose, VF grained sandstone. Common chert pebble congl stringers and clay drapes	Interbedded parallel laminated and rippled beds and mottled beds. Some clay ripups. Rare hummocky cross stratification	Abundant, Crawling traces, Planolites, Terebellina, horizontal Ophiomorpha.
(1) Basal Conglomerate	Moderate to well sorted matrix supported, chert pebble congl. Clasts range from 2-10 cm thick	Erosional scours	No burrowing.

The basal conglomerate generally sharply overlies a laterally continuous, 2-3 cm thick, light-gray clay layer. The clay layer may represent a fault gauge between the Kemik and the Kingak Shale below. A regional unconformity marks the contact between the clay layer and the Kingak Shale. Bioturbated sandstones gradationally overlie the basal conglomerate.

Interpretation

The basal conglomerate is interpreted to represent a storm reworked transgressive lag deposit. Uplift and rapid regression resulted in erosion of Kingak shelf deposits by streams and prograding strandlines or deltas. This was followed by rapid transgression and relict clastic deposits on the shelf. Shelf processes reworked and sorted the relict clastics. Rapid deposition from storm generated shelf currents may explain the matrix-rich character of the conglomerate.

(2) Interbedded Rippled and Bioturbated Sandstone

Description

The interbedded rippled and bioturbated sandstone lithofacies forms the lowest unit west of the Canning River and in Ignek Valley where the basal conglomerate is not exposed. The sandstones are composed of well sorted, very fine-grained, chert litharenites (Folk, 1968). Mean sand size is 90 microns and a slight coarsening upward trend is apparent. Sandstone beds are laterally continuous for several tens to hundreds of meters. Thin clay drapes separate most of the sandstone beds, which are marked by irregular bedding contacts. Rare chert pebble conglomerate stringers, 2 to 8 cm thick, pinch and swell at the base of sandstone beds. Some appear to be semi-continuous over several hundreds of meters.

Parallel lamination, rippled tops, symmetrical ripples, and asymmetrical ripples are the most abundant sedimentary structures preserved. Commonly, parallel lamination grades upward into ripple lamination or rippled tops. Internal ripple laminations are commonly obscured, but the outline of the upper surface of the ripple ("rippled top") is exposed where siltier beds have been eroded away. Straight crested, symmetrical wave ripples were observed on several bedding surfaces. Rare wave ripple laminations occur as symmetrical bundled lenses with undulatory lower boundaries. Current ripples consist of asymmetrical lenses of small scale cross strata which are curved and tangential. Climbing ripples with ripple laminae in-drift (Reineck and Singh, 1973) were observed at a few localities. Rare long wavelength, low-angle cross stratification with undulatory lower boundaries is interpreted to be hummocky cross stratification.

Parallel laminated and rippled beds are usually less than 15 cm thick and have sharp, erosive bases locally marked by chert pebble conglomerate stringers. The upper boundary may be sharp, gradational or bioturbated. Clay ripups and wood fragments were found in association with these beds.

Bioturbated beds are generally 8 to 50 cm thick and have a mottled appearance. Upper and lower contacts range from sharp to gradational. Burrows are best exposed on bedding plane surfaces. Trace fossils characteristic of the *Cruziana* ichnofacies including *Planolites*, horizontal *Ophiomorpha, Terebellina* and several crawling traces were identified. The *Cruziana* ichnofacies typically represents low to moderate energy levels below fairweather wave base but above storm wave base (Frey and Pemberton, 1984).

The lower contact of this lithofacies, where exposed, is gradational with the basal conglomerate lithofacies. The upper contact with the burrowed sandstone lithofacies or the crossbedded sandstone lithofacies ranges from sharp to erosional.

Interpretation

The interbedded rippled and bioturbated sandstone lithofacies displays features indicative of fluctuations in hydrodynamic energy and sediment supply. The parallel laminated and rippled sandstones are the product of high energy storms when large volumes of suspended sediment were transported offshore. Storm generated current erosion resulted in sharp, erosive, sometimes conglomeratic bases. With waning storm intensity, parallel lamination and current ripple lamination formed as sand fell out of suspension. Post-storm oscillatory wave action may have reworked the tops of the beds to produce wave ripples. The return to fairweather conditions resulted in clay deposition from suspension and the recolonization of the substrate by burrowing organisms. Lower energy storms transported small volumes of sand intermittently, but burrowing organisms were able to churn the substrate until buried by the next major storm.

Fairweather wave base separates environments dominated by day to day sand transport from those where sand moves only during storms. The interbedded rippled and bioturbated sandstone lithofacies was not reworked by fairweather currents into angle of repose crossbeds, instead horizontal burrowing and clay deposition from suspension took place between high energy storm events.

(3) Burrowed Sandstone

Description

The burrowed sandstone lithofacies is distinguished from the crossbedded sandstone lithofacies primarily by the presence of burrows. It consists mainly of very well sorted, very fine to fine-grained, chert sublitharenite. Mean sand size is 120 microns. The sandstone beds are usually 15 to 50 cm thick and are laterally continuous for several tens of meters. They have sharp, planar bases and commonly are separated by thin clay drapes. Rare chert pebble conglomerate stringers, 2 to 8 cm thick, mark the base of sandstone beds.

The dominant sedimentary structure is parallel lamination. A few trough crossbeds in sets 10 to 30 cm thick, and long, low-angle crossbeds (5-10 deg) in sets 20 to 40 cm thick occur in the upper half of the lithofacies. Many of the sandstone beds appear to be massive or structureless. This is probably a result of their nearly uniform grain size and uniform cementation rather than burrowing. Rare primary current lineation was observed on the bottoms of beds.

Trace fossils are dominated by vertical dwelling burrows of the *Skolithos* ichnofacies. Vertical *Skolithos*, ranging from 2 to 50 cm long, is the most common type observed. U-shaped *Arenicolites* was recognized at a few localities. The *Skolithos* ichnofacies is characteristic of moderate to relatively high-energy conditions associated with well-sorted, shifting sands (Frey and Pemberton, 1984).

The upper and lower contacts of the burrowed sandstone lithofacies are usually sharp or erosional. The burrowed sandstone lithofacies both underlies and overlies the crossbedded sandstone lithofacies.

Interpretation

The burrowed sandstone lithofacies was deposited under moderate to high energy conditions above fairweather wave base. It's presence below the crossbedded sandstone lithofacies records the shoaling of the sand body above fairweather wave base. After deposition of the high energy crossbedded sandstone lithofacies, the burrowed sandstone lithofacies was deposited again as the sand body subsided or sea level rose and moderate energy conditions favorable for vertically burrowing organisms prevailed again. Thick, parallel laminated beds reflect upper flow regime conditions in which abundant sand was introduced from suspension by storm generated currents and then deposited as traction load. Where high bed shear stress persisted, sweeping the sand out as flat sheets, primary current lineation developed (Johnson, 1978). The presence of clay drapes indicates that sand transport was intermittent. Trough crossbeds resulted from the migration of megaripples where sand size was coarse enough.

Harms and others (1982) have shown that very fine-grained sand favors the formation of ripples and planar beds rather than dunes or sand waves. Long, low-angle crossbeds may indicate locally intense reworking of the top of the sand body by waves.

(4) Crossbedded Sandstone

Description

The crossbedded sandstone lithofacies represents the highest energy lithofacies in the Kemik Sandstone. The sandstones are composed of clean, very well sorted, very fine to fine-grained, chert sublitharenites. They are characteristically very well indurated and display a conchoidal fracture pattern. Mean sand size is 120 microns. Sandstone beds range from 25 to 90 cm thick and have sharp, planar lower and upper contacts. They can be traced laterally for up to few hundred meters. Red weathered, muddy sandstone lenses containing shell debris, and commonly pebbles, are fairly abundant. Rare chert pebble conglomerate stringers, 2 to 8 cm thick, pinch and swell at the base of sandstone beds.

The dominant sedimentary structures are parallel lamination and long, low-angle crossbeds. The low angle crossbeds are composed of 8 to 20 cm thick sets of parallel, evenly laminated sand with low angle discordances (5 to 10 deg). Contacts of sets are straight erosional surfaces and individual laminae may extend for several meters. The long, low-angle sets are difficult to distinguish from thick parallel laminated beds where individual beds are not continuous. Trough crossbeds in sets 20 to 40 cm thick are rare. Graded beds, 10 to 30 cm thick, are present at a few localities. Many beds appear to be massive or structureless in a similar fashion to those observed in the burrowed sandstone lithofacies.

The crossbedded sandstone lithofacies has sharp to erosional upper and lower contacts. Commonly, chert pebble conglomerate defines the upper and lower contacts.

Interpretation

The crossbedded sandstone lithofacies was deposited under high energy conditions, above fairweather wave base, at the crest of the sand bodies. The long, low-angle crossbeds and trough crossbeds may be indicative of strong longshore current conditions. The very fine-grained nature of the sands probably limited megaripple development. Graded beds were deposited from waning sediment-laden storm surges. Shells and pebbles were reworked to form a winnowed lag over the storm generated erosion surface.

(5) Bioturbated Sandstone

Description

The bioturbated sandstone lithofacies abruptly overlies the burrowed sandstone lithofacies in Ignek Valley and along the Canning River. Along the range front in the Marsh Creek area and along the Sadlerochit River where Kemik lithofacies typical of Ignek Valley are not present, the bioturbated sandstone lithofacies defines the base of the Kemik. It consists dominantely of argillaceous, well sorted, very fine-grained, chert litharenites. Sandstone beds range from 8 to 30 cm thick and have sharp, irregular upper and lower contacts. Clay drapes separate many of the sandstone beds. Floating chert pebbles and discontinuous chert pebble lenses are common.

Intense burrowing has destroyed most of the sedimentary structures. Remnant parallel lamination, rippled tops and possible hummocky cross-stratification were rarely observed.

Rare clams were found *in situ* . A mixed assemblage of trace fossils were identified including *Skolithos* (5-40 cm long), *Planolites* and *Zoophycos* .

The bioturbated sandstone lithofacies sharply overlies the burrowed sandstone lithofacies or it lies directly on an unconformity. The upper contact with the interbedded siltstone and mudstone lthofacies is gradational.

Interpretation

The bioturbated sandstone lithofacies represents a major change in the depositional history of the Kemik sand bodies. Subsidence and/or transgression resulted in burial of the sand bodies by muddy sandstone, siltstone and mudstone. The bioturbated sandstone lithofacies unconformably overlies Triassic aged rocks in the Marsh Creek area and along the Sadlerochit River. These may have been pre-existing high areas which were buried during rapid transgression.

The bioturbated sandstone lithofacies was deposited in a low energy environment, probably below fairweather wave base but above storm weather wave base, where sand and mud were deposited from suspension. Clams and other benthic organisms churned the substrate. Periodic high energy events are suggested by the rare sedimentary structures. The pebbles may have been rafted in by sea ice. The low diversity boreal fauna present in the Kemik is not incompatible with sea ice (R. C. Allison, written commun., 1986).

(6) Interbedded Siltstone and Mudstone

Description

The interbedded siltstone and mudstone lithofacies occurs at the top of the Kemik in the Marsh Creek area and along the Sadlerochit River. In western Ignek Valley, lithofacies (2) sandstones locally overlie this lithofacies. It consists of friable, irregularly fractured, argillaceous siltstone and mudstone. Rare thin, silty sandstone interbeds were observed. Floating chert pebbles and clay ironstone beds and concretions are common.

Extreme bioturbation has destroyed most of the sedimentary structures. Remnant parallel lamination was rarely observed.

Rare clams were found *in situ* . Trace fossils identified include abundant *Planolites* and *Skolithos*..

The interbedded siltstone and mudstone lithofacies gradationally overlies the bioturbated sandstone lithofacies. The upper contact with the pebble shale unit appears to be gradational.

Previous workers have included the interbedded siltstone and mudstone in the lower part of the pebble shale unit (Detterman and others, 1975; Molenaar and others, 1984). The writer places the pebble shale contact at the beginning of fissile, dark-gray shale. In contrast to the siltstone and mudstone, the pebble shale is not bioturbated and contains no interbeds of coarser grain size. Pelecypods from the interbedded siltstone and mudstone are identical to those found in the underlying bioturbated sandstone. No pelecypods were found in the pebble shale unit.

Interpretation

The interbedded siltstone and mudstone lithofacies represents a continuation of the transgression which buried the Kemik sandstone bodies. The sand source was effectively removed at this time as transgression continued through deposition of the pebble shale unit.

The lithofacies was deposited in a low energy environment, below fairweather wave base and possibly below storm weather wave base, where suspension deposition of silts and muds and little physical reworking of sediments was favorable for benthic organisms. The pebbles may have been rafted in by sea ice.

REFERENCES CITED

Craig, S. D., Sherwood, K. W., and Johnson, P. P., 1985, Geologic report for the Beaufort sea planning area, Alaska: OCS Report MMS 0111, U.S. Department of Interior, Minerals Management Service, Anchorage, Alaska.

Detterman, R. L., Reiser, H. N., Brosge, W. P., and Dutro, J. T., Jr., 1975, Post-Carboniferous stratigraphy, northeastern Alaska: U.S. Geological Survey Professional Paper 886, 46 p.

Frey, R. W., and Pemberton, S. G., 1984, Trace fossil facies models, *in* Walker, R. G., ed., Facies Models, 2nd edition: Geoscience Canada Reprint Series 1, p. 189-207.

Grantz, A., and May, S. D., 1982, Rifting history and structural development of the continental margin north of Alaska, *in* Watkins, J. S., and Drake, C. L., eds., Studies in continental margin geology: American Association of Petroleum Geologists Memoir 34, p. 77-100.

Harms, J. C., Southard, J. B., and Walker, R. G., 1982, Structures and sequences in clastic rocks: Society of Econmic Paleontologists and Mineralogists, Short Course No. 9, p. 1-55.

Imlay, R. W., and Detterman, R. L., 1973, Jurassic paleobiogeography of Alaska: U.S. Geological Survey Professional Paper 801, 34 p.

Johnson, H. D., 1978, Shallow siliciclastic seas, *in* Reading, H. G., ed., Sedimentary environments and facies: Amsterdam, Elsevier, 557 p.

Keller, A. S., Morris, R. H., and Detterman, R. L., 1961, Geology of the Shaviovik and Sagavanirktok Rivers region, Alaska: U.S. Geological Survey Professional Paper 303-D, p. 169-222.

Lerand, M., 1973, Beaufort Sea, *in* McCrossan, R. G., ed., The future petroleum provinces of Canada-their geology and potential: Canadian Society of Petroleum Geologists Memoir 1, p. 315-386.

Molenaar, C. M., 1983, Depositional relations of Cretaceous and Lower Tertiary rocks, northeastern Alaska: American Association of Petroleum Geologists Bulletin, v. 67, no. 7, p. 1066-1080.

Molenaar, C. M., Bird, K. S., and Kirk, A. R., 1986, Cretaceous and Tertiary stratigraphy of northeastern Alaska, *in* Tailleur, I. L., and Weimer, P., eds., Alaskan North Slope Geology: Pacific Section, Society of Economic Paleontologists and Mineralogists, in press.

Mull, C. G., 1986, Kemik Formation, Arctic National Wildlife Refuge, northeastern Alaska, *in* Tailleur, I. L., and Weimer, P., eds., Alaskan North Slope Geology: Pacific Section, Society of Economic Paleontologists and Mineralogists, in press.

Reineck, H. E., and Singh, I. B., 1973, Depositional sedimentary environments: New York, Springer-Verlag, 439 p.

Reiser, H. N., Dutro, J. T., Jr., Brosge, W. P., Armstrong, A. K., and Detterman, R. L., 1970, Progress map, geology of the Sadlerochit and Shublik Mountains, Mt. Michelson C-1, C-2, C-3, and C-4 quadrangles, Alaska: U.S. Geological Survey Open-File Report 70-273.