Micropaleontology of the Mesozoic Rocks of Northern Alaska

EXPLORATION OF NAVAL PETROLEUM RESERVE NO. 4 AND ADJACENT AREAS, NORTHERN ALASKA, 1944-53

PART 2, REGIONAL STUDIES

GEOLOGICAL SURVEY PROFESSIONAL PAPER 302-D

Prepared and published at the request of and in cooperation with the U.S. Department of the Navy, Office of Naval Petroleum and Oil Shale Reserves

Micropaleontology of the Mesozoic Rocks of Northern Alaska

By HARLAN R. BERGQUIST

EXPLORATION OF NAVAL PETROLEUM RESERVE NO. 4 AND ADJACENT AREAS, NORTHERN ALASKA, 1944-53

PART 2, REGIONAL STUDIES

GEOLOGICAL SURVEY PROFESSIONAL PAPER 302-D

Prepared and published at the request of and in cooperation with the U.S. Department of the Navy, Office of Naval Petroleum and Oil Shale Reserves

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1966

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

William T. Pecora, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

CONTENTS

ILLUSTRATIONS

[Plates are in separate volume]

TABLES

MICROPALEONTOLOGY OF THE MESOZOIC ROCKS OF NORTHERN ALASKA

By Harlan R. Bergquist

ABSTRACT

During the period 1944–53, more than 15,000 samples from outcrops and subsurface rocks were studied as part of the U.S. Navy's petroleum exploration in northern Alaska. More than 4,100 outcrop samples were collected from the foothills province, and more than 11,000 subsurface samples were taken from 81 test holes and core tests drilled by the U.S. Navy.

Rocks of Paleozoic to Pleistocene age are represented, but the bulk of the samples are from rocks of Cretaceous age. Each Cretaceous formation, including its microfauna, is discussed, and six microfaunal zones are described. From the oldest to youngest, these are the *Gaudryina tailleuri* and *Verneuilinoides borealis* zones of Albian age, the *Gaudryina irenensis–Trochammina rutherfordi* zone of Cenomanian age, the *Hedbergella loetterlei–Heterohelix globulosa* and the *Pseudoclavulina hastata–Arenobulimina torula* zones of Turonian age, and the *Neobulimina canadensis* zone of Senonian age. Faunal subzones occur in some of these zones. The microfaunas found in samples from each test hole and several core tests are described and listed on faunal charts. Strata in the Umiat field, the Barrow-Simpson-Fish Creek area, and the Topagoruk area may be correlated by means of faunal zones and horizons.

INTRODUCTION

During the period 1944–53, the U.S. Navy conducted a program of petroleum exploration in Naval Petroleum Reserve No. 4 in northern Alaska. The U.S. Geological Survey cooperated with the Navy in various phases of this program. Drilling of 45 core tests and 36 test holes was accompanied by geophysical surveying and field and photogeologic work. Locations of the test wells are shown in figure 33.

The wells were drilled by the Seabees and by Arctic Contractors, Inc.; United Geophysical Co. was responsible for much of the seismic and gravity work, and an airborne-magnetometer survey was made by the U.S. Geological Survey. Extensive field and photogeologic studies were also made by the Survey.

During the exploration, in order to obtain information needed in the program, samples from the wells, core tests, and several hundred seismograph shot holes, as well as samples from outcrops, were studied for lithologic character, fossil content, porosity, and permeability in a laboratory maintained by the U.S. Geological Survey at Fairbanks, Alaska.

This report presents the results of an exhaustive study of the microfossils found in approximately 15,000 samples representing rocks of Paleozoic to Tertiary age; these samples were collected from the subsurface by well drilling and from the outcropping rocks by U.S. Geological Survey geologists. Because Cretaceous rocks form the greater part of the sections penetrated in the subsurface, they are the subject of much of this discussion. Six microfaunal zones and two subzones have been distinguished in the Cretaceous strata.

Most of the fossil names used in this report conform to current usage, but it was impracticable to make some of the more recent nomenclatural changes. For example, the genus *Pallaimorphina* Tappan 1957 described from Lower Cretaceous rocks in northern Alaska and cited extensively in this report, has recently been placed in synonomy with *Quadrimorphina* Finlay, 1939 (Loeblich, Tappan, and others, 1964). The reader should consult the section on "Classification of Foraminifera" in the "Treatise on Invertebrate Paleontology" (Loeblich, Tappan, and others, 1964) for possible additional changes.

ACKNOWLEDGMENTS

I wish to express my sincere thanks to Mr. Henry Bender, who efficiently prepared a great number of samples, and to Mrs. Tatiana Ashurkoff and Mrs. Audrey Loftus, who mounted the microfossils. Wenonah E. Bergquist aided in certain faunal studies and in the compilation of the charts. All the taxonomic studies on the Foraminifera were made by Helen Tappan Loeblich in collaboration with my subsurface studies; her help is greatly appreciated. Stratigraphic information supplied by Arthur L. Bowsher, William P. Brosgé, Robert L. Detterman, J. Thomas Dutro, Jr., Marvin D. Mangus, William W. Patton, Edward G. Sable, Irvin L. Tailleur, Hillard N. Reiser, and Charles L. Whittington was extremely important in establishing faunal

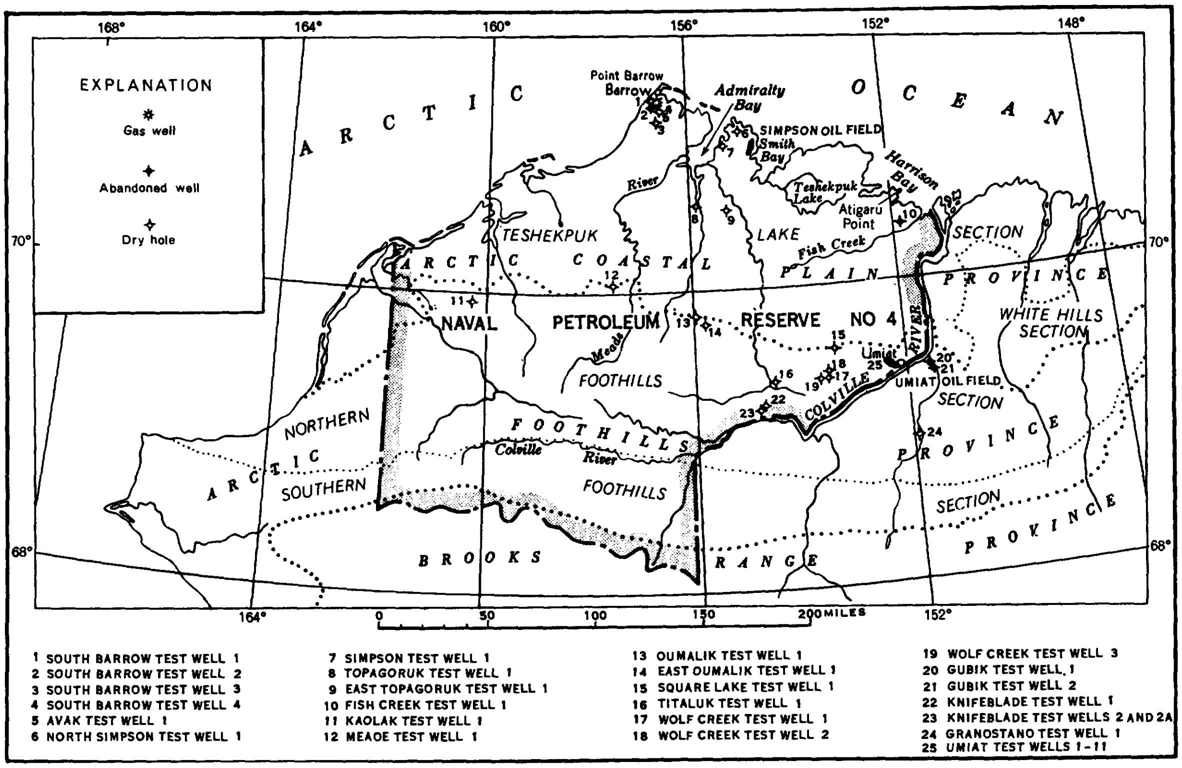


FIGURE 33.—Location of test wells in northern Alaska.

zones. The subsurface lithologic data supplied by Mrs. Florence Collins and Mrs. Florence Weber were also very helpful.

PREVIOUS WORK

Preliminary determinations of the age of the sequence of Cretaceous beds in NPR–4 were published by Helen Loeblich (Tappan, 1951b, 1960) and by Gryc, Patton, and Payne (1951); more recently the Cenomanian age of the Ninuluk Formation and the middle to late Albian age of the Grandstand and Tuktu Formations were more precisely determined by Imlay (1961). Regional stratigraphic relationships determined by Payne (1951) as the result of his excellent work on facies studies of northern Alaska have been modified only slightly in recent years, and his conclusions are similar to those based on microfossil studies for the formations. The paleontological relationships of the formations of Albian and Cenomanian age as determined by Imlay (1961) from his recent studies corroborates relationships based on microfossil studies which I made during the time of active petroleum exploration in the Reserve.

Taxonomic studies on the Foraminifera were made by Mrs. Loeblich (Tappan, 1951a, b, 1955, 1957, 1962), and the biostratigraphy of Cretaceous Formaminifera from northern Alaska has been presented by the same author (Tappan, 1960).

Brief preliminary reports on the microfossils found in most of the test wells and on the microfaunal zones in the Cretaceous rocks have been published (Bergquist, 1956b, 1958a, b, c, d, e, 1959a, b). A small fauna of possible Miocene or Pliocene age was described by Todd (1957); the fauna, collected from the Carter Creek area near the northeastern Arctic coast of Alaska, represents the only microfossils of possible Tertiary age that were found throughout northern Alaska. Late Paleozoic arenaceous Foraminifera and Middle to Late Triassic conodonts have been noted in samples collected over an area of more than 250 miles in an east-west direction parallel to the Brooks Range, south of the Colville River (Bergquist, 1960). Lithologic descriptions of the sections penetrated in the test wells have been made by Collins (1958a, b, c, 1959, 1961) and Robinson (1956, 1958a, b, 1959a, b) and by Robinson and Collins (1959).

SURFACE SAMPLE STUDIES

All outcrop samples examined for microfossils for each stratigraphic unit are listed in table 1. Of the 4,126 outcrop samples collected for microfossil studies, 1,882 were fossiliferous; of this number, 1,597 were from Cretaceous rocks. Triassic microfossils found in outcropping rocks in the Sadlerochit area of northeastern Alaska are tabulated in table 2. The relative abun-

TABLE 1.—*Stratigraphic distribution of surface samples*

	Total	Fossiliferous
Stratigraphic position known		
Tertiary rocks		
Pliocene and Miocene rocks undifferentiated	8	2
Sagavanirktok Formation	27	8
Cretaceous rocks		
Ignek Formation—upper part	34	12
Ignek Formation—lower part	17	3
Ignek(?) Formation	13	0
Kogosukruk Tongue of Prince Creek Formation	31	3
Sentinel Hill Member of Schrader Bluff Formation	69	55
Barrow Trail Member of Schrader Bluff Formation	101	51
Rogers Creek Member of Schrader Bluff Formation	32	22
Rogers Creek Member and Tuluvak Tongue undifferentiated	8	7
Tuluvak Tongue of Prince Creek Formation	8	1
Ayiyak Member of Seabee Formation	41	30
Shale Wall Member of Seabee Formation	274	136
Niakogan Tongue of Chandler Formation	8	2
Ninuluk Formation	148	85
Killik Tongue of Chandler Formation	59	0
Killik Tongue and Grandstand Formation	69	41
Grandstand Formation	41	33
Tuktu Formation	127	92
Corwin Formation	323	112
Kukpowruk Formation	281	174
Torok Formation—upper part	531	271
Torok Formation—"middle" part	27	0
Torok Formation—lower part	441	224
Torok Formation undifferentiated	27	14
Torok(?) Formation	4	1
Fortress Mountain Formation	410	153
Fortress Mountain or Okpikruak Formation	13	3
Okpikruak Formation	186	65
Jurassic rocks		
Kingak Formation	56	30
Tiglukpuk Formation	138	36
Triassic rocks		
Shublik Formation	103	72
Permian(?) rocks		
Siksikpuk Formation	16	15
Siksikpuk(?) Formation	15	14
Sadlerochit Formation	23	1
Mississippian rocks		
Lisburne Group	13	2
Lisburne(?) Group	4	3
Black chert and shale member of Alapah Limestone	2	0
Wachsmuth Limestone	1	1
Kayak Shale	6	0
Nuka Formation	15	1
Upper Devonian rocks		
Kanayut Conglomerate	2	0
Total	3,752	1,775
Stratigraphic position doubtful		
Colville Group undifferentiated	8	4
Lower Cretaceous undifferentiated	4	3
Cretaceous rocks undifferentiated	8	1
Cretaceous(?) rocks	1	1
Cretaceous or Jurassic rocks undifferentiated	22	2
Lower Cretaceous or Jurassic rocks:		
Fortress Mountain or Tiglukpuk Formation	38	0
Okpikruak Formation or Jurassic	14	5
Okpikruak Formation or Tiglukpuk Formation	4	0
Fortress Mountain or Okpikruak Formation or Jurassic	4	0
Lower Cretaceous or Triassic rocks	3	2
Lower Cretaceous, Jurassic or Triassic	1	0
Jurassic rocks undifferentiated	39	9
Jurassic rocks—lower part	5	3
Jurassic(?) rocks	42	18
Jurassic or Triassic rocks	6	0
Jurassic or Carboniferous rocks	3	3
Triassic rocks undifferentiated	58	11
Triassic or Permian rocks	24	0
Permian rocks undifferentiated	52	13
Permian(?) or Jurassic rocks:		
Siksikpuk or Tiglukpuk Formation	13	1
Carboniferous rocks undifferentiated	1	1
Mississippian rocks	2	2
Mesozoic or Paleozoic rocks	1	1
Devonian rocks	13	1
Paleozoic rocks	6	4
Age unknown	8	3
Total	380	88
Grand total	4,132	1,863

dance of characteristic microfossils for groups of outcrop samples from each Cretaceous unit, the available stratigraphic data, quality of specimens, and ratio of specimens to species are tabulated on tables 3–15. The comparative abundance of microfossils of Early Cretaceous age—identified in 781 outcrop samples from the Fortress Mountain, Torok, Grandstand, and Chandler Formations and in 418 outcrop samples from formations of Late Cretaceous age—are shown on bar charts (pls. 13, 14).

Data from seismograph shot holes other than those in the Shaviovik area (Keller and others, 1961) are not included in this report as much of the data concerned only Pleistocene beds. Some data on microfossil samples have been published in areal geologic reports: the Shaviovik and Sagavanirktok Rivers region (Keller and others, 1961), the Utukok-Corwin region (Chapman and Sable, 1960), the Killik-Etivluk Rivers region (Chapman and others, 1964), and the Chandler River region (Detterman and others, 1963).

Geographic names used in this report may be located by referring to Oil and Gas Map OM–126 (Payne and others, 1951).

STRATIGRAPHIC SUMMARY

PALEOZOIC ROCKS

In northern Alaska, rocks of Paleozoic age are exposed only in the Brooks Range and about 20 miles northward in the foothills belt. The greatest recorded thickness, a 7,500–8,000-foot-thick Paleozoic section that has clastic rocks of Late Devonian age and limestone and dolomite of Early and Late Mississippian age, was measured in the vicinity of Shainin Lake (Bowsher and Dutro, 1957). A few hundred feet of rocks of Permian age overlie this sequence. Relatively few samples from Paleozoic rocks were collected for microfossil examination (table 1) during the investigation. No identifiable Foraminifera were found in any of the 60–65 samples collected from rocks older than Permian? age, but a number of arenaceous Foraminifera were found in a few samples from the Siksikpuk Formation (Permian) (Bergquist, 1960).

Most of the Foraminifera from the Siksikpuk Formation came from type exposures in the Tiglukpuk Creek area (lat 68°17′ N., long 151°48′ W.), where approximately 300 feet of red and green shale and siltstone crop out above strata of Mississippian age and below the Triassic Shublik Formation. The section, which has been described by Patton (1957), yielded specimens of *Hyperammina*, *Thurammina*, *Reophax?*, *Ammodiscus*, *Glomospira*, *Glomospirella*, *Ammobaculites*, *Spiroplectammina* or *Mooreinella*, and two or three species of *Trochammina* (*T. arenosa* Cushman and Waters? and *T. grahamensis* Cushman and Waters?).

Two samples from the Siksikpuk Formation from the Oolamnagavik River area, approximately 65 miles west of the type locality, yielded abundant specimens of *Ammodiscus*, fragments of *Hyperammina*, specimens of *Thurammina* and *Spiroplectammina*? or *Moore-inella*? plus discoidal Radiolaria (Bergquist, 1960). Numerous specimens of *Ammodiscus* and fragments of a few other agglutinate Foraminifera came from samples of the Siksikpuk Formation along the east fork of the Etivuluk River (lat 68°22′ N., long 155°35′ W.). Two collections from red and green shale of the Siksikpuk Formation made along a tributary to the Kuna River approximately 140 miles west of the type locality provided numerous fragments of *Hyperammina* sp., specimens of *Ammodiscus* sp., plus a few specimens of *Thurammina* sp., *Glomospira* sp., *Trochammina* sp., aff. *T. arenosa* Cushman and Waters, *Trochammina* sp., and *Ammobaculites* sp. (Bergquist, 1960).

Broken conodonts and agglutinated Foraminifera similar to species from the Siksikpuk Formation in the Tiglukpuk Creek area were found in a sample of presumed Permian age from the Kiligwa River area, approximately 180 miles west of the type locality of the Siksikpuk Formation. The conodonts are a large species of *Gondolella* and have smooth platforms and low nodes along the axis.

Paleozoic rocks were found in the subsurface only in Topagoruk test well 1, where a few hundred feet of section was considered to be of Permian age because coelocanth fish teeth were present in a core; plant prints in a lower core suggested that rocks of Early or Middle Devonian age were penetrated.

TRIASSIC ROCKS

SHUBLIK FORMATION

Rocks of the Shublik Formation (Early(?) to Late Triassic) crop out in the Canning River–Sadlerochit Mountain area of the eastern part of northern Alaska and occur at numerous places along the northern front of the Brooks Range. In the Shaviovik and Sagavanirktok Rivers region, the Shublik Formation is 200–300 feet thick. Lower beds are phosphatic siltstone, carbonaceous black shale, and very fine grained sandstone. Upper beds are clayey to silty shale with interbeds of dark-gray limestone; the uppermost part is sandy to cherty limestone (Keller and others, 1961, p. 188). In the same area, 1,000–2,000 feet of clastic rocks of the Ivishak Member of the Sadlerochit Formation at least in part contains ammonoids of Early Triassic age (Keller and others, 1961, p. 169). In the central foothills the Shublik Formation may include some strata of Early Triassic age (Patton, 1959). In the subsurface of the coastal plain of northern Alaska, rocks of Late Triassic age were penetrated in Simpson test well 1, South Barrow test well 3, and Topagoruk test well 1.

Of the more than 100 outcrop samples of Triassic rocks examined for microfossils (table 1), about 70 percent were fossiliferous, and the best collections came from a suite of about 50 samples from the type locality of the Shublik Formation in the Canning River area. Nine of the samples were collected by E. G. Sable in 1948; they, together with samples from equivalent subsurface beds in Simpson test well 1, provided the fauna described by Mrs. Loeblich (Tappan, 1951c) as of Late Triassic age, the first microfauna of this age to be recorded from the Western Hemisphere. In 1952 C. L. Whittington measured and sampled 420 feet of exposed beds of a 720-foot shale section in the Sadlerochit area. His samples carried an assemblage of 23 species of Foraminifera, but 11 or 12 species constitute most of the fauna. The Foraminifera identified in Whittington's samples are shown in table 2.

At a few localities along the front of the Brooks Range, shale samples from the Shublik Formation have yielded fragmented compound and platelike conodonts in addition to Foraminifera (Bergquist, 1960). The most fossiliferous of these samples are from the Tiglukpuk Creek area (lat 68°17′ N., long 151°48′ W.), where Patton and Matzko (1959, p. 8) divided the Shublik Formation into three members; the lowest member is more than 500 feet thick and is dated by megafossils as Early(?) and early Middle Triassic age. Samples from this member yielded a small foraminiferal fauna consisting of *Tolypammina* sp., a small species of *Ammodiscus*, delicate tests of a small *Ammobaculites*, and a slender species of *Spiroplectammina*, and, in the uppermost 100 feet, a few specimens of *Rectoglandulina lata* (Tappan) and *R. simpsonensis* (Tappan). The middle and upper members of the Shublik Formation in the Tiglukpuk Creek area are approximately 150 feet thick and 80 feet thick; they yielded a few specimens of *Astacolus connudatus* Tappan, *Nodosaria shublikensis* Tappan, and *Rectoglandulina simpsonensis* (Tappan). Some of these species are part of the fauna described by Mrs. Loeblich (Tappan, 1951c) from the Late Triassic rocks of northern Alaska.

Conodonts were found in two samples from beds of the Shublik Formation in the Welcome Creek area (approx. lat 68°25′ N., long 150°48′ W.) about 25 miles northeast of the Tiglukpuk Creek area. One sample contained numerous broken specimens of platelike conodonts (gondolellids) along with a few fragments of

TABLE 2.—*Microfossils from a 720-foot shale section in the Shublik Formation (Triassic), Sadlerochit River and Dodo Creek, northern Alaska*

[V, very abundant; A, abundant; C, common; f, fragment; ?, questioned identification]

Interval (feet)	Sample 52A-Wh-	*Tolypammina glareosa* Tappan	*Pelosina?* sp.	*Trochamminoides vertens* Tappan	*Ammobaculites* sp.	*Trochammina contornata* Tappan	*Trochammina helicta* Tappan	*Astacolus connudatus* Tappan	*Marginulina prisca* Tappan	*Vaginulinopsis acrulus* Tappan	*Nodosaria larina* Tappan	*Nodosaria shublikensis* Tappan	*Rectoglandulina densa* (Tappan)	*Rectoglandulina lata* (Tappan)	*Rectoglandulina simpsonensis* (Tappan)	*Lingulina alaskensis* Tappan	*Lingulina borealis* Tappan	*Lingulina* sp. [six costae]	*Frondicularia acmaea* Tappan	*Frondicularia* sp. [large, smooth]	*Eoguttulina bulgella* Tappan	*Pyrulinoides plagia* Tappan	*Spirillina gurgitata* Tappan	*Dentalina?* sp.	*Dictyomitra* sp.	"*Monotis*" fragments	Echinoid spine	Ostracodes	Pyritic casts of minute pelecypods (P), gastropods (G)	Remarks
20	262							7			3f			1													f			
	261							C	6f	8	7	C		1	7		1		6							f	f	4	G	
	260							C				4			6		2		2							f				
10																														Covered.
20	259																		1							f				
	258							A				C		1	10	6	5		4							f	2f	1	P	
50																														Do.
40	257				1 sp. A			A	?f			C			10		4	C	4							f		C		
	256							A		3		8		1	4		4				1					f	f	8	G, P	
40	255							V		4		C			4		8	C	1		1			5		f	f	10	P2	
	254							C		2		8			9	2	2									f	3f	2		
100	253							4		?1														3						
	252							11				1				2			1					?3	1					
	251							C		1		3			2		1	1	1						2					
	250							2			?f				2				1											
	249							A				5				9	1				1			9				1		
	248							C				3			7		5		C	f	3				1			1	P	
	247							12		2	?f	3							4									2		
	246							10				f					1				2			?2				1	P	
	245							4											2									1		
	244							4				1							2											
	243							9				1					1		1									1		
	242							C				4					2		10					?1						
60																														Do.
150	241	?f			1 sp. B			A	?2	5		5	?1	1	9	2	5		5	f	2		1	3				2	G	
	240				5 sp. B		6	A				9			10	2	5		8		4			C				7	G, P	
	239			4			6	V		2	1	4	2		11	6	11	1	10	1	3			9				11	G2, P	
	238	?4f		3	4 sp. B		3	C		2		2	2	1		4	4	1	8			4	1	6				7	G2	
	237		2 small	5	?1	?2	C	A		7	2	2	1	5	11	2	7	1	7	1	3	3	1	11				9	G, P	
	236		1 large		2 sp. B	?2 sp.		C				6		3	5	2	5	2	6		?4			8				9	P2	
	235		1 small			?1 sp.		C		?3	5	6		4	5		5	4	6	1				9				6		
	234							V		?4		3		2	4	2	6		7			2		C				6	G	
	233							C				1			2	1	2		5			1		3				3		
180																														Do.
50	232							C		?f		5		2	8f		3		2					1				f		
	231		1 small	?4		?1		V		9		3f			4f		C		5					6f				4	G	
	230							A		5		5		1	?11f		C			1				1				2		

compound conodonts, abundant specimens of *Astacolus connudatus* Tappan, a few specimens of *Nodosaria shublikensis* Tappan, *Rectoglandulina simpsonensis* (Tappan), and *Vaginulinopsis acrula* Tappan.

Although too fragmented for positive identification, some of the compound conodonts from the Tiglukpuk Creek and Welcome Creek areas can be tentatively identified as hindeodellids and others as prioniodinids (Bergquist, 1960). In addition, there are two or three species of *Gondolella.*

Fragments of compound and gondolellid conodonts were found in four samples collected by Tailleur and Patton from beds of the Shublik Formation exposed at a locality (approx. lat 68°23′ N., long 152°55′ W.) along Monotis Creek, a tributary of the Kiruktagiak River; and a few conodonts were found in three samples collected by J. T. Dutro, Jr., along Thunder Creek, 7 miles west of Noluck Lake (approx. lat 68°45′ N., long 160°17′ W.) and west of the De Long Mountains in western Alaska. In the area along Thunder Creek, the samples were relatively high in the formation and came from 60–100 feet below an occurrence of *Monotis subcircularis* (Gabb). A few miles west of this locality, near lat 63°43′ N., long 160°31′ W., on the east side of Kidney Creek, a tributary of Driftwood Creek, Sable collected a sample from a rubble of shale and chert associated with *Monotis*-bearing limestone of the Shublik(?) Formation, and fragments of conodonts were common in it.

The presence of conodonts in samples of Triassic rocks collected over a distance of more than 250 miles indicates their apparent distribution throughout the Triassic rocks of the northern foothills of the Brooks Range. The subsurface sections of Triassic rocks penetrated in northern Alaska, however, did not yield conodonts, but a fairly good foraminiferal fauna was obtained. The species identified in these sections are listed on the faunal charts for Simpson test well 1 and Topagoruk test well 1 (pl. 18, 19).

JURASSIC ROCKS

A detailed study of all the Jurassic rocks of northern Alaska has not been published. Ralph Imlay has presented an excellent résumé in a paper on the characteristic Jurassic mollusks, and has indicated that three lithologic facies have been recognized (Imlay, 1955). A coarsely clastic facies of Late Jurassic age, which has been called the Tiglukpuk Formation, occurs in the foothills north of the Brooks Range and extends from the Utukok River in the west to the Lupine River in the east. A dominantly shale and siltstone facies, which has generally been called the Kingak Shale and which includes beds of Early, Middle, and Late Jurassic age, is found in an area from the west fork of the Ivishak River northeastward to the Sadlerochit River. A third facies, of Early Jurassic to early Middle Jurassic age, is characterized by calcareous, glauconitic, quartz-bearing sandstone interbedded with a considerable amount of dark-gray shale and siltstone; locally there are pebbles of chert, slate, and sandstone. This third facies is considered part of the Kingak Shale but is also known as a platform facies; it has been found only in the subsurface in South Barrow test wells 2, 3, and 4, Avak test well 1, and Simpson test well 1. The age of the Jurassic rocks has been determined by Imlay (1955) from his studies on ammonites and by Mrs. Loeblich from her studies on Foraminifera (Tappan, 1955).

TIGLUKPUK FORMATION

The Tiglukpuk Formation was described by Patton (1956a) as a section of 1,450 feet of shale, siltstone, and graywacke exposed along Tiglukpuk Creek, a tributary of the Chandler River. Generally the graywacke is a poorly sorted sandstone or conglomerate, but at several localities it is tuffaceous and may include tuffs, sills, and pillow lavas. The conglomerate constituents range in size from granules to boulders and consist of chert and igneous and metamorphic rocks in a graywacke matrix. At the type locality the formation rests on rocks of the Shublik Formation with little or no discordance and is overlain by the Okpikruak Formation or younger Cretaceous rocks. Megafossils indicate a late Jurassic age of Oxfordian to early Portlandian (Keller and others, 1961, p. 195).

The Tiglukpuk Formation crops out along the front of the Brooks Range for about 350 miles. It has been recognized along the Nuka and Utukok Rivers about 200–250 miles west of the type locality, and is exposed along the Lupine River about 100 miles east of Tiglukpuk Creek. The thickness of the formation is estimated as approximately 1,800 feet along Lupine River, but 15–20 miles to the west, in the area west of Elusive Lake, the formation is considered to be not more than 500 feet thick; it is missing several miles northwest of the lake (Keller and others, 1961, p. 194).

Recently Jones and Grantz (1964) have questioned the Jurassic age and validity of the Tiglukpuk Formation as a stratigraphic sequence. Jones and Grantz report *Buchia sublaevis* (Keyserling), a Lower Cretaceous (Valanginian) fossil from beds of the type section of the Tiglukpuk Formation and consider its presence as evidence that most of this unit is younger than the type Okpikruak Formation of Neocomian age. They further consider that the several rock types composing the Tiglukpuk Formation are a tectonic assemblage brought about by thrust faulting rather than a stratigraphic unit and believe the formation should be revised or abandoned.

Relatively few microfossils were found in samples from the Tiglukpuk Formation. Of 138 samples collected for microfossil examination, 36 were fossiliferous (table 1), but only a few species of arenaceous Foraminifera and a few Radiolaria were found. Very few samples were collected from the type locality of the formation, and none were collected from the thick exposures along Lupine River. Eight samples collected by Keller along Tiglukpuk Creek from the upper part of the formation were barren, but a few Foraminifera were found in two samples of four he collected from the lower part of the formation in the same area. One of two samples collected by Keller along the Siksikpuk River yielded a number of specimens of *Bathysiphon* and Ammodiscidae along with a few other Foraminifera.

In the eastern area of outcrop of the Tiglukpuk Formation, a suite of 10 samples was collected by Patton along Welcome Creek (tributary to Kanayut Creek) and the east fork of the Nanushuk River. The samples came from shales that directly overlie the Shublik Formation; these shales are interbedded with limestone bearing *Buchia concentrica* (Sowerby) and *B. rugosa* (Fisher), two fossils of Oxfordian to Kimmeridgian age. Eight of the samples yielded most of the Foraminifera and the Radiolaria found anywhere in the Tiglukpuk Formation, but only two species of Foraminifera were found in any degree of abundance. Fourteen samples collected by Keller from the lower part of the Tiglukpuk Formation along the east fork of the Nanushuk River and along Peregrine Creek were barren except for one sample in which *Glomospira pattoni* Tappan was common and in which a few other Foraminifera were found; few of the Foraminifera found, however, could be determined generically.

In the Ipnavik and Killigwa Rivers areas in the western part of the exposed area of the Tiglukpuk Formation, only 13 percent of a suite of 82 samples collected by Tailleur yielded microfossils; these microfossils consist of a few arenaceous Foraminifera and a few Radiolaria.

KINGAK SHALE

The Kingak Shale was originally described by Leffingwell (1919, p. 119) as a sequence of 4,000 feet of black shale overlying the Shublik Formation in the southeast end of the Sadlerochit Mountains; but in a recent report on the geology of the Shaviovik and Sagavanirktok Rivers region, Keller, Morris, and Detterman (1961, p. 191) included within this Jurassic formation all strata between the Triassic and Cretaceous systems east of Lupine River. The distribution of the Kingak Shale over this area and the variations in lithology have been discussed by these authors. A late Pliensbachian (Early Jurassic) through Callovian and late Oxfordian (Late Jurassic) age has been assigned by Imlay to these beds (Keller and others, 1961, p. 193), the Triassic Shublik Formation being overlapped by successively younger beds of the Jurassic at different localities.

Of 56 samples from the Kingak Shale examined for microfossils, 30 samples yielded some fossils (table 1). A suite of nine samples collected by E. G. Sable along Dodo Creek and the Sadlerochit River from the base of the formation to 2,650 feet above it yielded Foraminifera, but in only two of the samples were there specimens in some degree of abundance. The foraminiferal collection obtained includes 12 species, and in three samples one or two of the following species were common to abundant: *Bathysiphon anomalocoelia* Tappan, *Haplophragmoides kingakensis* Tappan, *Haplophragmoides barrowensis* Tappan, *Ammobaculites alaskensis* Tappan?, *Trochammina canningensis* Tappan, and *T. sablei* Tappan.

Fourteen samples collected by Keller and Detterman from exposures of the formation along the Lupine River and the west fork of the Ivishak River were barren.

A few samples collected by Keller and Detterman from the Kingak Shale along Kemik Creek and in the area between it and the Shaviovik River yielded a small assemblage of arenaceous Foraminifera of which specimens of one or two species were abundant. The most fossiliferous samples from the formation, however, came from the west fork of the Shaviovik River where Detterman collected from beds which may be the Kingak Shale part of a sequence that he mapped as undifferentiated Kingak Shale and Okpikruak Formation. These samples carried an arenaceous fauna of 11 or 12 species. Some of the Foraminifera are common to abundant in the Kingak samples, but none have been identified with certainty although they seem to be the same as Foraminifera found in some of the Upper Jurassic rocks. These same species were found in each sample of a suite of 30 collected from the overlying beds of the Okpikruak Formation. The age of the younger sequence is established as early Neocomian (Berriasian to Valanginian) by the presence of specimens of *Buchia okensis* (Pavlow), *B. subokensis* (Pavlow), and *B. sublaevis* (Keyserling) (Imlay, written commun., 1952; Keller and others, 1961, p. 197). No mention of Foraminifera from either the Kingak Shale or the Okpikruak Formation was made in the report on the geology of the area by Keller, Morris, and Dettermen (1961).

The lithology of Jurassic rocks penetrated in the subsurface has been briefly discussed by Mrs. Loeblich (Tappan, 1955) and reported on in detail in published well reports (Collins, 1958c, 1961; Robinson, 1959b). Mrs. Loeblich described a fauna of 111 species of Foraminifera, ranging in age from Early Jurassic (Sinemurian, Pliensbachian, and Toarcian) to Late Jurassic (Callovian and late Oxfordian to Kimmeridgian). The Foraminifera were found mostly in South Barrow test wells 2, 3, and 4, Simpson test well 1, and Topagoruk test well 1, and in surface samples from the regions of the Canning, Sadlerochit, and the Siksikpuk and Nanushuk Rivers. Most of the Lower Jurassic forms came from South Barrow test well 3, where a large and well-preserved fauna of 83 species was found (Tappan, 1955, chart 1; pl. 17, this report). Foraminifera found in South Barrow test wells 2 and 4, Avak test well 1, and Simpson test well 1 are shown on plates 17 and 18 of this report. Foraminifera found in the section from 6,600–7,820 feet in Topagoruk test well 1 were determined as Late Jurassic age (Oxfordian or early Kimmeridgian) by Mrs. Loeblich. A complete list for each sample from the well is given on plate 19 of this report. The fauna is also discussed under the section on Topagoruk test well 1.

CRETACEOUS ROCKS

Beds of both Early and Late Cretaceous age crop out in the northern foothills of the Brooks Range and underlie Pleistocene and Recent alluvial deposits in the Arctic coastal plain. The Lower Cretaceous rocks were recognized by Schrader (1904) more than 60 years ago, and Upper Cretaceous rocks were later mapped by Smith and Mertie (1930). The present knowledge of the extent and relationship of the Cretaceous rocks, however, is the result of detailed studies of outcrop and subsurface made by members of the U.S. Geological Survey in recent years; in 1951 a nomenclature of the Cretaceous formations was formulated (Gryc and others, 1951). A few years later some of the formations were redefined and additional formations were described (Gryc and others, 1956; Sable, 1956). Most of the type localities of the Cretaceous formations are within an area south and southwest of Umiat, bounded on the north by the Colville River, on the east by the Anaktuvuk River, on the west by the Killik and Okokmilaga Rivers, and on the south by an east-west line drawn about 50 miles south of Umiat. (See Gryc and others, 1956, fig. 5.)

OKPIKRUAK FORMATION (EARLY NEOCOMIAN)

The basal Cretaceous unit mapped in northern Alaska is the Okpikruak Formation which was described by Gryc, Patton, and Payne (1951, p. 159). It crops out in the southern part of the Arctic foothills province from the Kukpowruk River in the west to the Itkillik River in the east and is exposed discontinuously from the Lupine River to the Sagavanirktok River (Keller and others, 1961). The formation rests on rocks of Jurassic and Triassic age, and most of it is composed of fine-grained sandstone of a graywacke type, clay shale, and silty shale or siltstone; minor beds of conglomerate are found at the base. From the Echooka River to the Kavik River in an area between the Sagavanirktok and Canning Rivers, a 220-foot bed of sandstone (Kemik Sandstone Member) is at the base (Keller and others, 1961, p. 196). In the type locality on the Okpikruak River at about lat 68°34′30″ N., and long 153°30′ W., the formation has a maximum thickness of 2,400 feet; but on the Siksikpuk River, the maximum thickness is 1,800 feet thick, and in the area of Elusive Lake east of the upper end of the Sagavanirktok River, it is about 1,500 feet (Keller and others, 1961). The formation has not been recognized in test holes drilled in the coastal plain or in the northern foothills region.

Several diagnostic species of *Buchia* occur in the Okpikruak Formation and identify the age of the beds as early Neocomian (Berriasian and Valanginian) (Imlay and Reeside, 1954, p. 241). A few Foraminifera have been found in the formation (table 1), but most are long-ranging species that occur throughout Lower Cretaceous strata in northern Alaska. Numerous well-preserved Foraminifera, however, were found in 30 samples collected by Detterman and Keller in the area of the west fork of the Shaviovik River; these samples were from beds containing specimens of *Buchia okensis* (Pavlow), *B. subokensis* (Pavlow), and *B. sublaevis* (Keyserling), which Imlay identified as early Neocomian forms (Imlay, written commun., 1952; Keller and others, 1961, p. 197). The Foraminifera appear to be similar to or the same as species found in rocks which have been considered Late Jurassic in age, but a detailed study has not been made.

FORTRESS MOUNTAIN AND TOROK FORMATIONS (ALBIAN)

In the Arctic foothills, several thousand feet of clay shale and shale with conglomerate and sandstone of graywacke type overlie the Jurassic beds and the Okpikruak Formation. These beds were formerly described as the Torok Formation by Gryc, Patton, and Payne (1951) but were later separated by Patton (1956b, p. 219–223) into two lithofacies; the Torok Formation was restricted to the predominantly shale facies in the northern part of the foothills, and the name Fortress Mountain Formation was given to the predominantly clastic-rock facies (sandstone and conglomerate) in the southern part.

FORTRESS MOUNTAIN FORMATION

The Fortress Mountain Formation is described (Patton, 1956b, p. 219) as a thick sequence of shale, coarse-grained graywacke sandstone, and conglomerate, which at the type locality along the Kiruktagiak River and on Castle Mountain is 10,000 feet thick and rests on Jurassic beds. Elsewhere in the foothills the thickness of the sequence is generally less than 3,000 feet. The formation extends westward to the Kukpowruk River and east to the Ribdon River. It has not been recognized in the subsurface. From megafossils, particularly *Aucellina dowlingi* McLearn and *Beudanticeras affine* (Whiteaves), Imlay (1961, p. 7) has identified the beds as Early Cretaceous (early Albian) in age—correlative with the Clearwater and Loon River Formations of Alberta and with the Moosebar, Gates, and lower part of the Buckinghorse Formations of northeastern British Columbia.

Pertinent data on characteristic Foraminifera and Radiolaria found in 195 fossiliferous samples from the Fortress Mountain Formation are shown in table 3; a total of 410 microfossil samples was collected from the formation. Most of the relatively few species of Foraminifera and Radiolaria found in the Fortress Mountain Formation were also present in outcropping beds of the lower part of the Torok Formation.

TOROK FORMATION

The Torok Formation as redefined by Patton (1956b, p. 222) includes a predominantly shale sequence about 6,000 feet thick underlying the Nanushuk Group. The type locality of the formation was designated as Torok Creek and the Chandler River between the mouth of Torok Creek and the mouth of the Kiruktagiak River. According to Patton, "The bulk of the Torok Formation is composed of gray silt and clay shale interbedded with subordinate amounts of green to gray siltsone. Ferruginous, calcareous, and siliceous concretions are abundant in the shale. Locally there are lenses of fine-

TABLE 3.—*Data for 410 outcrop microfossil samples from the Fortress Mountain Formation*

Number of samples: Total, 410; fossiliferous, 153.

Specimens/Species: Indicates ratio of abundance of all specimens to all species in fossiliferous samples.

[Q, indicates one or more questionable identifications in some samples; vr, very rare; r, rare; c, common (12-25); ab, abundant (26-50); vab, very abundant (over 50)]

Area, collector, and date	Stratigraphic data	Number of samples: Total	Number of samples: Fossiliferous	Quality of specimens	Ratio specimens/species	Number of samples in which characteristic species occur: *Bathysiphon vitta?*	*Glomospirella gaultina*	*Haplophragmoides topagorukensis*	*"Verneuilinoides tailleuri"*	*Trochammina eilete*	*Conorboides umiatensis*	*Pallaimorphina ruckerae*	*Lithocampe?* sp. (pyritic casts)	*Dictyomitra?* sp. (pyritic casts)
May Creek, 5 miles south of Arc Mountain syncline; Patton, 1950.	Lower part	7	3	Poor	vr/vr	2		1			1Q			
Autumn Creek, 13-16 miles above mouth; Keller, 1950	do	4	3	do	vr-c/vr-r	1	1	2Q	1					
Headwaters, east fork Nanushuk River; Patton, 1950	2,400-ft section sampled	3	3	Fair	vr-r/vr	2		1		1				
East fork Nanushuk River, south of Arc Mountain syncline; Patton, 1950.	Lower part	17	7	Poor	vr/vr			4						
East fork Nanushuk River, south of Arc Mountain syncline; Keller, 1950.	do	23	4	do	vr-r/vr	2					1			
Nanushuk River, south of Arc Mountain syncline; Keller, 1950.	do	3	2	do	vr/vr						1	2		
Peregrine Creek, above junction with Cascade Creek; Patton, 1950.	do	5	1	do	vr/vr					1Q				
Kanayut River, south of Arc Mountain syncline; Patton, 1950.	do	4	0											
At junction of Siksikpuk River and Tiglukpuk Creek; Patton, 1950.	2,100-ft section; base is 1,930 ft above Okpikruak Formation	5	5	Poor	vr-r/vr	2		2		3Q	2	1		
Tributary, west side Siksikpuk River, 10-12 miles south of Tuktu Escarpment; Keller, 1950.	Lower part	5	3	do	vr-r/vr	2			1					
Siksikpuk River, south of Ayiyak anticlinorium; Patton, 1950.	Lower(?) part	3	3	do	vr-r/vr	1						1	1	2
East side Chandler River, north flank Castle Mountain syncline; Patton, 1949.	None	1	1	Fair	vr/vr							1		
Chandler River at Horseshoe Mountain fault(?); Patton, 1949.	Lower part	1	0											
Torok Creek, approximately 0.1-1.2 miles south of Horseshoe Mountain fault(?); Patton, 1949.	do	12	3	Fair	vr-r/vr	1		2		1Q	1			
Torok Creek, 3 miles southeast of Castle Mountain; Tailleur, 1949.	None	15	7	do	vr/vr	1		4		1		2		
Torok Creek, north flank Castle Mountain syncline, 4 miles east of Castle Mountain; Tailleur, 1949.	do	5	5	do	vr-r/vr-r			4			2	5		
Torok Creek, 1½ miles north of peak of Castle Mountain; Tailleur, 1949.	7,400 ft above base	2	1	do	vr/vr							1		
Torok Creek, 3 miles northeast of peak of Castle Mountain; Tailleur, 1949.	7,200 ft above base	8	8	do	c/r	1		6		3	5	3		
East side Castle Mountain at Castle Mountain syncline; Patton, 1949.	8,600-8,950 ft above base	5	3	Poor	vr/vr							1		
East side of Castle Mountain; Tailleur, 1949	7,400 ft above base	5	4	Fair	vr-r/vr			1		1Q	3	1		
Northwest side Castle Mountain; Tailleur, 1949	8,600-8,950 ft above base	5	2	Poor	vr/vr			1				1		
Two miles northwest of peak of Castle Mountain; Tailleur, 1949.	7,400 ft above base	1	1	Fair	vr/vr					1		1		
East tributary Castle Creek, 1 mile above junction with Kiruktagiak River; Patton, 1949.	6,700-7,000 ft above base	2	2	do	vr-ab/r			1			1			
Castle Creek, 4½-6 miles south of Castle Mountain; Tailleur, 1949.	None	3	3		vr/vr	1		3						
Castle Creek, 3½ miles above mouth; Tailleur, 1949	do	3	2	Fair	vr-vab/vr			2Q						
Castle Creek, 2½ miles above mouth; Tailleur, 1949	5,500-6,000 ft above base	4	3	Good	vr-c/vr-r			1	2					
Castle Creek, 2 miles above mouth; Patton, 1949	6,700-7,000 ft above base	1	1	do	vr-r/vr			1	1	1				
	6,000 ft above base	2	0											
On Castle Creek, 1-2 miles above mouth (junction with Kiruktagiak River); Patton, 1949.	Middle part	2	1	Poor	1 specimen	1								
Castle Creek, 1½ miles above mouth; Patton, 1949	6,700-7,000 ft above base	2	2	Good	vr-c/vr-r		1	2	1	1				
Castle Creek, 1 mile above mouth; Patton, 1949	6,700-7,000 ft above base	2	2	Fair	vr/vr			1			1	1		
Castle Creek, three-fourths mile above mouth; Patton, 1949	6,000 ft above base	2	2	Good	vr/vr			2			1	1		
Castle Creek, 0.2-0.5 mile above mouth; Patton, 1949	5,500-6,000 ft above base	3	2	Poor	vr/vr						1	1		
Near mouth of Castle Creek; Patton, 1949	5,050-5,300 ft above base	1	0											
Tributary on Kiruktagiak River, 1 mile above mouth of Castle Creek; Patton, 1949.	Lower part	1	1	Poor	vr/vr	1		1Q						
Tributaries of Castle Creek and Kiruktagiak River; west of Castle Mountain; Patton, 1949.	Middle part	7	3	Fair	vr/vr			1		2	1	1		

TABLE 3.—*Data for 410 outcrop microfossil samples from the Fortress Mountain Formation*—Continued

Area, collector, and date	Stratigraphic data	Number of samples: Total	Number of samples: Fossiliferous	Quality of specimens	Ratio specimens/species	Number of samples in which characteristic species occur: *Bathysiphon vitta?*	*Glomospirella gaultina*	*Haplophragmoides topagorukensis*	"*Verneuilinoides tailleuri*"	*Trochammina eilete*	*Conorboides umiatensis*	*Pallaimorphina ruckerae*	*Lithocampe?* sp. (pyritic casts)	*Dictyomitra?* sp. (pyritic casts)
Tributary of Kiruktagiak River, 3 miles northwest of peak of Castle Mountain; Tailleur, 1949.	5,500–6,000 ft above base	1	1	Fair	1 specimen							1		
Kiruktagiak River, Castle Mountain syncline; Patton, 1949.	3,400–4,200 ft above base	2	2	do	vr-c/vr			2			2			
Kiruktagiak River, north flank Castle Mountain syncline; Patton, 1949.	2,950–3,400 ft above base	3	3	do	vr/vr			3		1		1		
	2,480–2,950 ft above base	2	2	do	vr/vr			2						
Kiruktagiak River, 1–1½ miles southeast to south-southeast of Horseshoe Mountain; Patton, 1949.	500–1,150 ft above base	1	1	do	c/r		1Q	1	1					
Kiruktagiak River, 1½ miles south-southeast of Horseshoe Mountain; Patton, 1949.	0–500 ft above base	1	1	do	r/r			1	1Q	1				
Kiruktagiak River, 1 mile southeast of Horseshoe Mountain; Patton, 1949.	1,150–1,750 ft above base	4	4	do	c-ab/r	1		4	3	1				
Horseshoe Mountain thrust plate, 1 mile distance along Kiruktagiak River; Patton and Tailleur, 1949.	None	14	8	do	vr-r/vr-r	2		4	4			1	1	1
Kiruktagiak River, west end of small anticline, north of Horseshoe Mountain thrust plate; Tailleur, 1949.	do	10	3	Good	vr/vr							1		
Ayiyak River and Chert Creek; Patton, 1949	do	1	1	Poor	1 specimen			1Q						
West of Chert Creek, 1½ miles; 3 miles above junction with Ayiyak River; Patton, 1949.	Middle part	2	0											
Tributary of Fortress Creek, 2 miles northeast of Fortress Mountain; Patton, 1949.	None	1	1	Fair	vr-c/r	1		1	1					
Fortress Creek, south limb of Fortress Mountain syncline; Tailleur, 1949.	do	4	4	Fair-good	vr-ab/vr-r	3	2	3	1Q					1
North limb of Fortress Mountain syncline, spanning 1 mile along Fortress Creek, west side Fortress Mountain; Patton, 1949.	do	9	9	do	vr-c/vr-r	1		6	2		2	4		
An area along Fortress Creek and south flank of small syncline, 1–1½ miles northwest Fortress Mountain; Patton, 1949.	Lower part	4	1	Fair	vr-c/vr	1		1			1			
Canoe Hills, northwest of Fortress Mountain; Patton, 1949	None	4	1	Poor	1 specimen					1				
Area adjacent a small anticline, north of Fortress Creek, between Canoe Creek and tributaries to Ayiyak River; Tailleur, 1949.	do	5	0											
Upper part of Canoe Creek, 2 miles northwest of Fortress Mountain; Patton, 1949.	Lower part	11	2	Fair	2 specimens			2						
Pediment Creek, approximately 5–6 miles northwest of Canoe Hills; Patton, 1949.	do	10	4	Poor	vr/vr					2Q	1	2		
Okokmilaga River, approximately 7 miles above mouth (junction with Okpikruak); Patton, 1949.	None	1	0											
Along Okpikruak River, approximately 6–7 miles above junction with Okokmilaga River; Patton, 1949.	do	5	0											
Colville River, west end Killik Bend anticline; Warner, 1945.	do	8	0											
Oolamnagavik River, approximately 10–11 miles south of Oolamnagavik syncline; Chapman and Reynolds, 1950.	Low in formation	3	1	Poor	vr/vr									
On tributary of Kurupa River, 6 miles west of Oolamnagavik River, and 13 miles south of Oolamnagavik syncline; Chapman, 1950.	None	3	0											
Ipnavik River from a point approximately 8 miles above junction with Colville River to a point approximately 1 mile above mouth; Tailleur, 1950.	Middle part	10	0											
Ipnavik River from a point approximately 1½ miles above mouth of Cula Creek to a point approximately 4½ miles below mouth of Medial Creek; Tailleur, 1951.	Lower part	25	0											
Ipnavik River between mouth of Hardway Creek and point 6 miles upstream; Tailleur, 1951.	Middle part(?)	13	0											
Numerous points in the Lisburne Ridge area, tributaries of Ipnavik River adjacent to Ekakevik Mountain, and headwaters of the Ipnavik River; Tailleur and Kent, 1950.	1,000–1,500 ft above Okpikruak Formation.	8	8	Poor	vr-r/vr-r	4				2Q	2	2		
Numerous points along Kiligwa River, west and south of Liberator Ridge, and along tributaries to Kuna and Ipnavik Rivers; Tailleur and Kent, 1950.	Lower part; 1,000–2,000-ft section.	34	0											
East fork Kiligwa River, approximately 12 miles above junction with west fork; Tailleur, 1950.	Middle part	5	0											
West fork of Kiligwa River approximately 10 miles above juntion with east fork; Tailleur, 1951.	None	1	0											
Approximately 3 miles southeast of Lake Noluk on Pilly Fork of Nuka River; Sable, 1951.	Approximately 1,100 ft below top.	1	0											
Tributary of Storm Creek approximately 4 miles southwest of Lake Noluk; Dutro, 1951.	Approximately 2,150 ft below top.	1	0											
Thunder Creek approximately 10 miles above junction with Colville River; Sable, 1951.	Approximately 500–1,450 ft below top.	5	0											
Elbow Fork near junction with Driftwood Creek; Sable and Dutro, 1951.	Approximately 1,850-2,000 ft below top.	4	0											
Numerous points in area 10–12 miles south and southwest of Driftwood anticline through 25 miles distance from the Iliglurak Creek east to Driftwood Creek; Sable and Mangus, 1950.	Generalized section of 4,400 ft thickness.	20	3	Poor	vr/vr			1						1

grained graywacke sandstone as much as 800 feet thick. Thin lenses of cherty-granule conglomerate were found in several such sandstone bodies."

Fossils from the Torok Formation indicate that the lower two-thirds of this sequence is approximately contemporaneous with the Fortress Mountain Formation but that the upper third of the formation is distinctly younger as is noted by its different and much larger assemblage of both microfossils and megafossils. The fossils of the upper part of the Torok Formation are mostly restricted to middle Albian age (Imlay, 1961, p. 4).

Approximately 1,000 outcrop samples from the Torok Formation were examined for microfossils (table 1). Some of these samples, however, were inadequately located stratigraphically and therefore were not included in the statistical data (tables 4 and 5). Two-thirds of the excluded samples were nonfossiliferous. A comparison of the statistical data for the outcrop samples from the upper and lower parts of the Torok Formation indicates certain distinct differences. The upper part of the formation is characterized by such arenaceous Foraminifera as *Verneuilinoides borealis* Tappan, *Guadryina nanushukensis* Tappan, *Textularia topagorukensis* Tappan, and species of *Ammobaculites*, besides calcareous species such as *Eurycheilostoma robinsonae* Tappan. Microfossils from the lower part of the Torok Formation are included in the *Gaudryina tailleuri* faunal zone. These faunal differences are discussed more fully on pages 126 to 140.

In the subsurface, a sequence of several thousand feet of predominantly shale beds that are equivalent to much of the Torok Formation has been divided into two units and described as the Oumalik and Topagoruk Formations (Robinson and others, 1956, p. 223–232). The name Oumalik Formation was applied to the older part of the sequence as recognized in a 6,000-foot section of medium-gray to dark-gray shale, sandy shale, and siltstone occurring between 4,860 and 10,880 feet in Oumalik test well 1. These beds, which are believed to be approximately equivalent to the lower two-thirds of the Torok Formation, apparently thin rapidly northward as only a few hundred feet of this sequence was found in the subsurface in the coastal area of Cape Simpson and Point Barrow.

The Topagoruk Formation was described from a 2,550-foot section (1,350–3,900 ft) in Topagoruk test well 1. The shale of the formation is generally slightly softer and lighter in color than the shale of the Oumalik Formation and seemingly breaks into less angular fragments than does the older shale. Throughout the type section in Topagoruk test well 1, there are thin beds and laminae of siltstone and fine-grained sandstone in the shale, but the siltstone and sandstone increase in proportion to the shale in the upper 800 feet. Possibly in some areas the upper part of the formation is approximately equivalent to part or all of the Tuktu Formation. In most of the section, there is a microfaunal assemblage that is also found in the upper part of the Torok Formation and in the Tuktu Formation. This assemblage is described as the *Verneuilinoides borealis* faunal zone.

Beds defined as Topagoruk and Oumalik Formations in previous reports by me (Bergquist, 1956b, 1958a), and by Robinson (1956, 1958a, b, 1959a, b), Robinson and Collins (1959), and Collins (1958a, b, c, 1959, 1961) are included under the Torok Formation in this report.

NANUSHUK GROUP

The Nanushuk Group, as currently defined, is a sequence of rocks of Early Cretaceous and early Late Cretaceous age which overlies the Torok Formation. The rocks are of both marine and nonmarine origin and include sandstone, conglomerate, siltstone, shale, minor amounts of coal and ironstone, and limestone in lenses and concretions. Originally recognized by Schrader (1904) as a sequence of Cretaceous rocks along the Nanushuk River where it cuts across the Arctic foothills, the group was modified by Gryc, Patton, and Payne (1951, p. 162), who excluded beds now considered to be part of the Colville Group. Thus at present the Nanushuk Group is known to crop out north of the Brooks Range from the Sagavanirktok River west to the Kukpowruk River and to include the Tuktu and Grandstand Formations of Albian age, the Chandler Formation of Albian to Cenomanian(?) age, and the Ninuluk Formation of Cenomanian age. The Grandstand and Ninuluk Formations were described by Detterman (1956), who also redefined the Tuktu and Chandler Formations. Type localities of these formations are on the Chandler Anaktuvuk, Colville, and Killik Rivers.

TUKTU FORMATION (ALBIAN)

The basal sandstone unit of the Nanushuk Group was described as a member of the Umiat Formation (Gryc and others, 1951, p. 162), but was later redefined as the Tuktu Formation, and the name Umiat Formation was abandoned (Detterman, 1956, p. 233–235). Rocks of the Tuktu Formation form a prominent south-facing escarpment along the southern edge of the northern foothills and can be traced laterally for 200 miles. According to Detterman (1956, p. 234), the rocks grade into shale northward across the strike. Keller, Morris, and Detterman (1961, p. 202) reported exposures of the

TABLE 4.—*Data for 414 outcrop microfossil samples from the lower part of the Torok Formation*

Number of samples: Total, 414; fossiliferous, 215.

$\frac{\text{Specimens}}{\text{Species}}$: Indicates ratio of abundance of all specimens to all species in fossiliferous samples.

[Q, indicates one or more questionable identifications in some samples; vr, very rare; r, rare; c, common (12–25); ab, abundant (26–50); vab, very abundant (over 50)]

Area, collector, and date	Stratigraphic data	Number of samples		Quality of specimens	Ratio specimens/species	Number of samples in which characteristic species occur								
		Total	Fossiliferous			*Bathysiphon brosgei*	*Bathysiphon vitta?*	*Gaudryina tailleuri*	*Haplophragmoides topagorukensis*	*Trochammina eilete*	*Gavelinella awunensis*	*Conorboides umiatensis*	*Lithocampe?* sp. (pyritic casts)	*Dictyomitra?* sp. (pyritic casts)
Tributary, Kanayut River, approximately 5 miles south of Arc Mountain anticline; Patton, 1950.	None	3	0											
On tributaries of Siksikpuk River, approximately 9 miles south of Ayiyak Mesa syncline; Patton, 1950.	do	2	0											
Autumn Creek, 5–11 miles above mouth (junction with Siksikpuk River); Keller, 1950.	do	10	7	Fair	vr-c/vr-r			1	3Q		1		4	
Bend of Chandler River, 3½–4 miles southeast of Tuktu Bluff; Detterman, 1948.	3,240–4,720 ft below top	12	8	do	vr-ab/r			3	2Q	2			1	3
Torok Creek, north limb Ayiyak anticlinorium; Tailleur, 1949.	None	2	0											
Torok Creek, south limb Ayiyak anticlinorium; Patton, 1949.	do	7	4	Poor	vr/vr			1	2	1			2	2
Ayiyak anticlinorium on Torok Creek and Chandler River; Patton, 1949.	Type section 400–1,600 ft below *Subarcthoplites* zone.	10	8	do	vr/vr					1	1Q		5	
Kiruktagiak River, north limb Ayiyak anticlinorium; Patton and Tailleur, 1949.	Above *Subarcthoplites* zone	4	2	do	vr/vr								1	
Kiruktagiak River, north limb Ayiyak anticlinorium; Tailleur, 1949.	Below *Subarcthoplites* zone	11	6	do	vr-c/vr-r								4	
Kiruktagiak River, south limb Ayiyak anticlinorium; Tailleur, 1949.	None	28	23	Fair	vr-ab/vr-r			9	12	1	1		8	3
Ayiyak River, above Canoe Creek, south of Tuktu Escarpment; Tailleur, 1949.	Above *Subarcthoplites* zone	9	2	Poor	vr/vr								1	
Ayiyak River, above Canoe Creek, south of Tuktu Escarpment; Patton, 1949.	Below *Subarcthoplites* zone	6	5	do	vr-c/vr					1			5	
Canoe Creek, south limb Ayiyak anticlinorium; Tailleur, 1949.	In part below *Subarcthoplites* zone.	9	3	do	vr/vr				1					
Pediment Creek, 5–7 miles above mouth (junction with Okokmilaga River); Tailleur, 1949.	*Subarcthoplites* zone	3	3	Fair	vr-r/vr-r			3		1			1	
Okpikruak River, south limb Ayiyak anticlinorium; Patton, 1949.	None	4	1	Poor	1 specimen				1Q					
Killik River, approximately 15 miles above junction with Okokmilaga River; Kirschner, 1945.	do	5	0											
Kurupa River, approximate lat 68°39′; Thurrell and Chapman, 1946.	do	4	0											
Okpikruak River, approximately 5 miles above junction with Okokmilaga River; Kirschner, 1945.	do	3	0											
Killik River, 10 miles above mouth of Okokmilaga River; Bickel, 1953.	490-ft exposure	7	2	Poor	vr/vr									
Etivluk River, 3½–10 miles above mouth (junction with Colville); Bickel, 1953.	None	20	11	do	vr-r/vr								4	1
Along east fork of Etivluk River, extending from mouth of Iteriak Creek to 6 miles upstream; Reynolds, 1950.	do	8	4	do	vr/vr							2		
Along east fork of Etivluk River, extending from mouth of Iteriak Creek to 4 miles upstream; Eberlein, 1950.	do	8	3	do	vr-c/vr-r					1Q		2		
Kucher Creek, south of Brower anticline from a point on the crest to 10 miles upstream; Eberlein and Reynolds, 1950.	do	12	2	do	vr/vr			2				2		
Etivluk River, east of Smith Mountain; Mangus and Dutro; 1949.	do	4	0											
Etivluk River, east of Smith Mountain Lake; Mangus, 1949.	do	2	0											
Along Kuna River and Cutaway Creek for approximately 6 miles north of lat 68°45′, and along Swayback Creek for about 1 mile above mouth; Detterman, Mangus, and Lachenbruch, 1949.	do	39	1	Poor	1 specimen								1	

TABLE 4.—*Data for 414 outcrop microfossil samples from the lower part of the Torok Formation*—Continued

Area, collector, and date	Stratigraphic data	Number of samples		Quality of specimens	Ratio specimens/species	Number of samples in which characteristic species occur								
		Total	Fossiliferous			*Bathysiphon brosgei*	*Bathysiphon vitta?*	*Gaudryina tailleuri*	*Haplophragmoides topagorukensis*	*Trochammina eilete*	*Gavelinella awunensis*	*Conorboides umiatensis*	*Lithocampe?* sp. (pyritic casts)	*Dictyomitra?* sp. (pyritic casts)
Kiligwa River, west and northwest of Liberator Lake; Kent, 1951.	Lower(?) beds	14	3	Fair	r-ab / vr									
Area of junction of Nuka River and East Fork; Kent, 1951	Within lower 1,000 ft	8	1	do	vr-ab / r									
Small syncline, Nuka River area, long 159°40′ W.; Morris, 1951.	Lower beds; 900–1,900 ft below top of 3,700-ft exposure.	9	1	Poor	1 specimen									
Small syncline, Nuka River area, long 159°40′ W.; Sable, 1951.	Lower beds; 2,000–3,300 ft below top of 3,700-ft exposure.	11	1	do	1 specimen							1		
Colville River, between lat 68°50′ and 69° N. at long 160°20′ W.; Morris, 1951.	None	1	1	do	vr-r / r			1			1			
Driftwood Creek and Noluk Creek area; Sable, 1951	do	4	0											
Colville River, approximately 8 miles northwest of Noluk Lake; Mangus, 1950.	Lower beds	2	2	Fair	vr / vr				1	1	1			
Tributary of Colville River, approximately 5 miles south of Meat Mountain; Mangus, 1950.	do	6	6	do	vr-ab / r			5	5	5	3	1		
Tributary to Kugururok River, approximately 2 miles south of Meat Mountain; Mangus and Sable, 1950.	Middle to upper beds	6	5	do	vr-r / vr			1	3	3	1			
Driftwood Creek, south flank, east end of Driftwood anticline; Sable, 1950.	Middle beds	7	7	do	vr-r / vr			1	4					
Along east-west tributaries of Driftwood Creek, 3–5 miles south of east end of Driftwood anticline; Mangus and Sable, 1950.	Lower beds	5	2	do	vr-ab / r			2	1	1	2	2		
West tributary of Driftwood Creek, approximately 2 miles above mouth; Mangus, 1950.	Near base	1	0											
At mouth of Driftwood Creek; Sable 1950	do	1	1	Fair	vr-c / r				1					
East-west section of tributary of Utokok River, north of west end of Driftwood anticline; Mangus, 1950.	None	5	2	Poor	vr / vr			1Q	1Q	1	1	1	1	
Utokok River, approximately 1½–4 miles above mouth of Driftwood Creek; Mangus and Sable, 1950.	Middle beds	9	9	Fair	vr-c / vr-r			3	6	5	2			
Adventure Creek, south flank of Driftwood anticline, ¼–2 miles above juction with Utokok River; Sable, 1950.	Upper beds: 2,600–4,700 ft section.	7	7	do	vr-c / vr			3Q	7		1Q			
	Lower beds: 50–1,800 ft section.	6	6	do	vr-vab / vr-r			4	5		1Q			
Creek west of Adventure Creek approximately 1–5 miles above mouth (junction with Utokok River); Mangus, 1950.	Lower beds	12	11	do	vr-c / vr			3	9					
Adventure Creek, 2–6 miles above mouth (junction with Utokok River); Mangus, 1950.	None	19	16	Poor	vr-c / vr-c			5	6	5	1			
Creek west of Adventure Creek approximately 8–10 miles above mouth; Mangus, 1950.	do	4	3	Fair	vr-c / vr			1	2					
North flank, west end Driftwood anticline on west tributary of Utokok River; Sable, 1950.	Lower beds	3	2	Poor	vr / vr				1					
Iligluruk Creek, approximately 1 mile above mouth of north fork; Sable, 1950.	do	1	1	Fair	vr-c / r			1Q	1	1Q				
Iligluruk Creek, 1–3 miles below mouth of east fork; Mangus, 1950.	Lower(?) beds	16	9	do	vr-ab / vr			2	1	3Q				
"North fork" Iligluruk Creek, 1½–4 miles above mouth; Sable, 1950.	Near base	3	3	do	vr-ab / vr				8					
Headwaters of "North fork" Iligluruk Creek, 6 miles west of Adventure Creek; Sable, 1950.	Lower beds	6	5	do	vr-ab / vr			1	5	1				
Iligluruk Creek near junction with Kokolik River; Chapman, 1949.	None	3	3	Poor	vr-c / vr	3	2					1		
Kokolik River, above junction with Iligluruk Creek; Sable, 1949.	do	6	6	do	vr-c / vr	3	1					2		
Along Kokolik River, from a point ½ mile above junction with Tingmirkpuk River to 3 miles downstream; Chapman and Sable, 1949.	do	7	7	do	vr / vr	2						2		

TABLE 5.—*Data for 523 outcrop microfossil samples from the upper part of the Torok Formation*

Number of samples: Total, 523; fossiliferous, 266.

$\frac{\text{Specimens}}{\text{Species}}$: Indicates ratio of abundance of all specimens to all species in fossiliferous samples.

[Q, indicates one or more questionable identifications in some samples; vr, very rare; r, rare; c, common (12–25); ab, abundant (26–50); vab, very abundant (over 50)]

Area, collector, and date	Stratigraphic data	Number of samples		Quality of specimens	Ratio specimens/species	Number of samples in which characteristic species occur																
		Total	Fossiliferous			*Bathysiphon brosgei*	*Bathysiphon vitta?*	*Haplophragmoides topagorukensis*	*Verneuilinoides borealis*	*Ammodiscus rotalarius*	*Miliammina manitobensis*	*Ammobaculites fragmentarius*	*Ammobaculites wenonahae*	*Gaudryina nanushukensis*	*Textularia topagorukensis*	*"Tritaxia" manitobensis*	*Marginulina planiuscula*	*Lenticulina marcrodisca*	*Gavelinella stictata*	*Conorboides umiatensis*	*Eurycheilostoma robinsonae*	*Ditrupa cornu*
East fork Nanushuk River (Cobble Stone Creek) 3½ miles above mouth; Patton, 1950.	None	1	0	----------	----------																	
Lower part of Desolation Creek and tributary, east of Siksikpuk River; Patton, 1950.	do	4	0	----------	----------																	
Lower part of Autumn Creek, near junction with Siksikpuk River; Keller, 1950.	do	5	3	Poor	vr/vr				1Q													
Along Chandler River, south of Tuktu Escarpment, approximately 2 miles southeast of mouth of Kiruktagiak River; Detterman, 1948.	10–910 ft below base of Tuktu Formation.	56	22	do	vr-ab/vr		9	12	9		1		2Q						1Q		1	
On Chandler River, south of Tuktu Bluff; 1½–2½ miles below mouth of Torok Creek; Detterman, 1948.	920–1,430 ft below base of Tuktu Formation.	52	14	do	vr-r/vr		1	7Q	5										1Q			
Okpikruak River approximately 4 miles above junction with Okokmilaga River; Kirschner, 1945.	Lower beds	2	0	----------	----------																	
Okpikruak River near junction with Okokmilaga River, Kirshner, 1945.	do	2	0	----------	----------																	
Kurupa River, north flank Kurupa anticline; Zumberge, 1947.	At contact with Tuktu Formation.	1	1	Good	vr-ab/vr			1	1													
Near crest, south flank Awuna anticline, near east end; 1½ miles east of of Section Creek; Whittington, 1947.	240 ft section	6	4	Poor	vr/vr			3				2										
On Birthday Creek, approximately 1 mile above junction with Awuna River, south flank Awuna anticline; Troyer, 1947.	Top 20 ft of 1,700-ft intermittent exposure.	1	1	Good	vr-ab/r	1	1	1	1	1		1				1						
Near crest of Awuna anticline, approximately 0.7 mile below mouth of west fork of Birthday Creek; Troyer, 1947.	120 ft of 1,700-ft intermittent exposure.	5	5	do	vr-ab/r-c	2	3	5	5	3		5				4					1	
Near crest of Awuna anticline, approximately 0.7 mile below mouth of west fork of Birthday Creek; Whittington, 1952.	305 ft of same exposure.	26	26	do	vr-ab	14	7	26	18	11	5	21	7	4		9	3				6	
Near crest Awuna anticline, approximately ½ mile below mouth of west fork of Birthday Creek; Whittington, 1952.	65-ft section of same exposure.	6	5	Fair	vr-ab/vr-r	3	3	3	1	2		2Q			1Q	3Q	2				1	
Near crest Awuna anticline, approximately ½ mile below mouth of west fork of Birthday Creek; Troyer, 1949.	Lower 20 ft of 1,700-ft intermittent exposure	1	1	Good	vr-c/r	1	1	1	1							1						
North flank Awuna anticline 1–1½ miles above mouth of west fork of Birthday Creek; Troyer, 1947.	Top 20 ft of 3,000-ft section.	1	1	Fair	vr/vr				1							1						1
	220–240 ft below top of 3,000-ft section.	1	0	----------	----------																	
North flank Awuna anticline, 1 mile above mouth of west fork Birthday Creek; Whittington, 1947.	200 ft of continuous section.	5	5	Good	vr-vab/r-c	1	2	5	2	5	1	5				1		1		2		
North flank Awuna anticline, 1 mile above mouth of west fork Birthday Creek; Whittington, 1952.	Same section as above.	15	15	do	vr-ab/r-c	14	3	15	3	15		15		5		1		5	1	6		
North flank Awuna anticline, 2½–4½ miles above west fork of Birthday Creek; Troyer, 1947.	220 ft of 1,200-ft intermittent exposure.	7	7	do	vr-vab/vr-c	2		6	4	2	3	5				4				1Q	2	
North flank Awuna anticline, 2½–4½ miles above west fork of Birthday Creek; Whittington, 1952.	Samples from 90 ft of above section.	5	5	do	vr-c/r	1		5	3			5				2					1	
South flank Awuna anticline, on tributary 2½–3 miles east of Quartzite Creek; Troyer, 1947.	None	2	2	Fair	vr-c/vr-r		2	1	1			1										

TABLE 5.— *Data for 523 outcrop microfossil samples from the upper part of the Torok Formation*—Continued

Area, collector, and date	Stratigraphic data	Number of samples: Total	Number of samples: Fossiliferous	Quality of specimens	Ratio specimens/species	Number of samples in which characteristic species occur: *Bathysiphon brosgei*	*Bathysiphon vitta?*	*Haplophragmoides topagorukensis*	*Verneuilinoides borealis*	*Ammodiscus rotalarius*	*Miliammina manitobensis*	*Ammobaculites fragmentarius*	*Ammobaculites wenonahae*	*Gaudryina nanushukensis*	*Textularia topagorukensis*	*"Tritaxia" manitobensis*	*Marginulina planiuscula*	*Lenticulina macrodisca*	*Gavelinella stictata*	*Conorboides umiatensis*	*Eurycheilostoma robinsonae*	*Ditrupa cornu*
Awuna anticline and Quartzite Creek, 5½ miles above junction with Awuna River: Whittington, 1947.	330-ft section near center of breached anticline.	14	14	Fair	vr-vab/vr-c	1	2	10	10	2		9						1	3			
Awuna anticline and Quartzite Creek, 5½ miles above junction with Awuna River; Whittington, 1952.	160 ft near center of breached anticline.	14	10	Good	vr-c/vr-r	4		8	8			6			3	6	2		1		2	
North flank Awuna anticline, 6-10 miles above mouth of Quartzite Creek; Whittington, 1947.	3 sections, each 100-150 ft thick.	16	13	Fair	vr-vab/vr-r			5	10			7				2			1			
On Colville River near Etivluk River; Thurrell, 1947.	None	12	9	Poor	vr-vab/vr	2	1	1					1 Q									
Three miles west of Etivluk River near Colville River; Thurrell, 1947.	do	4	4	do	vr-vab/vr	3	2															
At junction of Colville River and Ipnavik River; Thurrell, 1947.	do	1	1	do	vr-c/r	1			1													
South side of Colville River, 5 miles west of mouth of Ipnavik River to 7½ miles east of Lost Temper Creek; Detterman and Lachenbruch, 1949.	do	9	1	do	1 specimen																	
Kuna River, approximately 1 mile above junction with Colville River; Mangus, 1949.	do	3	0																			
South flank Lookout Ridge syncline, on Grayling Creek; Whittington, 1949.	do	6	3	Poor	vr/vr			1														
Axis of Carbon Creek anticline, long 158°30′-40′ W.; Whittington, 1949.	do	16	8	do	vr-c/vr	1	5	1	1										1			
Tributary of Carbon Creek, Carbon Creek anticline, lat 69°12′ N., long 158°46′ W.; Keller, 1949.	do	13	2	do	vr/vr	1	1															
Two miles east of the above; Keller, 1949.	do	2	1	do	1 specimen	1																
Headwaters of Carbon Creek, north of Carbon Creek anticline; Whittington, 1949.	500 ft below top of 2,800-ft section.	7	0																			
Tributary of Carbon Creek, near long 159° Carbon Creek anticline; Keller, 1949.	None	2	2	Poor	vr-r/vr	1		2				1 Q										
Utukok River, north flank of Carbon Creek anticline, 3½-4 miles above mouth of Elusive Creek; Bickel, 1953.	do	1	0																			
Junction of Reynard Creek and Colville River northeast of Noluk Lake; Webber, 1948.	do	5	5	Poor	vr-c/vr-r		3	4	1								1				1	
From 0.1 mile north of Colville River to 1.8 miles north, along stream between long 160°3′ and 160°4′ W.; Morris, 1951.	350-3,500 ft below top of 5,600-ft section.	5	0																			
Near bend in Colville River, 2½ miles northwest of west end of Lake Noluk; Sable, 1951.	4,700 ft below top of 5,600-ft section.	1	0																			
On Colville River, north flank of Meat Mountain syncline; Sable, 1951.	1,500 ft below top of 5,600-ft section.	1	0																			
On Colville River, 4½ miles below mouth of Thunder Creek; Sable, 1951.	32-3,300 ft below top of 5,600-ft section.	2	0																			
On Colville River, from 0.9 mile above mouth of Thunder Creek to 1½ miles below mouth; Sable and Morris, 1951.	From more 3,500 ft to 5,500 ft below top of 5,600 ft of beds.	5	0																			
North flank of Driftwood anticline. Driftwood Creek; Sable, 1950.	Uppermost part of formation; 150-ft section.	4	3	Poor	vr/vr							1 Q										

TABLE 5.—*Data for 523 outcrop microfossil samples from the upper part of the Torok Formation*—Continued

Area, collector, and date	Stratigraphic data	Number of samples: Total	Number of samples: Fossiliferous	Quality of specimens	Ratio specimens/species	*Bathysiphon brosgei*	*Bathysiphon vitta?*	*Haplophragmoides topagorukensis*	*Verneuilinoides borealis*	*Ammodiscus rotalarius*	*Miliammina manitobensis*	*Ammobaculites fragmentarius*	*Ammobaculites wenonahae*	*Gaudryina nanushukensis*	*Textularia topagorukensis*	*"Tritaxia" manitobensis*	*Marginulina planiuscula*	*Lenticulina marcrodisca*	*Gavelinella stictata*	*Conorboides umiatensis*	*Eurycheilostoma robinsonae*	*Ditrupa cornu*
West bluff Kokolik River on south flank of Archimedes anticline, near crest; Whittington, 1952.	150-ft section, base equivalent to top of following section.	15	9	Poor	vr/vr	4		8		4					5 Q							
Along west bluff Kokolik River on north flank of Archimedes anticline extending from crest to 1½ miles downstream to the northeast; Whittington, 1952.	(AR-C) lowest 129 ft of approximately 1,150 ft section (somewhere in upper part of formation).	14	2	do	3 specimens			2														
	(AR-D) 207 ft stratigraphically higher than AR-C	20	14	do	vr-c/vr-r	8		7		2		4			2		1				1	
	(AR-E) 154 ft of same section, base beginning in upper ⅓ of AR-D.	16	2	do	vr/vr	1		2				1										
	(AR-F) 83 ft of 1,150-ft section (higher than AR-D).	8	1	do	1 specimen					1												
	(AR-G) 120 ft of same section, part equivalent to AR-F.	12	3	do	4 specimens	1		3														
	(AR-H) 127 ft of same section: lower 30 ft equivalent to upper 30 ft of AR-G.	13	3	do	vr/r			3				1										
	(AR-I) 117 ft of same section with 50 ft equivalent to part of AR-H.	12	4	do	vr/vr	2		3														
	(AR-J) 104 ft of same section, stratigraphically higher than AR-I.	10	8	do	vr/vr			6							2							
	(AR-L) uppermost 340-350 ft of 1,150-ft section.	36	15	do	vr-c/vr	6		11							1				3	2		
Kokolik River, south, flank, Blizzard anticline; Sable, 1949.	1,000 and 1,100 ft below top of 1,900-ft exposure.	2	1		6 charophytes																	
Kokolik River, north flank, Blizzard anticline; Sable, 1949.	1,700 ft below top of same exposures.	2	0																			
Kukpowruk River, 2-6 miles south of axis of Raven Basin syncline; Chapman and Sable, 1949.	None	6	6	Poor	vr-c/vr	5		1 Q		2			1 Q									
Kukpowruk River, Raven Basin syncline area; Sable, 1949.	Lower beds	8	4	do	vr/vr			4														
Kukpowruk River, approximately ½ mile below mouth of Deadfall Creek; Sable, 1949.	150 and 250 ft below top of 400-ft exposure.	2	1	do	vr-c/vr			1					1 Q			1						

Tuktu Formation as far east as the Saviukviayuk River near long 149° W., and they measured 800 feet of interbedded siltstone, shaly siltstone, and silty sandstone on the east side of the mesa at Marmot syncline. This syncline lies west of the headwaters of Sagavanirktok River between lat 68°45′ N. and lat 68°50′ N.

The Tuktu Formation has been mapped westward from the type locality at Tuktu Bluff on the north side of the Chandler River to about long 156° where it merges with the Kukpowruk Formation.

The Tuktu Formation is described (Detterman, 1956, p. 234) as predominantly green to greenish-gray fine-grained sandstone and subordinate siltstone and silt shale. It is commonly thinly bedded. At the type locality the formation is 1,030 feet thick. Megafossils from the formation are much the same as those found in the upper part of the Torok Formation and are identified as middle Albian in age (Imlay, 1961, p. 4) as are also some of the species of Foraminifera. The microfaunal assemblage is also much like that found in the upper part of the Torok Formation and is part of the *Verneuilinoides borealis* faunal zone. Pertinent data on diagnostic Foraminifera found in 92 fossiliferous samples from the Tuktu Formation are given in table 6. Samples examined are all from the area between the Anaktuvuk and Kurupa Rivers.

GRANDSTAND FORMATION (ALBIAN)

A sequence of marine and lagoonal sands and sandstone with subordinate amounts of shale overlies the Tuktu Formation along the Anaktuvuk River southeast of the Petroleum Reserve; it is described as the Grandstand Formation by Detterman (1956, p. 235). His lithologic description is as follows: "The basal part of the formation is predominantly fine-grained, light olive-gray to dark yellow-red sandstone with a thin, greenish, salt-and-pepper sandstone bed at the base, and subordinate amounts of siltstone and shale. In the upper part, siltstone and silt shale constitute about 50 percent of the unit; minor amounts of coal occur within this sequence." At the type locality the Anaktuvuk River breaches the Grandstand anticline, and 1,700 feet of the Grandstand Formation is exposed; the upper part of the section interfingers with the lower part (Killik Tongue) of the nonmarine Chandler Formation (Detterman, 1956, p. 237).

The Grandstand Formation is exposed only in the central area of the northern foothills region and is replaced westward and southward by the Killik Tongue of the nonmarine Chandler Formation. In the eastern area of the foothills, the Torok Formation is overlain by the Tuktu Formation (Keller and others, 1961, p. 202), but in the western foothills the Kukpowruk Formation occupies this stratigraphic position (Sable, 1956, p. 2637). In the subsurface the Grandstand Formation is thickest in Grandstand test well 1, where a few hundred feet of the formation occur. In many of the test wells in the foothills and Arctic coastal plain, however, sections that have been referred to the Grandstand in published reports (Bergquist, 1956b; Collins, 1958a,b, 1959; Robinson, 1956, 1958a, 1959a,b) are considered here as Tuktu and (or) Grandstand Formations undifferentiated.

Megafossils obtained from outcrops of the Grandstand Formation are relatively few but are similar to those from the Tuktu Formation and the upper part of the Torok Formation; they indicate an Albian age (Imlay, 1961, p. 16, tables 6, 12). Microfossils are limited to a few Foraminifera of the *Verneuilinoides borealis* zone, but species that are characteristic of the Tuktu Formation and the upper part of the Torok Formation are absent. Some Foraminifera, such as *Ammobaculites* were formerly attributed to the formation (Detterman, 1956, p. 236), but in northern Alaska these genera are now known to be from beds that are older than the Grandstand Formation. One hundred and ten outcrop samples from the Grandstand Formation and its interbeds with the Chandler Formation (Killik Tongue) were examined for microfossils; 74 samples were fossiliferous, but yielded only a very small foraminiferal assemblage. Pertinent data on the samples are given in table 7.

CHANDLER FORMATION (ALBIAN TO CENOMANIAN?)

A sequence of beds that are largely nonmarine occurs in the upper part of the Nanushuk Group in the northern foothills; these beds are named the Chandler Formation from exposures along the Chandler River (Gryc and others, 1951, p. 164). The Chandler Formation overlies the Tuktu Formation southward, but toward the north the lower part interfingers with the Grandstand Formation. The lower and thicker part of the Chandler Formation was described as the Killik Tongue by Detterman (1956, p. 237), who has redefined the upper part as the Niakogon Tongue. At the type locality along the east bank of the Killik River between lat 68°52′ N. and 68°55′ N. at long 153°26′ W., the Killik Tongue is 2,815 feet thick (Detterman, 1956, p. 237); whereas the Niakogon Tongue, at its type locality on the Killik River 10 miles upstream from the confluence of the Killik River with the Colville River, is about 650 feet thick (Detterman, 1956, p. 240).

Killik Tongue

The lower part of the Killik Tongue is described by Detterman (1956, p. 238) as 1,095 feet thick and consists of thick-bedded bluff-forming sandstone, carbonaceous

TABLE 6.—*Data for 127 outcrop microfossil samples from the Tuktu Formation*

Number of samples: Total, 127; fossiliferous, 92.

$\frac{\text{Specimens}}{\text{Species}}$: Indicates ratio of abundance of all specimens to all species in fossiliferous samples.

[Q, indicates one or more questionable identifications in some samples; vr, very rare; r, rare; c, common (12–25); ab, abundant (26–50); vab, very abundant (over 50)]

Area, collector, and date	Stratigraphic data	Number of samples: Total	Number of samples: Fossiliferous	Quality of specimens	Ratio specimens/species	*Haplophragmoides topagorukensis*	*Verneuilinoides borealis*	*Psamminopelia bowsheri*	*Miliammina awunensis*	*Miliammina manitobensis*	*Ammobaculites fragmentarius*	*Ammobaculites wenonahae*	"*Tritaxia*" *manitobensis*	*Gaudryina nanushukensis*	*Gavelinella stictata*	*Eurycheilostoma grandstandensis*	*Ditrupa cornu*
Nanushuk River below junction of east fork Peregrine Creek; Patton, 1950.	240–950 ft below top	3	3	Good	vr-ab/vr	3	3				3			2			1
East side Nanushuk River at north flank Arc Mountain anticline; Webber, 1947.	500–600 ft below top	3	3	Poor	vr/vr		2										1
West end of Arc Mountain anticline; Patton, 1950	None	4	3	Good	vr-ab/vr-r	3	3	2			3			1		1	1
Nanushuk River, east end Rooftop Ridge anticline; Detterman, 1953.	25–280 ft and 420–530 ft below top.	3	2	Fair	vr-c/vr	2	1				2						1
South flank Rooftop Ridge anticline, west side Nanushuk River; Webber, 1947.	160–1,240 ft below top	5	4	do	vr-vab/vr-r	3	2				1						4
Malemute Creek (Nanushuk River area); Keller, 1950	In lower 100 ft	5	4	Good	vr-ab/r	4	4	4			4			1			
Kanayut River, junction with Anaktuvuk River; Detterman, 1953.	80 ft below top	1	1	Poor	vr/vr	1Q											
Anaktuvuk River, Kanayut River anticline, Bickel, 1953.	None	1	1	do	vr-ab/vr	1	1			1Q							
Chandler River, west end Big Bend anticline; Detterman, 1948.	Top	1	1	Fair	vr-ab/r	1	1		1		1						
Chandler River at Grandstand anticline; Detterman, 1948.	300–500 ft above base	8	7	do	vr-ab/vr-r	5	6		1Q	2	3						
Chandler River at Big Bend anticline; Detterman and Gryc, 1948.	Near top	13	8	Good	vr-ab/vr-r	4	8	1Q	4		2						
	50–260 ft below top	5	5	do	vr-ab/vr-r	5	5	4			4						1
Trouble Creek at Big Bend anticline; Bickel and Detterman, 1948.	160–200 ft below top	2	2	do	ab/r	2	2				2						
Chandler River at Tuktu Bluff; Detterman and Gryc, 1948.	Type section base to 275 ft above.	6	2	Poor	vr-c/vr	1	2					1Q					3
Fossil Creek, 2–6 miles above junction with Colville River; Detterman, 1947.	1,360-ft section	14	12	Good	vr-ab/r-c	12	12	2		9	12			2	1	7	3
Pediment Creek below junction of Okpikruak River and Okokmilaga River; Detterman, 1953.	None	1	0														
1½ miles south of junction of Killik-Okokmilaga Rivers; Warner, 1945.	do	1	0														
Killik River, 1 mile above mouth of Okokmilaga River; Detterman, 1953.	30–60 ft below top	1	1	Fair	vr-ab/vr		1		1								
Killik River at Oolamnagavik syncline; Detterman, 1953.	Upper 75–100 ft	1	1	do	vr-r/vr	1Q	1		1								
Coal Creek, 10 miles above junction with Killik River, east end Kurupa anticline; Bickel, 1953.	None	1	1	Good	vr-c/r	1	1		1								
Killik River, east end Kurupa anticline; Kirshner, 1945.	Basal	2	0														
Killik River, east end Kurupa anticline; Warner, 1945	None	1	0														
Killik River, east end Kurupa anticline; Detterman, 1953.	5–120, 330–510, and 670–810 ft below top.	3	2	Poor	vr/vr	1Q	1		1								
Killik River at Kurupa anticline; Bickel, 1953	Lower half	8	4	Fair	vr-c/vr	3			1	1	1Q						
Colville River, west of junction with Killik River; Bickel, 1953.	None	2	0														
Oolamnagavik River, 3–5 miles above mouth of east fork; Thurrell, 1946.	At contact	1	1	Poor	1 specimen		1										
Near mouth of east fork Oolamnagavik River, and extending 1 mile above; Thurrell, 1946.	Upper part	3	1	do	vr-ab/vr	1	1			1		1					1
East side Oolamnagavik River near junction with Colville River; Thurrell, 1946.	do	1	1	Fair	r-ab/r	1Q	1		1			1					
Colville River, west end Killik Bend anticline; Bickel, 1953.	Near top	2	1	do	vr/vr	1	1										
Near Aupuk gas seep, south side Colville River, near crest, east end Aupuk anticline; Thurrell, 1946.	None	1	1	Good	r-vab/r	1Q	1	1			1						
North side Colville River, north flank, east end Aupuk anticline; Thurrell, 1946.	do	1	1	do	vr-vab/r	1	1	1									
Tributary near mouth of Oolamnagavik River; 4 miles west of Killik Bend; Thurrell, 1946.	do	1	1	Fair	vr/vr	1		1									
Kurupa River, 7 miles above junction with Colville River; Thurrell, 1946.	do	1	0														
Kurupa River at north flank Kurupa anticline; Zumberge, 1946.	1,200-ft section	8	8	Good	vr-ab/vr-c	7	7	3	2			2Q	6		2		2
Kurupa River, 5 miles above junction with Colville River; Chapman, 1947.	None	3	2	Fair	vr-ab/vr-r		2	2					1				
South bluff Awuna River, 7½ miles southwest of junction with Colville River; Zumberge and Thurrell, 1947.	Upper part	8	6	do	vr-ab/vr-c	6	6			3	6		4		2	1	
North side Colville River, 1 mile northwest of mouth of Etivluk River; Zumberge, 1947.	None	2	2	Poor	vr-c/r	2	1					2					

TABLE 7.—*Data for 110 microfossil samples from the Grandstand Formation*

Number of samples: Total, 110; fossiliferous, 74.

$\frac{\text{Specimens}}{\text{Species}}$: Indicates ratio of abundance of all specimens to all species in fossiliferosu samples.

[Q, indicates one or more questionable identifications in some samples; vr, very rare; r, rare; c, common (12–25); ab, abundant (26–50); vab, very abundant (over 50)]

Area, collector, and date	Stratigraphic data	Number of samples: Tota	Number of samples: Fossiliferous	Quality of specimens	Ratio specimens/species	Number of samples in which characteristic species occur: *Verneuilinoides borealis*	*Psamminopelta bowsheri*	*Miliammina awunensis*	*Ditrupa cornu*
Nanushuk River, below mouth of east fork, west end Arc Mountain anticline; Patton, 1950.	320–660 ft above base	1	1	Good	vr-vab/vr	1	1		
Kanayut River at junction with Anaktuvuk River; Detterman, 1953.	Interbedded with Killik Tongue of Chandler Formation.	2	1	Poor	vr/vr			2 Q	
South side Chandler River, 2 miles north to 6 miles northeast of Tuktu Bluff: Detterman and Gryc, 1948.	Interbedded with Killik; 240–1,580 ft above Tuktu Formation.	18	3	do	vr-c/vr	2			
West end of Hawk anticline, 5 miles north of Hatbox Mesa; Detterman, 1952.	Interbedded with Killik	2	1	do	vr-r/vr				
Chandler River at Grandstand anticline; Detterman, 1948	1,700-ft section, interbedded with Killik.	6	4	do	vr/vr	2		2 Q	
	300-ft section, 500–800 ft above Tuktu Formation.	8	7	Fair	vr-ab/vr-r	5	1	3	
Chandler River, west end Big Bend anticline; Detterman, 1948.	600–900 ft above base	5	4	do	vr-vab/vr-r	4		4	
Fossil Creek, 5–10 miles above mouth (junction with Colville River); Gryc, 1946.	Several hundred ft of intermittent exposures.	5	4	do	vr-c/vr	2			1
Fossil Creek, 2–6 miles above Colville River; Detterman, 1947.	10–740 ft below top(?)	10	6	Good	vr-ab/vr-r	4		1	
Ninuluk Creek syncline, south of Fossil Creek; Detterman, 1952.	Interbedded with Killik	1	[1] 1	Poor	vr/vr				
Near mouth of Okokmilaga River (Killik River junction); Detterman, 1953.	do	2	2	Fair	vr-c/vr-r	1		1	
Oolamnagavik syncline at Killik River; Detterman, 1953	do	1	0						
Killik River south limb Kurupa anticline; Detterman, 1953	780–1,070 ft below top(?)	2	2	Poor	vr/vr	1		1	
Coal Creek, 10 miles above junction with Killik River; Bickel, 1953.	50–350 ft below top(?)	4	4	Good	vr-ab/vr	4			
Killik River, Killik Bend; Detterman, 1953	Interbedded with Killik; 880 ft exposed.	5	4	Poor	vr/vr	2			
North flank Killik Bend anticline, north side Colville River; Thurrell, 1946.	Lower(?) part	1	1	Fair	vr-ab/r	1			
East side Oolamnagavik River near junction with Colville River; Thurrell, 1946.	Interbedded with Killik	3	3	Fair-good	vr-vab/vr-r			1	
West bank Colville River at Killik Bend; Detterman, 1953.	do	2	1	Poor	vr/vr	1			
Colville River, west end Killik Bend anticline; Bickel, 1953.	do	5	3	Fair	vr-c/vr	2		1	
West bank Colville River, 3 miles northwest of Killik Bend; Detterman, 1953.	do	1	1	Poor	vr/vr	1 Q			
West bank Colville River, 5 miles northwest of Killik Bend; Bickel, 1953.	do	3	3	do	vr-ab/vr	2			
West bank Colville River, 7 miles northwest of Killik River; Detterman, 1953.	do	1	1	do	vr/vr				
South side Colville River, 4–6 miles above junction with Oolamnagavik River; Chapman and Thurrell, 1946.	do	3	3	Good	c-ab/vr	2			
Colville River, east end Aupuk anticline; Reynolds, 1950	do	3	2	Fair-poor	vr-ab/vr-r	1		1	
South flank, east end Aupuk anticline, Colville River; Thurrell and Chapman, 1946.	do	5	4	Good	vr-c/r	3	1		
Kurupa River, 4 miles above mouth (junction with Colville River); Zumberge, 1946.	950–1,150 ft above Tuktu Formation	2	2	do	vr-ab/r	2	2		
North flank Kurupa anticline, Kurupa River; Zumberge, 1946.	260–700 ft above Tuktu Formation	3	2	Fair	vr/vr	1	2		
Colville River, 15 miles above junction with Awuna River to 10 miles below junction; Thurrell, 1947	Interbedded with Killik	6	4	do	vr/vr	2			

[1] Not diagnostic.

siltstone, and silt shale that contains numerous coal seams. The upper 1,720 feet of the Killik Tongue at the type locality is characterized by a series of massive quartz conglomerate ledges and beds of sandstone that are thinner, finer grained, and more argillaceous than those in the lower part; siltstone and silty shale are more abundant, but coal is present only as thin seams (Detterman, 1956, p. 238).

The Chandler Formation is not present in the western part of northern Alaska; in the eastern part of the foothills, the Killik Tongue was recognized only at Marmot syncline (Keller and others, 1961, p. 202), where a 2,500-foot section of nonmarine sandstone, conglomerate, siltstone, shale, and coal is partly exposed.

Foraminifera listed by Detterman (1956, p. 237–238) as characteristic of the Killik cannot be regarded as such because most of the species found are a few long-ranging forms of the *Verneuilinoides borealis* faunal zone. In particular, *Ammobaculites humei* Nauss should be excluded from Detterman's list, as species of *Ammobaculites* have not been found higher in the section than the Tuktu Formation. I believe that the fossiliferous rocks considered by Detterman to be the Killik Tongue represent thin marginal marine intertongues of the Grandstand Formation and that the fauna represents laggards or the last evidence of marine forms in the Albian deposits.

Outcrop samples from the Killik Tongue that were examined for microfossils are grouped with samples from the Grandstand Formation in table 7. In the subsurface in the foothills and coastal plain, the Killik Tongue was identified in several test holes.

Niakogon Tongue

The Niakogon Tongue, which is lithologically similar to the Killik Tongue and which everywhere is separated from it by a thin section of marine Ninuluk Formation, is the uppermost part of the Chandler Formation (Detterman, 1956, p. 240). Only eight outcrop samples from this tongue were collected for microfossil examination (table 1). Two of these contained a few specimens of *Saccammina lathrami* Tappan. All the samples are from the Kurupa River and Kurupa anticline area.

NINULUK FORMATION (CENOMANIAN)

The uppermost part of the Nanushuk Group is a sequence of a few hundred feet of marine siltstone, clay shale, sandstone, and conglomerate which conformably overlies the Grandstand Formation or the nonmarine beds of the Chandler Formation. Detterman (1956, p. 241) described this as the Ninuluk Formation. At the type locality of the formation at Ninuluk Bluffs on the Colville River, two units of the nonmarine Niakogon Tongue totaling 261 feet in thickness interfinger with about 657 feet of the Ninuluk Formation about midway in the section (Detterman, 1956, p. 242).

The Ninuluk Formation is described by Detterman (1956, p. 242) as follows: "Greenish gray siltstone, silt shale, and dark blue-gray clay shale constitute about 60 percent of the sequence. Coarse clastics account for most of the remainder. Several thick sandstone units are present near the top of the formation. Stringers and lenses of grit-pebble conglomerate are present at intervals throughout the coarser clastic units. The sandstone grades from salt-and-pepper through various shades of gray and yellow-red. Most of them have a distinct greenish cast. Siliceous, argillaceous, and ferruginous concretions are commonly associated with the siltstone and silt-shale units. The interfingering nonmarine Niakogon Tongue contains numerous thick coal beds and thinner bentonite beds."

South of the Colville River the Ninuluk Formation has been recognized from the Nanushuk to the Killik Rivers, and north of the Colville River it crops out in the area of the Ikpikpuk and Titaluk Rivers. In the eastern part of the foothills, the Ninuluk Formation has been recognized only at Marmot syncline, where about 100 feet is exposed (Keller and others, 1961, p. 203).

In the subsurface the thickest section of the Ninuluk Formation is in Titaluk test well 1, where nearly 600 feet was penetrated. The formation was identified in the Wolf Creek test wells and in Square Lake test well 1. In the Square Lake test, it seems to interfinger with the Killik Tongue of the Chandler Formation. In the Umiat field the formation is relatively thin, and it was not found in three (2, 3, and 4) of the 11 test holes. In the Gubik test holes, an even thinner section than that occurring in the Umiat field interfingers with the Chandler Formation. The Ninuluk Formation was not recognized in the test holes in the coastal plain.

Inoceramus dunveganensis McLearn found in the Ninuluk Formation relates the beds to the Dunvegan Formation in Alberta and British Columbia (Imlay, written commun., 1956; Jones and Gryc, 1960) and affixes a Cenomanian age. Foraminifera are limited largely to two species of *Gaudryina* and *Trochammina* and form a zone distinctive from that found in the Albian beds of the Nanushuk Group. Of the outcrop samples examined (see table 8), less than 60 percent contained microfossils. These microfossils are principally two species of Foraminifera, *Gaudryina irenesis* Stelck and Wall and *Trochammina ribstonensis* subsp. *rutherfordi* Stelck and Wall. One sample given in table 8 contained only a few specimens of the long-ranging *Saccammina lathrami* Tappan. A few samples in table 1

TABLE 8.—*Data for 148 outcrop microfossil samples from the Ninuluk Formation*

Number of samples: Total, 148; fossiliferous, 85.

Specimens/Species: Indicates ratio of abundance of all specimens to all species in fossiliferous samples.

[Q, questionable identification; vr, very rare; r, rare; c, common (12–25); ab, abundant (26–50); vab, very abundant (over 50)]

Area, collector, and date	Stratigraphic data	Number of samples: Total	Number of samples: Fossiliferous	Quality of specimens	Ratio specimens/species	Number of samples in which characteristic species occur: *Gaudryina irenensis*	*Trochammina ribstonensis rutherfordi*	*Trochammina wetteri*
Nanushuk River, 5 miles above mouth; Webber, 1947	None	1	1	Fair	r/vr		1	
Tuluga River, Grandstand anticline; Detterman, 1952	100 ft above base	1	0					
Trouble Creek (east tributary to Chandler River), south of Big Bend anticline; Detterman, 1952.	400 ft above base	1	0					
West end of Hawk anticline near east fork Ayiyak River; Detterman, 1952.	Lower 300–400 ft	3	2	Poor	vr-ab/vr	1Q	1	
Chandler River, at Big Bend anticline; Detterman 1948 and 1952; Gryc, 1945.	From base to 400 ft above base	7	0					
Chandler River at Big Bend anticline; Detterman, 1948 and 1952	170 ft exposed	3	1	Poor	vr/vr	1		
Ayiyak River, at Grandstand anticline; Detterman, 1952	660-ft intermittent exposure	4	4	Fair	vr-ab/vr	3	1	3
Tributary of Ayiyak River, 6 miles above Wolverine Creek; Bickel, 1952.	810 ft exposed	4	4	do		1Q	4	
North side Colville River, approximately 4 miles upstream from mouth of Prince Creek; Kirschner, 1945; Detterman, 1947; Warner, 1947.	From 40 ft below top to base of 180 ft exposure.	9	5	do	vr-ab/vr	2	3	
On Fossil Creek, approximately 9½ miles above mouth; and approximately 14 miles airline S. 55° W. of Umiat; Detterman, 1947.	From section 30–370 ft above base of 540-ft intermittent exposure.	4	2	do	vr-c/vr	2		2
Ninuluk Creek, syncline, south of Fossil Creek; Detterman, 1952	From base to 100 ft above base	4	0					
On Fossil Creek, approximately 4 miles south of Colville River; Gryc, 1946.	150 ft above base of 280-ft intermittent exposure.	1	1	Poor	vr/vr			
Ninuluk Creek, west end of Grandstand anticline; Determan, 1952.	Near base	1	0					
On stream 4 miles west of Fossil Creek, and 2½–3 miles south of Colville River; Detterman, 1947.	At 200 and at 640 ft below top of 1000-ft intermittent exposure.	2	0					
Area west of Ninuluk Creek, approximately 2 miles south of southeast end of Ninuluk Bluff; Lathram, 1946.	900 ft below top of 1200-ft intermittent posure.	1	1	Poor	2 specimens		1Q	
South side Colville River between west end of Ninuluk Creek syncline and Little Twist anticline; Warner, 1945.	Contact with Seabee Formation	1	0					
South side Colville River, southwest end Ninuluk Bluff: approximately 32 miles airline southwest of Umiat; Detterman 1947 and Kirschner, 1945.	70–870 ft below top of 900 ft exposure with intertongues of Niakogon.	46	26	Fair	vr-ab/vr-r	8	20	3
Adjacent to Prince Creek; 12–18 miles above mouth (junction with Colville); Detterman, 1953.	None	2	0					
Coal Creek, 1–2 miles above junction with Killik River, and on Killik River, 2–5 miles below mouth of Coal Creek, between Kurupa aticline and Awuna syncline: Bickel and Detterman, 1953.	700-ft exposure	5	4	Poor	vr/vr	1Q	3	
Killik River; Kirschner, 1945	Basal	4	1	Good	vr-vab/vr	1	1	
Colville River at Starfish Bluff approximately 7 miles northeast of mouth of Killik River; Detterman, 1953.	None	2	2	Fair	vr-ab/vr	1	1	
South side Colville River, north flank Killik Bend anticline; Warner, 1945.	do	3	0					
South flank, east end Wolf Creek anticline headwaters of Wolf Creek; Ray, 1946.	Top	1	0					
North flank, east end Wolf Creek anticline; Ray, 1946	100-ft exposure	6	6	Good	vr-vab/vr-r	2	5	
Headwaters of Maybe Creek, approximately long. 153°35′; Ray, 1946.	630–670 ft below top of 700-ft. intermittent exposure.	3	2	Poor	vr-c/vr			
Weasel Creek anticline near long. 154°; Fischer, 1946	500 ft below top of 700-ft intermittent exposure.	1	1	do	vr/vr		1Q	
Maybe Creek; approximately 1½ miles airline southeast of junction with Kigalik River; Webber, 1947.	150-ft exposure	2	2	Fair	vr-c/vr		2	
Ikpikpuk River, south flank Titalik anticline; Webber, 1947	210-ft exposure	3	2	Good	a-vab/vr	1	2	
Ikpikpuk River, south flank of Titaluk anticline; Webber, 1947	None	2	2	Poor	vr/vr			
Titaluk anticline, Ikpikpuk River; Webber, 1947	Top	1	1	Good	ab/vr		1	
West of Ikpikpuk River, north flank Titaluk anticline; Webber, 1947.	80-ft exposure	1	1	Fair	r/vr		1	
Ikpikpuk River, between lat. 69°36′ and 69°37′; Webber, 1947	110 ft exposure	5	5	do	vr-vab/vr-r	4	5	
Titaluk River, lat 69°38′; Webber, 1947	None	1	1	Good	ab/vr		1	
Titaluk River, approximate lat 69°41′20″; Webber, 1947	do	2	2	Poor	vr/vr		2	
Titaluk River, approximate lat 69°47′ to 47′30″; Webber, 1947	do	3	1	do	3 specimens		1	
Ikpikpuk River, south flank Billy syncline; Webber, 1947	In 100-ft exposure	3	1	Good	vr-vab/vr	1	1	
Ikpikpuk River, approximately 8–12 miles above junction with Price River; Webber, 1947.	350 ft of intermittent exposure	5	4	do	vr-ab/vr	3	4	

were not given in table 8 because of insufficient locality data.

COLVILLE GROUP

Upper Cretaceous beds aggregating 5,500 feet in thickness form the Colville Group and unconformably overlie the Ninuluk and Chandler Formations of the Nanushuk Group. The "Colville series" was a name originally proposed by Schrader (1904), but this series was redefined by Gryc, Patton, and Payne (1951, p. 164) to include rocks along the Colville River "from approximately the junction of Prince Creek east and north to the 70th parallel." These authors defined the Colville Group as consisting of the nonmarine Prince Creek Formation and the marine Schrader Bluff Formation, and they considered these two formations to be approximately equivalent in age. They further divided the Schrader Bluff Formation into three members (Seabee, Tuluga, and Sentinel Hill) and designated the type locality of the formation at Schrader Bluff on the Anaktuvuk River just south of the Tuluga River. The Prince Creek Formation as defined by Gryc, Patton, and Payne (1951, p. 166) includes all nonmarine beds above the top of the Niakogon Tongue of the Chandler Formation and the intertongues with the Schrader Bluff Formation; the lower part of the formation is the Tuluvak Tongue and the upper part, the Kogosukruk Tongue.

SEABEE FORMATION (TURONIAN)

The oldest marine unit of the Schrader Bluff Formation was redefined by Whittington (1956, p. 246) as the Seabee Formation from beds exposed along Seabee Creek, a tributary to the Colville River in the vicinity of Umiat. The predominantly dark-gray clay shale beds crop out in the Arctic foothills, and in the vicinity of Umiat the maximum thickness is 1,500 feet. The only complete section, however, is in Umiat test well 11. The formation has been identified in five other wells in the Umiat field, in test holes to the northwest and to the east of Umiat, and in test holes in the coastal area. South of the Umiat area the upper part of the formation is a sequence of a few hundred feet of tuffaceous siltstone, sandstone, and shale described as the Ayiyak Member by Detterman (1956, p. 253); Detterman also named the lower shale sequence the Shale Wall Member (Detterman, 1963, p. 269–270).

Megafossils such as *Inoceramus labiatus* (Schlotheim), *Scaphites delicatulus* Warren, and *Watinoceras reesidei* Warren indicate that the Shale Wall Member of the Seabee Formation is of early Turonian age (Cobban and Gryc, 1961, p. 178), equivalent to beds of the Carlile Shale and Greenhorn Limestone of the Western Interior and the Eagle Ford Shale of the gulf coastal area (Imlay and Reeside, 1954, chart 10d). This age determination is substantiated by certain Foraminifera, particularly by a few planktonic forms found in the lower shale beds of the formation (Tappan, 1951b). Occurrences and significance of these and other microfaunas, together with the faunal zones that can be recognized in the Seabee Formation, are discussed on pages 142–144; tables 9 and 10 give data on numerous microfossil samples from the formation. A few collections are not included in these tables because of meager locality data; the total samples examined are listed in table 1.

Only *Inoceramus* aff. *I. cuvierii* Sowerby has been found in the Ayiyak Member of the Seabee Formation, and the age of this member is therefore considered as late Turonian, probably correlative with the upper part of the Carlile Shale (Jones and Gryc, 1960, p. 153).

PRINCE CREEK AND SCHRADER BLUFF FORMATIONS (SENONIAN)

The Prince Creek Formation as defined by Gryc, Patton, and Payne (1951, p. 166) and Whittington (1956, p. 252) includes all nonmarine beds above the top of the Niakogon Tongue of the Chandler Formation and intertongues with the Schrader Bluff Formation; the lower part of the formation is the Tuluvak Tongue and the upper part the Kogosukruk Tongue. The formation overlies the Seabee Formation in the southern foothills region south of Umiat, and in some subsurface sections it is interbedded with the Schrader Bluff Formation.

The Schrader Bluff Formation at the type locality in Schrader Bluff is a sequence of 1,900 feet of south-dipping rocks which has been divided by Whittington (1956, p. 249) into three members. The Rogers Creek or lowest member, 700 feet thick, is largely clay shale but has considerable silty shale and bentonite, and minor siltstone and tuff; beds of sandstone 10–35 feet thick total about 100 feet. Above this is the Barrow Trail Member (700 ft thick) composed of beds of fossiliferous sandstone 25–65 feet thick interbedded with siltstone, clay shale, tuff, and bentonite. The Sentinel Hill or youngest member, which was named by Gryc, Patton, and Payne (1951, p. 166), consists of approximately 500 feet of siltstone, tuffaceous siltstone, and tuff and lesser amounts of clay shale and bentonite.

The Schrader Bluff Formation is exposed in the northern foothills from the Anaktuvuk River east to the Toolik River and the Sagavanirktok River, and from Schrader Bluff northwest to about long 152°45′ W., in the area of the headwaters of Prince and Wolf Creeks. The formation was penetrated in the subsurface only in the following tests: Sentinel Hill core test 1, Fish Creek test well 1, North Simpson test well 1, Gubik test wells 1 and 2, and Square Lake test well 1.

TABLE 9.—*Data for 274 outcrop microfossil samples from the Shale Wall Member of the Seabee Formation*

Number of samples: Total, 274; fossiliferous, 136.

$\frac{\text{Specimens}}{\text{Species}}$: Indicates ratio of abundance of all specimens to all species in fossiliferous samples.

[Q, indicates one or more questionable identifications in some samples; vr, very rare; r, rare; c, common (12–25); ab, abundant (26–50); vab, very abundamt (over 50)]

Area, collector, and date	Stratigraphic data	Number of samples: Total	Number of samples: Fossiliferous	Quality of specimens	Ratio specimens/species	*Saccammina lathrami*	*Haplophragmoides bonanzaense*	*Haplophragmoides rota*	*Textularia* sp. and *T. rollaensis*	*Trochammina diagonis*	*Trochammina ribstonensis*	*Trochammina whittingtoni*	*Verneuilinoides fischeri*	*Praebulimina seabeensis*	"*Zonodiscus*" sp. A	"*Zonodiscus*" sp. C
Nanushuk River, between Rooftop Ridge anticline and Ayiyak Mesa syncline; Detterman, 1953.	Basal to middle	4	3	Good	vr-vab/vr	1			2			1	1			
Nanushuk River, and east end Rooftop Ridge anticline; Webber, 1947.	20–1,570 ft of 1,600-ft intermittent exposure	26	8	Poor	vr-c/vr	2			5Q		8Q		4		1	
On Nanushuk River, starting on axis of Shalewall anticline and continuing 2½ miles north; Webber, 1947.	40–460 ft below top of 1,500-ft exposure.	8	7	Good	vr-ab/vr	1		7			3	1				
	510–1,280 ft below top of same exposure.	78	25	Poor	vr-ab/vr	2		5			2Q	2Q			14	1
	1,290–1,390 ft below top of same exposure.	11	9	do	vr-r/vr	3		1Q	6		2Q	4		2		
	1400 ft below top to base of 1,500-ft exposure.	12	11	Good	vr-vab/vr-r	10			10			10				2
Tuluga River, 6 miles south of Ayiyak Mesa syncline; Bickel, 1952.	Approximately 1,000 ft above base.	1	1	Poor	vr-c/vr	1			1Q					1		
One mile east of Tuluga River, and 1½ miles south of axis, Ayiyak Mesa syncline; Detterman, 1952.	Uppermost 10 ft	2	2	Good	vr-c/vr	1		2	2		2		1			
Area near Chandler River, between Ayiyak Mesa syncline and Hawk anticline; Detterman, 1948.	Lower beds	2	2	Poor	2 specimens	1Q		1								
Chandler River, Big Bend anticline; Detterman, 1948.	100–200 ft above base	1	0													
Chandler River, Big Bend anticline; Detterman, 1948 and 1952.	None	2	2	Fair	vr-ab/vr-r			2	1Q							1
Trouble Creek (tributary of Chandler River) at Big Bend anticline; Gryc, 1945 and Detterman, 1948.	110 ft of shale	15	5	Poor	vr/vr	1		1Q			2Q					1
Chandler River at Schrader anticline; Gryc, 1945 and Detterman, 1948.	Middle to upper beds	9	2	do	r-c/vr			2				1Q				
Chandler River, near crest of Schrader anticline; Taylor, 1945.	None	4	0													
Along Ayiyak River, west of Hawk anticline; Bickel and Detterman, 1952.	20–70 and 450–500 ft above section on tributary of Ayiyak River; fauna near top.	7	3	Poor	vr-r/vr-r	1		3	1		1Q					1
On axis west end Ayiyak Mesa syncline 2 miles north of Ayiyak River, and approximately 6 miles west-southwest of mouth of Wolverine Creek; Bickel, 1952.	None	2	2	Good	vr-ab/vr	2		2	2			1				
Tributary of Ayiyak River, 6 miles above Wolverine Creek; Detterman, 1952.	360-ft section; fauna 210–340 ft below top.	9	4	do	vr-vab/vr	3		1	2		1Q	2				
East side of Seabee Creek, 1 mile northeast and 1¼ miles east-northeast of Umiat test well 1; Stefansson, 1946.	800–1,000 ft below top	2	0													
Fossil Creek at Outpost Mountain syncline; Bickel, 1952.	120 ft of beds	3	3	Poor	vr-c/vr	4			1Q			1Q				
Between Fossil Mountain anticline and Outpost Mountain syncline along a tributary of Fossil Creek; approximate long 152°40'; Detterman, 1947.	20–320 ft above base of 360-ft exposure.	11	8	do	vr-ab/vr	4			10		9	4	4			
Fossil Creek approximately 4–4½ miles south of Colville River; Gryc, 1946.	40 and 180 ft above base of 260-ft intermittent exposure.	2	2	do	vr/vr	1										
South side Colville River, between west ends of Little Twist anticline and Ninuluk Creek syncline; Warner, 1945.	Lower beds	6	4	Fair	vr-vab/vr-r	2		2Q			3	3				
North side Colville River, approximately 4 miles upstream from mouth of Prince Creek; Kirschner, Warner, 1945; and Detterman, 1947.	10–140 ft above base of 180-ft exposure and 10–30 ft below top of another 180-ft exposure.	8	6	Poor	vr-ab/vr	1	1Q		2		2	2	1			
Ninuluk Creek, 2 miles east of southwest end of Ninuluk Bluff; Detterman, 1947.	210 ft above base	1	1	Good	r-ab/vr	1			1	1		1				
South side Colville River, southwest end Ninuluk Bluff, approximately 32 miles airline southwest of Umiat; Kirschner, 1945 and Detterman, 1947.	20–360 ft above base	15	13	do	vr-ab/vr-r		1		12	10		9	7			2
South side Colville River, southwest end Ninuluk Bluff, approximately 32 miles airline southwest of Umiat; Detterman, 1947.	Near base of formation	1	1	Good	vr-ab/r		1		1	1						
Creek west of Ninuluk Creek; Lathram, 1946	None	1	1	Poor	vr/vr							1Q				
Weasel Creek, north flank of Bing syncline; Ray, 1946.	Approximately 250 ft above base(?).	1	0													
Near junction of Anuk Creek, and Maybe Creek, south of Lupine anticline; Ray, 1946 and Kover, 1949.	Approximately 300–350 ft below top(?).	2	1	Poor	1 specimen	1										

TABLE 9.—*Data for 274 outcrop microfossil samples from the Shale Wall Member of the Seabee Formation*—Continued

Area, collector, and date	Stratigraphic data	Number of samples: Total	Number of samples: Fossiliferous	Quality of specimens	Ratio specimens/species	*Saccammina lathrami*	*Haplophragmoides bonanzaense*	*Haplophragmoides rota*	*Textularia* sp. and *T. rollaensis*	*Trochammina diagonis*	*Trochammina ribstonensis*	*Trochammina whittingtoni*	*Verneuilinoides fischeri*	*Praebulimina seabeensis*	"*Zonodiscus*" sp. A	"*Zonodiscus*" sp. C
On Anuk Creek, south flank of Titaluk anticline; Ray, 1946 and Kover, 1949.	Lower part	2	1	Fair	c/vr											1
East end Wolf Creek anticline, south of axis, headwaters of Wolf Creek; Ray, 1946.	110–490 ft above base	3	3	do	vr-vab/vr-r	3		2			2Q					1
North flank, east end Wolf Creek anticline, 1 mile east of Wolf Creek test well 2; Fischer, 1946.	100–450 ft below top of 600-ft intermittent exposure.	5	3	do	vr-ab/vr-r	1		3	2		2			1		
Titaluk anticline, east of Baby Creek, Brosgé and Kover, 1949.	Approximately 170–230 ft below top.	3	1	Poor	1 specimen							1				
Maybe Creek, approximately 3½ miles airline west of Banshee Creek; Brosgé, 1952.	Approximately 400–450 ft below top.	11	0													
Knifeblade Ridge area, on September Creek, (tributary of Maybe Creek) at approximate lat 69°11'; Whittington, 1947.	65-ft section in 800-ft exposure.	4	2	Fair	vr-c/vr	1		2	1		1	1				

TABLE 10.—*Data for 41 outcrop microfossil samples from the Ayiyak Member of the Seabee Formation*

Number of samples: Total, 41; fossiliferous, 30.

$\frac{\text{Specimens}}{\text{Species}}$: Indicates ratio of abundance of all specimens to all species in fossiliferous samples.

[Q, questionable identification, vr, very rare; r, rare; c, common (12–25); ab, abundant (26–50); vab, very abundant (over 50)]

Area, collector, and date	Stratigraphic data	Number of samples: Total	Number of samples: Fossiliferous	Quality of specimens	Ratio specimens/species	*Saccammina lathrami*	*Haplophragmoides rota*	*Dorothia* sp.	*Pseudoclavulina hastata*	*Arenobulimina torula*	*Trochammina ribstonensis*	"*Zonodiscus*" sp. C
Nanushuk River, north flank May Creek syncline; Webber, 1947.	None	2	2	Fair	vr-vab/vr	2	2		2	2	1	
Nanushuk River, 3 miles above May Creek; Webber, 1947.	40–200 ft above base of 600-ft intermittent exposure.	4	3	do	vr-vab/vr	1	3	1	1		2	
Nanushuk River, south flank of unnamed syncline, approximately 3 miles north of Shalewall anticline; Webber, 1947.	110 ft section	5	5	do	vr-vab/vr	2	5		4		5	
Schrader Bluff on the Anaktuvuk River; Webber, 1947	Upper 95 ft	5	5	do	vr-vab/vr-r	1	5		5	3	1Q	1
East of Tuluga River and south of Ayiyak Mesa syncline; Detterman, 1952.	230 ft section	10	6	do	vr-ab/vr-r	3	6	6	5		3	
Ayiyak River west of Hawk anticline; Bickel, 1952	Basal 200 ft	3	2	Good	vr-ab/vr-r	1	2	1	2	1	1Q	
Axis of Niakogon syncline at Chandler River; Detterman, 1952.	50–100 ft above base	1	0									
Trouble Creek (tributary of Chandler River) and Big Bend anticline; Gryc, 1945, and Detterman, 1948.	120–160 ft above base of 200-ft exposure.	7	4	Poor	vr-r/vr	1Q	1Q					
Outpost Mountain syncline, east of Chandler River; Bickel, 1952.	Basal bed	1	0									
East side Seabee Creek, 1 mile northeast and 1½ miles east-northeast of Umiat test well 1; Stefansson, 1946.	420 ft below top	1	1	Fair	r-ab/vr	1	1	1				
Headwaters of Wolf Creek, east end of Billy syncline; Ray, 1946.	Near top	2	2	Good	r-c/vr		1		1			1

In each of these tests, it is interbedded with the Prince Creek Formation.

All three members of the Schrader Bluff Formation were penetrated in Fish Creek test well 1; volcanic glass shards were found in cores and cuttings in the lower part of the Sentinel Hill Member and in the upper part of the Barrow Trail Member, and Radiolaria were abundant in the Barrow Trial Member. (See p. 176–180.) Radiolaria were also found in samples from the Schrader Bluff Formation in North Simpson test well 1, but very few were found in the outcrop samples collected by Survey parties.

One major foraminiferal zone characterizes the Schrader Bluff Formation, but minor faunal subzones are present. Pertinent microfossil data on outcrop samples are shown in tables 11–13, where it can be seen that the higher percentage of fossiliferous samples are from the Sentinel Hill Member, although more species were found in the Barrow Trail Member.

Specimens of *Inoceramus* are the most diagnostic of the megafossils found in the Schrader Bluff Formation; these specimens have been studied recently by Jones and Gryc (1960). The work of these authors, as well as that of Tappan (1951b) and Imlay and Reeside (1954, p. 242), indicates that these beds are of Senonian age; strata of Coniacian age may be missing, and an unconformity may separate the Schrader Bluff and Seabee Formations (Jones and Gryc, 1960, p. 153).

KUKPOWRUK FORMATION (ALBIAN) AND CORWIN FORMATION (ALBIAN AND CENOMANIAN?)

In the western part of the Petroleum Reserve from the general area of the Utukok River west to Corwin Bluff on the coast, the Nanushuk Group has been divided into two formations by Sable (1956); these two formations were further described by Chapman and Sable (1960). The older is the Kukpowruk Formation, a marine sequence of interbedded shale, siltstone, and minor amounts of claystone, conglomerate, and carbonaceous shale. The type locality of this formation is along the Kukpowruk River, about 34 miles above its mouth. The upper 1,765 feet of the formation is well exposed in the river banks, and the lower 1,100 feet is poorly exposed in adjacent hillsides (Sable, 1956, p. 2637). On the upper Kukpowruk River the formation is about 5,000 feet thick, but it thins eastward and northward to about 2,000 feet along the lower Utukok River (Sable, 1956, p. 2637). Eastward from the type locality the Kukpowruk Formation has been recognized and mapped along Carbon Creek and the Carbon Creek anticline, the Awuna anticline, the Awuna River and its tributaries and along the Kigalik River on the south flank of the Kigalik anticline to about long 156° W.

TABLE 11.—*Data for 40 outcrop microfossil samples from the Rogers Creek Member of the Schrader Bluff Formation*

Number of samples: Total, 40; fossiliferous, 29.

$\frac{\text{Specimens}}{\text{Species}}$: Indicates ratio of abundance of all specimens to all species in fossiliferous samples.

[Q, indicates one or more questionable identifications in some samples; vr, very rare; r, rare; c, common (12–25); ab, abundant (26–50); vab, very abundant (over 50)]

Area, collector, and date	Stratigraphic data	Number of samples: Total	Number of samples: Fossiliferous	Quality of specimens	Ratio specimens/species	*Saccammina lathrami*	*Haplophragmoides rota*	*Flabellammina chapmani*	*Spiroplectammina webberi*	*Verneuilinoides fischeri*	*Textularia rollaensis*	*Trochammina ribstonensis*	*Anomalinoides talaria*	*Quinqueloculina sphaera*
Nanushuk River at unnamed syncline; 3 miles north of Shale Wall anticline; Webber, 1947.	Lower 80 ft	4	3	Poor	vr-ab/vr					1		1		
Anaktuvuk River at Schrader Bluff; Webber, 1947	Scattered through 680-ft section	5	4	Fair	vr-ab/vr-r	2	2	1		1		1Q		
	Interbedded with Tuluvak Tongue (335 ft of beds) of the Prince Creek Formation.	6	4	do	vr-vab/vr	3	4			1		3Q		
Near Chandler River, between Ayiyak Mesa syncline and Hawk anticline; Detterman, 1948.	230 ft above base	1	1	Poor	r-c/vr	1				1				
Chandler River area, Schrader anticline to Umiat; Gryc, 1945 and Detterman, 1948.	None	6	4	do	vr-c/vr	2	1Q			2				
	Basal 140 ft	5	4	Fair	vr-vab/vr-r	2	3		3	2Q		1Q		
On Prince Creek, approximate long 152°43′; Detterman, 1947.	Lower 100(?) ft	5	4	Poor	vr-ab/vr-r	1	1			3		1		1
On Prince Creek, long 153° between lat 69°28′ and 69°29′; Detterman, 1947.	1,000 ft section	6	3	do	vr-c/vr					2		1Q		
Headwaters of Wolf Creek between Wolf Creek anticline and Prince Creek syncline; Fischer, 1946 and Stefansson, 1947.	320 and 550 ft above base	2	2	Good	vr-vab/r	2	2			2	2	2	1	

A total of 281 outcrop samples from the Kukpowruk Formation was examined for microfossils (see table 1), but 21 of these are not given in table 8 because of insufficient locality data. About 60 percent of these samples (55 percent of the fossiliferous samples) are from the area east of the Utukok-Corwin region. Pertinent data on most samples are given in table 14, which shows 18 of the more characteristic Foraminifera. The assemblage is part of the *Verneuilinoides borealis* faunal zone of middle to late Albian age. The stratigraphic data, however, are insufficient for most of these samples to allow precise correlation with other Albian formations of the Nanushuk Group.

The best stratigraphic data available concern 57 samples collected by C. L. Whittington from a 2,530-foot section along Section Creek and the south flank of the Awuna anticline (see third item in table 14) and 30 samples collected by R. L. Bickel from a 1,020-foot section of the lower part of the formation along Carbon Creek at the north end of Carbon Creek anticline (see 15th item in table 14). The Whittington samples, which were channeled through 40- to 50-foot intervals, shows a concentration of Foraminifera at 550–660 feet, 1,270–1,620 feet, and 2,160–2,360 feet above the base of the section. The Bickel samples, taken at intervals of 20 to 30 feet, show a concentration of Foraminifera from 290–975 feet above the base of that section.

TABLE 12.—*Data for 101 outcrop microfossil samples from the Barrow Trail Member of the Schrader Bluff Formation*

Number of samples: Total, 101; fossiliferous, 51.

$\frac{\text{Specimens}}{\text{Species}}$: Indicates ratio of abundance of all specimens to all species in fossiliferous samples.

[Q, indicates one or more questionable identifications in some samples; vr, very rare; r, rare; c, common (12–25); ab, abundant (26–50); vab, very abundant (over 50)]

Area collector, and date	Stratigraphic data	Number of samples: Total	Number of samples: Fossiliferous	Quality of specimens	Ratio specimens/species	*Saccammina lathrami*	*Haplophragmoides rota*	*Textularia rollaensis*	*Dorothia smokyensis?*	*Verneuilinoides fischeri*	*Trochammina diagonis*	*Trochammina ribstonensis*	*Trochammina whittingtoni*	*Quinqueloculina sphaera*	*Nonionella taylorensis*	*Praebulimina carseyae*	*Praebulimina venusae*	*Lacostina gouskovi*	*Gavelinella tumida*	*Anomalinoides talaria*	*Archicorys* sp.	*Dictyomitra multicostata*
Toolik River, lat 69°25′ N., south of White Hills; Gryc, 1946.	Upper part	2	1	Good	vr-ab/c	1	1		1	1Q					1		1	1		1Q		
South end Twin Bluffs on Nanushuk River; Webber, 1947.	Both lower and upper beds.	6	0																			
Schrader Bluff on the Anaktuvuk River; Webber, 1947.	Near base	1	1	Fair	vr-c/vr		1		1	1		1										
Chandler River, north flank Schrader anticline; Taylor, 1945.	None	4	2	do	vr/vr-r	1	2									1			1			
Chandler River at Tuluvak Bluffs, north flank Schrader anticline; Gryc, 1945 and Detterman, 1948.	Approximately 710–1,100 ft above base.	23	21	Good	vr-ab/vr-r	7	16		2	6	4		1	3	2	9Q	4		8	7	1	1
	Lower beds and 500–700 ft above base.	9	2	Poor	vr/vr															2		
Chandler River at Tuluvak Bluffs, north flank Schrader anticline; Detterman, 1948.	570–710 ft above base	7	5	Fair	vr/vr	1	3			4									1Q	2		
	Basal beds	7	5	Poor	vr-r/vr		1Q					3Q	1							1	2	1
	140–260 ft above base	5	2	Fair	vr-ab/vr-r	1	1	1	1													
North side Colville River 2 miles northeast of Umiat Mountain; Stefansson, 1946.	550 ft above base	1	1	Good	r-ab/vr	1	1		1	1			1									
Tributary of Seabee Creek, north flank Umiat anticline, 3 miles north-northeast of Umiat test well 1; Whittington, 1946.	At base	1	1	Fair	vr/vr	1	1															
Colville River at the mouth of Fossil Creek; Kirschner, 1945 and Detterman, 1947.	160 ft of beds	6	1	Poor	vr/vr																	
Prince Creek 2–4½ miles above junction with Colville River; Detterman, 1947.	660–680 ft above base	3	3	Good	vr-c/vr	2	3							1	1							1Q
	300–330 ft above base	2	2	do	vr-vab/r		1Q					1										2
	30–260 ft section	4	1	Poor	vr/vr																	
North fork of Prince Creek, Prince Creek syncline; Kreidler, 1945.	None	15	2	do	vr-c/vr	1		1														
Headwaters of Wolf Creek, south flank Prince Creek syncline; Fischer, 1946.	Near top	5	1	Fair	vr-c/vr		1															

TABLE 13.—*Data for 69 outcrop microfossil samples from the Sentinel Hill Member of the Schrader Bluff Formation*

Number of samples: Total, 69; fossiliferous, 55.

$\frac{\text{Specimens}}{\text{Species}}$: Indicates ratio of abundance of all specimens to all species in fossiliferous samples.

[Q, indicates one or more questionable identifications in some samples; vr, very rare; r, rare; c, common (12–25); ab, abundant (26–50); vab, very abundant (over 50)]

Area, collector, and date	Stratigraphic data	Number of samples		Quality of specimens	Ratio specimens/species	Number of samples in which characteristic species occur															
		Total	Fossiliferous			*Saccammina lathrami*	*Haplophragmoides rota*	*Dorothia smokyensis?*	*Verneuilinoides fisheri*	*Spiroplectammina mordenensis*	*Textularia rollaensis*	*Trochammina ribstonensis*	*Trochammina stefanssoni*	*Trochammina whittingtoni*	*Quinqueloculina sphaera*	*Nonionella taylorensis*	*Praebulimina carseyae*	*Neobulimina canadensis*	*Gavelinella ammonoides*	*Eoeponidella strombodes*	*Anomalinoides pinguis*
Sagavanirktok River, northern foothills; Gryc. 1951.	None	2	1	Good	vr-c/vr		1		1			1									
Toolik River, south of Kuparuk anticline, between lat 69°16′ and 69°18′; Fischer, 1951.	Approximately 225 ft of beds.	6	5	do	vr-c/r-c	2	5		5		3			1	3	4	2	2	4		
North end Twin Bluffs, Nanushuk River; Webber, 1947.	None	1	0																		
Nanushuk River, 5 miles air line above mouth; Webber, 1947.	do	2	0																		
Chandler River at Tuluvak Bluffs; Detterman, 1948.	At base	2	2	Poor	vr-ab/vr		2	2Q	2Q	4			1								
Colville River, 7 miles south of Sentinel Hill core test 1; Stefansson and Thurrell, 1947.	910 ft and 1,130 ft above base.	2	1		abundant spores																
Colville River, 9 miles south-southwest Sentinel Hill core test 1; Stefansson, 1947.	760 ft and 820 ft above base.	2	2	Good	vr-vab/r	1	2								2				2		
Colville River, 15 miles by river south, 30° W. of Sentinel Hill core test 1; Stefansson, 1947.	230 ft and 330 ft above base.	2	2	Fair	vr-ab/vr-r	1	2	1	1			2					1	1Q	1		
Colville River, 16 miles by river south, 30° W. of Sentinel Hill core test 1; Stefansson, 1947	10–110 ft above base	4	4	Good	vr-vab/r-c	4	2	4	2	2	1	3					1				
North side Colville River, 8 miles air line, northeast of Umiat; Gryc, 1949.	(Sta. 65) 160-ft exposure of lower beds.	8	8	Fair	vr-ab/vr-c	2	7	4	1Q									1			2
Colville River, 1 mile downstream from previous locality; Gryc, 1949.	(Sta. 66) 123-ft section above station 65.	4	1	do	vr-r/vr	1	1														
Colville River, 2 miles below (north of) mouth of Chandler River; Gryc, 1949.	(Sta. 69) 130-ft section of upper beds.	4	2	Poor	vr-r/vr															2	
Colville River, 4 miles below mouth of Fossil Creek; Detterman, 1947.	None	7	6	Fair	vr-ab/r-c	4	3	4	2			5						1			
Anaktuvuk River, Gubik anticline; Fischer, 1950.	Approximately 220 ft of section.	6	5	do	vr-vab/vr	1	2	1	1												
South flank Prince Creek syncline, tributary of Prince Creek, approximately 5–6 miles above Prince Creek and Colville River junction; Detterman, 1947.	130 ft of lower beds	6	6	do	vr-c/vr-r	3	4		1			1	1		1	1	1	2	3	1Q	
On Prince Creek, 1½–3½ miles above junction with Colville River; Detterman, 1947.	240 ft of lower beds (below previous section).	11	10	do	vr-ab/r-c	2	9	6	5			5		1	2	1	5	5	5	3	1Q

TABLE 14.—*Data for 260 outcrop microfossil samples from the Kukpowruk Formation*

Number of samples: Total, 260; fossiliferous, 160.

$\frac{\text{Specimens}}{\text{Species}}$: Indicates ratio of abundance of all specimens to all species in fossiliferous samples.

[Q, indicates one or more questionable identifications in some samples; vr, very rare; r, rare; c, common (12-25); ab, abundant (26-50); vab, very abundant (over 50)]

Area, collector, and date	Stratigraphic data	Number of samples: Total	Number of samples: Fossiliferous	Quality of specimens	Ratio specimens/species	*Bathysiphon brosgei*	*Ammodiscus rotalarius*	*Haplophragmoides topagorukensis*	*Ammobaculites wenonahae*	*Ammobaculites fragmentarius*	*Verneuilinoides borealis*	"*Tritaxia*" *manitobensis*	*Miliammina awunensis*	*Miliammina manitobensis*	*Psamminopelta bowsheri*	*Trochammina ribstonensis rutherfordi*	*Lenticulina macrodisca*	*Marginulina planiuscula*	*Globulina lacrima canadensis*	*Eurycheilostoma grandstandensis*	*Gavelinella stictata*	*Conorboides umiatensis*	*Pallaimorphina ruckerae*
East of Section Creek, near east end of south flank of Awuna anticline; Whittington, 1947.	1,730–1,830 ft below top of 2,250 ft intermittent exposure.	2	1	Poor	vr-r/vr		1	1															
East of Section Creek on north flank of Awuna anticline, a distance of 1½ miles near east end; Troyer, 1947.	80–1,730 ft below top of 2,250-ft intermittent exposure.	34	8	do	vr-c/vr		2				4				4	1							
Exposures along east side of Section Creek valley, near long 156°, beginning about lat 69°7′30″ and continuing 1½ miles north on south flank Awuna anticline to lat 69°8′50″; Whittington, 1947.	2,530-ft section	57	29	Good	vr-ab/vr-r	1	6	16		4	18	3	8		8	8							
Near long 155°51′ on upthrow side of fault, south of Kigalik anticline; Whittington, 1947.	200-ft intermittent exposure.	2	1	Poor	vr/vr						1		1										
Kigalik River, Kigalik fault, south flank of Kigalik anticline, near long 156°21′; Whittington, 1947.	None	1	1	do	vr/vr			1			1										1		
Awuna River, near Birthday Creek junction, south flank Awuna anticline; Troyer, 1947.	840–1,180 ft below top 2,400-ft intermittent exposure.	6	4	Fair	vr-vab/vr-r	1	1	2		1	3	2			1	2							
Bend of Awuna River, approximately 6 miles east of Quartzite Creek; Troyer, 1947.	None	1	1	do	vr-vab/r					1	1				1	1							
On Quartzite Creek, ½ mile air line above junction with Awuna River; Whittington, 1947.	do	1	1	do	vr-c/vr			1			1		1			1							
On Quartzite Creek, 1 mile air line above junction with Awuna River; Whittington, 1947.	do	1	0																				
South flank Awuna anticline on Quartzite Creek approximately 1¾ miles air line north of junction with Awuna River; Whittington, 1947.	do	1	1	Good	vr-vab/r			1		1	1			1		1							
Discovery Creek, south limb of Awuna anticline; Troyer, 1947.	320-ft section	5	4	Fair	vr-vab/vr-c	1		3		1	4	1			2	2					1		
Discovery Creek, north limb of Awuna anticline; Troyer, 1947.	240-ft section	2	2	do	vr-ab/vr-r		1	2			1				2	1							
Headwaters of Awuna River; Keller, 1949.	None	2	2	Poor	vr-c/vr						1												
Headwaters of Carbon Creek, east end of Carbon Creek anticline; long. 159°; Keller, 1949.	do	2	2	do	vr-c/vr			2			1	1											
Carbon Creek, north flank, east end Carbon Creek anticline; Bickel, 1953.	20–170 ft above base 220-ft exposure.	7	5	do	vr-c/vr			5			1	1	2 Q										1
	45 ft to base of 1,020-ft exposure in lower part of formation.	30	24	Fair	vr-c/vr-c	6	11	23	8 Q		18	3	1	1 Q	1 Q		2	6	5	5	3	2	14
Headwaters of Carbon Creek south flank Carbon Creek, anticline to north flank Lookout Ridge syncline; Keller, 1949.	380–1,750 ft above base of 1,820-ft intermittent exposure.	6	3	Poor	vr-c/vr			2				1 Q	1										
South side Utokok River near junction with Disappointment Creek; Barksdale and Thompson, 1947.	400–1,680 ft above base of 2,000-ft exposure.	5	5	Fair	vr-vab/vr-r	2	3	3			2							1					1
Utokok River, approximately 2 miles above junction with Elusive Creek; Barksdale and Thompson 1947.	1,800 ft intermittent exposure.	5	4	do	vr-ab/vr-r		1	3			2						1	1	1		2	2	1 Q
North side Utokok River, south flank Meat Mountain syncline; Barksdale, 1947.	20 ft below top of 1,900 ft exposure.	1	1	do	r-vab/r						1	1	1										
	1,450 ft below top (barren) and at base of 1,900-ft exposure.	2	1	Poor	1 specimen		1																
West side Utokok River south flank of Disappointment anticline; Thompson, 1947.	750–800 ft above base of 1,650-ft exposure.	5	4	Fair	vr-c/vr			4			3		2									1	
Utokok River, between Folsom Point syncline and Disappointment anticline; Barksdale and Thompson, 1947.	2,000-ft section from intermittent exposures.	13	10	do	vr-vab/vr-r			4	1		4	3	3	1		3	1				1	1	

TABLE 14.—*Data for 260 outcrop microfossil samples from the Kukpowruk Formation*—Continued

Area, collector, and date	Stratigraphic data	Number of samples: Total	Number of samples: Fossiliferous	Quality of specimens	Ratio specimens/species	Number of samples in which characteristic species occur: *Bathysiphon brosgei*	*Ammodiscus rotalarius*	*Haplophragmoides topagorukensis*	*Ammobaculites wenonahae*	*Ammobaculites fragmentarius*	*Verneuilinoides borealis*	"*Tritaxia*" *manitobensis*	*Miliammina awunensis*	*Miliammina manitobensis*	*Psamminopella bowsheri*	*Trochammina ribstonensis rutherfordi*	*Lenticulina macrodisca*	*Marginulina planiuscula*	*Globulina lacrima canadensis*	*Eurycheilostoma grandstandensis*	*Gavelinell. stictata*	*Conorboides umiatensis*	*Pallaimorphina ruckerae*
West side Utokok River, between Archimedes Ridge anticline and Howard syncline; Thompson, 1947.	60 and 260 ft below top of 1,000-ft intermittent exposure.	2	2	Poor	vr-vab/vr			2		2		2	1										
North side Utokok River, east end of Howard syncline; Barksdale, 1947.	Base to 200 ft below top of 640-ft exposure.	4	3	Fair	vr-ab/vr	1		2				1	1							1		1	
Kokolik River approximately 3 miles upstream (south) from axis of Tupikchak syncline; Sable, 1949.	At base of 2,750-ft section.	1	1	Poor	vr-c/vr			1				1											
Kokolik River, approximately 1½ miles upstream (south) from axis of Tupikchak syncline; Chapman, 1949.	250 ft above base of 1,550-ft section.	1	1	do	vr-c/vr	1		1				1											
Kokolik River, between Meat Mountain syncline and small anticline to south; Chapman and Sable, 1949.	900–950 ft above base of 2,700 ft exposure.	2	1	do	5 specimens			1															
Kokolik River, between Blizzard anticline and Meat Mountain syncline; Chapman and Sable, 1949.	420, 500, and 2,200 ft above base of 2,650-ft section.	3	3	do	vr-c/vr-r			1		1Q	1Q	2	1										
Kokolik River, 3 miles south of axis of Kokolik Warp syncline; Chapman, 1949.	630–730 ft above base of 3,900-ft section.	3	2	do	vr/vr						2												
Kokolik River, approximately 1 mile north of axis of Kokolik Warp syncline; Sable, 1949.	At 1,950 ft above base of 4,100-ft section.	1	1	do	6 specimens			1															
Kokolik River, at ½ mile south of axis of Kokolik Warp syncline; Chapman, 1949.	550 ft below top of 3,900-ft section.	1	0																				
Kukpowruk River, approximately 7 miles north of axis of Howard syncline; Sable, 1949.	650 ft below top of 1,000-ft exposure.	1	1	Poor	1 specimen.									1									
Kokolik River, approximately 5 miles upstream from axis of Howard syncline; Sable, 1949.	None	1	1	do	vr/vr	1		1															
Tributary to Kokolik River, west end of Deadfall syncline; Chapman, 1949.	650 ft above base of 2,750–3,050 ft.	1	1	do	1 specimen											1Q							
North flank Poko Mountain syncline; Chapman, 1949.	100 ft below top of 1,700-ft exposure.	1	1	do	vr-c/vr			1						1									
North flank Poko Mountain syncline; Sable, 1949.	Near base of same section.	3	3	do	vr-ab/vr			3		1Q	1	2											
Area adjacent to Kukpowruk River and Raven Basin syncline; Sable, 1949.	Lower beds	3	2	do	vr/vr	1		1					1			1Q							
Kukpowruk River, 3 miles downstream (north) from axis of Tupikchak syncline; Chapman, 1949.	1,840 ft and 2,400 ft above base of 4,450-ft section.	2	1	do	vr-c/vr						1	1	1										
Kukpowruk River, approximately 3 miles upstream (south) from axis of Tupikchak syncline; Chapman and Sable, 1949.	At 500, 2,250, and 3,050 ft above base of 3,550-ft section.	4	2	do	vr/vr								1										
Kukpowruk River, north flank Blizzard anticline; Chapman and Sable, 1949.	Base, 250 ft, and 2,600 ft above base of 4,050-ft section.	3	1	do	1 specimen						1												
Kukpowruk River, south flank of anticline, 3 miles north of east end Kukpowruk syncline; Chapman and Sable, 1949.	450–1,150 ft below top of 4,050-ft section.	7	5	do	vr-c/vr	1		3		1Q		2	1										
Kukpowruk River, from point 2½ miles south of west end of Deadfall syncline to mouth of Deadfall Creek; Chapman and Sable, 1949.	100–1,370 ft below top of 3,500-ft section.	11	7	do	vr-c/vr	1		5		1Q	1	2	1										
Kukpowruk River, approximately ½ mile below mouth of Deadfall Creek, south flank Archimedes Ridge anticline; Sable, 1949.	75 ft above base of 3,500-ft section.	2	1	do	vr-c/vr			1															
Kukpowruk River, from point approximately 2 miles below mouth of Deadfall Creek, north flank Archimedes Ridge anticline, to 4 miles southwest of axis of Howard syncline; Chapman and Sable, 1949.	Top to 1,540 ft below top of 1,600-ft exposure.	8	4	do	vr-ab/vr-r	1		2	2Q		2	2	1Q									1	
Kukpowruk River, approximately 5 miles down stream from axis of Howard syncline; Chapman, 1949.	530 and 800 ft above base of 3,450-ft section.	2	0																				
Arctic coast between Cape Lisburne and Corwin Bluff, approximately 10 miles west of Corwin Creek; Thompson, 1947.	None	2	2	Good	vr-vab/vr-r	1		2			2	1		1		1							

The Kukpowruk Formation was recognized in the subsurface only in Kaolak test well 1 in a section which I consider to be Corwin and Kukpowruk Formations undifferentiated (Bergquist, 1958e, p. 374). Collins (1958c, p. 355), however, referred the same section to the Topagoruk Formation.

Gradational upward from the Kukpowruk Formation is the Corwin Formation, described by Sable (1956, p. 2641) as a dominantly nonmarine sequence of shale, claystone, siltstone, sandstone, conglomerate, coaly shale, coal, ironstone, and a minor amount of bentonite. The type section is in bluffs bordering the Chukchi Sea along 4.9 miles of coastline between Thetis and Risky Creeks (approx. long 164°58′ and 165°22′ W.). The section has a measured thickness of 15,494 feet, and seven informally designated members were described (Chapman and Sable, 1960, p. 105–121). Northeastward from this area the formation thins to about 4,500 feet on the Utukok River. The Corwin Formation has been recognized about as far east as long 156° W., having been mapped by C. L. Whittington and others where it crops out in structures such as the Cache Ridge, Kigalik, and Shultz anticlines, Price and Awuna synclines and along the Kigalik River and Discovery and Section Creeks. Structures referred to in this report are shown on Oil and Gas Map OM–126 (Payne and others, 1951).

Plant remains are common in the westerly exposures of the formation, whereas megafossils are very rare, and only a few arenaceous Foraminifera and charophytes were found. Of a total of 323 samples collected from the Corwin Formation for microfossil examination (table 1), only 293 are given in table 15. Thirty samples lacked sufficient locality data to be included. About two-thirds of the samples are from areas of the Utukok-Corwin Rivers region, and these samples yielded most of the small fauna found. A general poor quality of specimens characterizes the small fauna.

Foraminifera found in the samples indicate that the fauna is a part of the *Verneuilinoides borealis* fauna of Albian age. (See p. 130–140.) Microfossils occurred in about 32 percent of the samples from northwestern Alaska, but in the area of the Awuna syncline and the Kigalik anticline, 80–95 miles east of the eastern edge of the Utukok-Corwin region, a higher percentage of the samples were fossiliferous; the arenaceous Foraminifera were more numerous, but in all the samples the specimens were in general poorly preserved.

TABLE 15.—*Data for 293 outcrop microfossil samples from the Corwin Formation*

Number of samples: Total, 293; fossiliferous, 103.

$\frac{\text{Specimens}}{\text{Species}}$: Indicates ratio of abundance of all specimens to all species in fossiliferous samples.

[Q, questionable identification; vr, very rare; r, rare; c, common (12–25); ab, abundant (26–50); vab, very abundant (over 50)]

Area, collector, and date	Stratigraphic data	Number of samples: Total	Number of samples: Fossiliferous	Quality of specimens	Ratio specimens/species	*Ammodiscus rotalarius*	*Haplophragmoides topagorukensis*	*Ammobaculites fragmentarius*	*Verneuilinoides borealis*	*"Tritaxia" manitobensis*	*Miliammina awunensis*	*Miliammina manitobensis*	*Psamminopelta bowsheri*	*Trochammina ribstonensis rutherfordi*	Charophytes
North flank, east end Shultz anticline; Whittington, 1947.	None	8	4	Poor	vr/vr									2	2
Tributary of Kigalik River, north flank of Shultz anticline near long 155°21′; Whittington, 1947.	do	1	0												
West end Shultz anticline; Troyer, 1947	do	2	0												
Tributary north side Kigalik River, west end Bing syncline; Troyer, 1947.	28-ft section	2	0												
East of Section Creek, 2–4 miles north of axis near east end of Awuna anticline; Troyer, 1947.	50–2,270 ft above base of 2,500-ft intermittent exposure.	41	15	Poor	vr-ab/vr	1	1		13	1Q	1		7	3	
Kigalik River, approximate long 155°27′; Troyer, 1947.	55-ft section	2	0												
South flank, near east end of Sugar syncline, headwaters of tributary to Kigalik Creek, between long 155°40′ and 155°50′; Troyer, 1947.	30–80 ft below top of 2,500-ft intermittent exposure.	2	1	Poor	vr/vr		1								
Section south of Kigalik anticline, extending from a point near long 155°51′ approximately 1½ miles south of Kigalik River, and continuing south for 6 miles to south flank of unnamed syncline; Whittington, 1947.	210 ft to top of 2,400-ft intermittent exposure.	38	7	do	vr/vr		1Q	1	4						
Kigalik River, adjacent, to Kigalik anticline; near long 155°51′; Whittington, 1947.	None	5	0												
Axis of Cache Ridge anticline to a point 3 miles southeast, near long 155°51′; Whittington, 1947.	do	5	0												
Upper Kigalik River, between Price syncline and Kigalik anticline, long 155°52′ and 155°54′; Troyer, 1947.	40-ft section	6	0												
South side Kigalik fault, long 156°11′; Troyer, 1947	None	1	0												
South flank Sugar syncline, long 156°14′; Troyer, 1947	do	1	0												

TABLE 15.—*Data for 293 outcrop microfossil samples from the Corwin Formation*—Continued

Area, collector, and date	Stratigraphic data	Number of samples: Total	Number of samples: Fossiliferous	Quality of specimens	Ratio specimens/species	*Ammodiscus rotalarius*	*Haplophragmoides topagorukensis*	*Ammobaculites fragmentarius*	*Verneuilinoides borealis*	"*Tritaxia*" *manitobensis*	*Miliammina awunensis*	*Miliammina manitobensis*	*Psamminopelta bowsheri*	*Trochammina ribstonensis rutherfordi*	Charophytes
Exposures on east side Section Creek valley, beginning on north flank Awuna syncline near long 156°, 1½ miles southeast of junction Section Creek and Awuna River, continuing 2 miles northeast, then 2½ miles north-northwest; Whittington, 1947.	Base to top of 1,720 ft-intermittent exposure.	39	23	Poor	vr-vab/vr-r	2	10	2	13		5	1	3	4	1
South flank Awuna syncline from approximately 1½ miles south-southeast of junction of Section Creek and Awuna River, south 1¾ miles to water's edge in bend of river; Whittington, 1947.	10–1,370 ft below top of 1,400-ft intermittent exposure.	30	19	do	vr/vr-r		12		9	3	3		1Q		
On bend of Kigalik River, west of Quartzite Creek, Awuna syncline; Whittington, 1947.	None	3	1	do	vr/vr				1					1Q	
On bend of Kigalik River, west of previous locality; Whittington, 1947.	do	1	1	do	vr-r/vr		1		1						
Quartzite Creek, approximately 8 miles air line above junction with Awuna River, Whittington, 1947.	do	1	0												
Discovery Creek and axis of Awuna syncline, 1½–4 miles above junction with Awuna River; Troyer, 1947.	do	2	1	Poor	c/vr										1
Headwaters of Meade River, Meade River anticline near long. 158°; Keller, 1949.	do	7	0												
Utukok River, between long 160°40′; and 161°34′ Thompson, 1947.	50–1,600 ft below top of 8,000-ft intermittent exposure of Corwin and Kukpowruk Formations.	4	2	Poor	vr/vr		1		1						
Utukok River, approximately 2 miles above junction with Elusive Creek; Thompson, 1947.	1,620 ft below top of previous section.	1	1	do	c/vr										1
Utukok River, between Flosom Point syncline and Disappointment anticline; Thompson, 1947.	50–1,250 ft below top of 3,700-ft intermittent exposures of Corwin and Kukpowruk Formations.	7	6	do	vr-ab/vr		1Q		1	1	1			1Q	2
Kokolik River approximately 3 miles upstream (south) of axis of syncline No. 9; Chapman and Sable, 1949.	1,300–1,800 ft above base of 4,300-ft intermittent exposure.	3	1	do	1 specimen										1
Kokolik River on anticline approximately 5 miles north of syncline No. 9; Sable, 1949.	1,100 ft above base of 4,300-ft intermittent exposure.	1	0												
Kukpowruk River area; 2–6 miles south of axis of Raven Basin syncline (lat 68°51′30″); Chapman, 1949.	1,400 ft above base of 6-000-ft intermittent section.	2	1	Poor	vr/vr										1
Kukpowruk River (approximate lat 69°5′), west end Kukpowruk syncline; Chapman and Sable, 1949.	250–400 ft above base of 700-ft exposure.	4	2	do	vr-c/vr-r				1	1	2		1		
Kukpowruk River, west end (lat 69°14′) Deadfall syncline; Chapman, 1949.	300-380 ft above base of 550-ft exposure.	2	1	do	2 specimens					1					
Kukpowruk River, approximately 1½ miles south of axis of Howard syncline (lat 69°20′30″); Chapman, 1949.	350 ft below top of 2,300-ft intermittent exposure.	2	1	do	1 specimen										
Kukpowruk River and north flank of Howard syncline to a point 4 miles northwest of axis; Chapman and Sable, 1949.	2,550–4,900 ft above base of 5,300-ft intermittent exposure.	4	0												
Kukpowruk River, north flank of Syncline No. 7 (lat 69°30′) and a point approximately 6 miles south of axis; Chapman and Sable, 1949.	At 2,500 ft above base and at top of 8,400-ft intermittent exposure.	2	1	Poor	vr/vr						1				
Arctic coast, approximately 4 miles west of mouth of Pitmegea River; Thompson, 1947.	None	3	2	do	vr/vr							2			
Corwin Bluff section, 29 miles east of Cape Lisburne; Thompson, 1947.	50–1,000 ft above base of 4,400-ft section.	9	2	do	vr/vr		1								
	600–48 ft below top of 5,200-ft intermittent exposure.	6	3	do	vr/vr	1	1								
	50–2,100 ft below top of 2,900-ft intermittent exposure.	4	1	do	vr/vr										1
Corwin Bluff, 29 miles east of Cape Lisburne; in Sea Cliffs 0.6 mile west of Thetis Creek and west for 11 miles; Sable, 1953.	Type section; 15,500 ft samples taken 70–14,930 ft above base.	42	7	do	vr-ab/vr		1Q								6

IGNEK FORMATION (EARLY AND LATE CRETACEOUS)

Formations of the Colville Group have not been mapped east of the vicinity of the upper Sagavanirktok River, and formations of the Nanushuk Group have not been recognized east of the Ivishak River. Between the Ivishak and Canning Rivers, however, a sequence of Cretaceous rocks is intermittently exposed and unconformably overlies the Okpikruak and Kingak Formations; this sequence is believed to be equivalent to parts of the Nanushuk and Colville Groups (Keller and others, 1961, p. 203). Keller, Morris, and Detterman referred the sequence to the Ignek Formation and described the rocks as consisting of two parts: "a lower member of siltstone, shale, and dirty to relatively clean subgraywacke-type locally fossiliferous sandstone; and and upper member, predominantly of shale with lesser sandstone and siltstone beds, characterized by pyroclastics." The lower member is about 3,000 feet thick along the Ivishak River but thins eastward to about 1,000 feet on the Canning River; the upper member is at least 4,000 feet thick and has, in its lower part, beds of silicified tuff and bentonite.

The lower member of the Ignek Formation has been mapped in the area between the Ivishak River and Gilead Creek (Keller and others, 1961, pl. 21) and is considered as probably equivalent to part of the Nanushuk Group. The few samples available for microfossil examination from the lower member (table 1) yielded a very meager foraminiferal fauna which is apparently part of the *Verneuilinoides borealis* faunal zone as specimens of *V. borealis* were found in it. Furthermore, the presence of specimens of *Ammobaculites* suggests that the beds could be approximately equivalent to the Tuktu Formation to the west because *Ammobaculites* is characteristic of the fauna of the upper part of the Torok Formation and the Tuktu Formation. R. W. Imlay, who identified megafossils from the lower member, indicated that the fauna is similar to that in the Tuktu Formation but differs by containing brachiopods, the pelecypod *Nuculana*, and belemnites (Imlay, 1961, p. 16).

The upper member of the Ignek Formation is exposed along Shaviovik anticline adjacent to Shaviovik River and Fin Creek, between Juniper Creek and the Kavik River, and along the lower part of the Canning River (Keller and others, 1961, pl. 21). The beds of this member are overlain by the Sagavanirktok Formation (Tertiary); stratigraphically the upper member is considered by Keller, Morris, and Detterman to be equivalent to at least part of the Colville Group. Fossils are seemingly scarce in the member, but a concretion in beds of silicified tuff and bentonitic shale in the lower part contained the pen of a squid, which Reeside identified as identical to *Teusoteuthis longus* Logan from the upper part of the Niobrara Formation (Senonian) of Kansas (Imlay and Reeside, 1954, p. 234, chart 10d). A few radiolarian species (*Archicorys* sp., *Theocorys* sp., *Spongodiscus* sp. B, and *Dictyomitra multicostata* Zittell) were found in a shale sample collected by Keller from the same beds that contained the fossil squid. These species are part of the radiolarian fauna that occurs in the lower part of the Sentinel Hill Member and the upper part of the Barrow Trail Member of the Schrader Bluff Formation. (See p. 176–180.) A few Foraminifera found in outcrop samples are species that range throughout the Colville Group; however, specimens of *Arenobulimina torula* Tappan found in a few samples from the lower part of the member in the Sagavanirktok River area suggest beds of the lower part of the Colville Group.

A few species of Foraminifera were found in samples from the following seismic shotholes drilled by United Geophysical Co. across the Shaviovik anticline: line 1, shotholes 1, 3, and 6; line 4, shothole 6; line 6, shotholes 10–15; line 8, shotholes 1–4; line 9, shotholes 2–6 and 8–20; line 10, shotholes 2, 11, and 12; line 11, shothole 5 (location given on seismic profiles, pl. 24, Keller and others, 1961). One of the most frequent and common foraminifers found in these samples is *Haplophragmoides rota* Nauss, a species that occurs throughout the Colville Group. A species of frequent and in places common to abundant occurrence, however, is *Arenobulimina torula* Tappan, which occurs in the Colville Group only in the Ayiyak Member of the Seabee Formation or in beds of approximately the equivalent stratigraphic section. This suggests that the upper part of the Ignek section penetrated in the shotholes on the Shaviovik anticline might at least be equivalent to the lower part of the Colville Group.

TERTIARY ROCKS

SAGAVANIRKTOK FORMATION

The Sagavanirktok Formation was described by Gryc, Patton, and Payne, (1951, p. 167) as consisting "mainly of red-bed-type, poorly consolidated siltstone, sandstone, conglomerate, and lignite"; the type exposure is in Franklin Bluffs east of the Sagavanirktok River, although similar exposures occur in the White Hills region. Plant fossils from the beds in the lower part of the formation in the White Hills region were identified by R. W. Brown, and an early Tertiary age was suggested (Keller and others, 1961, p. 208).

Rocks of the Sagavanirktok Formation do not crop out west of the Itkillik River and were not found in any of the test wells drilled in northern Alaska. East of Franklin Bluffs, however, in the area between the Kavik and Shaviovik Rivers (long 146°50′ N. to long 147°45′ N.), Keller, Moris, and Determan (1961, p. 207) mapped rocks which they assigned to the Sagavanirktok Formation. These nonmarine to beach sediments consist of poorly consolidated conglomerate, sandstone, and siltstone with interbeds of shale and coal; the sediments are exposed on the limbs of structures particularly on the flanks of the Shaviovik anticline. These authors (p. 207) stated, "The rock unit has been mapped as the Sagavanirktok Formation partly because of its lithologic similarity to the rock unit described by Gryc, Patton, and Payne and partly because it can be traced, although somewhat discontinuously, to the Sagavanirktok River where the Sagavanirktok Formation has been noted." They measured and described two sections 1,600 and 2,045 feet thick.

Megafossils are unknown from the Sagavanirktok Formation, and microfossils are relatively scarce (table 1). Three microfossil samples collected by Keller and Morris from a 1,500-foot section on Fin Creek provided a few specimens of *Saccammina lathrami* Tappan. Two samples of a suite of 11 collected by George Gryc along the Shaviovik River yielded a few specimens of *S. lathrami* and an abundance of *Trochamina* cf. *T. ribstonensis* Wickenden. These forms are found in the Colville Group and not in Tertiary rocks.

A few species of Foraminifera were found in samples from the following seismic shotholes (location given on seismic profiles, pl. 24, Keller and others, 1961) drilled in 1953 by United Geophysical Co. across the Shaviovik anticline: line 1, shotholes 9, 14, and 18; line 2, shotholes 2–4, 6, 9, and 10; line 3, shothole 3; line 6, shotholes 2, 3, 19, and 20; line 7, shotholes 1 and 2. The microfossils are largely specimens of *Saccammina lathrami* and *Trochammina* cf. *T. ribstonensis* with a few specimens of *Anomalina* sp.; a specimen of *Verneuilinoides fischeri* Tappan? was found in each of two samples, and a specimen of *Nonionella* cf. *N. taylorensis* Hofker occurred in another. A few samples yielded a few specimens of Radiolaria, for example, *Cenosphaera* sp. and *Spongodiscus* sp., similar to forms found in formations of the Colville Group. The Foraminifera from the shotholes samples are all Cretaceous species and indicate that the containing beds are not of Tertiary age, contrary to the opinion expressed by Keller, Morris, and Detterman (1961, p. 209).

Because the few Foraminifera and Radiolaria are similar to forms found in sediments of the Colville Group and because only plant fossils have been found in the White Hills region, I believe the assignment of an early Tertiary age to this sequence of rocks is incorrect. No marine Tertiary rocks are known in the region, and the only locality where marine Tertiary fossils have been found in northern Alaska is along Carter Creek, more than 50 miles to the east of the Shaviovik area.

Several collections of invertebrate fossils have been made by surveys geologists at the Carter Creek locality. These collections were studied by MacNeil (1957, p. 100–102), who determined two faunal zones within the upper 266 feet of a sequence of beds estimated by Morris (1955) as about 7,266 feet thick. MacNeil ascribed a late Miocene or early Pliocene age to the zones.

Six microfossil samples collected by Morris from the lower 1,450 feet of the sequence at Carter Creek were barren. Foraminifera were found in two samples collected within the upper 266 feet from clay shale that was below the highest sandstone at the top of the sequence. From these two samples, Todd (1957) identified about 37 species of Foraminifera and suggested a late Miocene or Pliocene age for the beds containing them.

Much remains unknown of the thick sequence of beds which Morris ascribed to the Tertiary and suggested might be correlated with the Sagavanirktok Formation. Only the upper 266 feet of the sequence has been determined to be of possible Tertiary age, and more than 7,000 feet was lumped by Morris as rubble traces and intermittent outcrops. If this sequence is actually more than 7,000 feet thick in this part of the section in the Carter Creek area, it is more than 5,000 feet thicker than the section in the Shaviovik area.

MacNeil (1957, p. 100) used the name Nuwok Formation of Dall (1919) for the highest beds on Carter Creek yielding the mollusks and the Foraminifera. Inasmuch as this is the only part of the section with an age determination, MacNeil's suggestion that the beds be separated from the Sagavanirktok Formation is valid.

PLEISTOCENE ROCKS

GUBIK FORMATION

The Gubik Formation of Pleistocene age is reported to range from 30 to 150 feet in thickness and to consist largely of marine "loosely consolidated, cross-bedded, brown or buff gravel, sand, silt, and clay" that mantles the older rocks in much of the Arctic coastal plain (Gryc and others, 1951, p. 167).

Fossils have been found at various localities. The invertebrate collections were studied by McNeil (1957), who reported four different faunules, each from a separate area; he suggested that the formation consists of several thin units of slightly different ages representing a series of strandline deposits.

Foraminifera were found in coastal seismic shotholes and in the coastal area, in test wells in the Barrow area, North Simpson test well 1, Simpson test well 1, the Simpson Seeps core tests west of Smith Bay, and Fish Creek test well 1. The species found include calcareous Foraminifera of such genera as *Anomalina*, *Cassidulina*, *Cornuspira*, *Cribroelphidium*, *Dentalina*, *Elphidiella*, *Elphidium*, *Eponides*, *Globulina*, *Nonion*, *Pyrulina*, *Quinqueloculina*, and *Rotalia*. Very few arenaceous forms were noted. The Gubik Foraminifera, however, have not been studied in detail and are not included on the faunal charts of this report.

Ostracodes were associated with Foraminifera in many samples of Gubik sediments. Preliminary studies were made relatively early in the exploratory program by Swain (1949), who differentiated between a small nonmarine fauna and a larger marine fauna of "Pliocene or younger" age. Subsequently Swain (1959) delimited the areas of the marine and nonmarine ostracodes in the Gubik Formation. He found that the ostracodes are predominantly marine, neritic, cold-water types at Barrow and immediately south of Barrow, but fresh-water or nearshore types occur there also at four horizons. Swain noted neritic species in Simpson core test 1, in the core tests on the west side of Smith Bay, in shotholes in the Teshekpuk Lake area and along Fish Creek, and in Sentinel Hill core test 1. Ostracodes from Oumalik core test 2 and shotholes near the Ikpikupk River are fresh-standing-water types, according to Swain.

Recently Swain (1963) published descriptions of ostracodes found in the Gubik Formation. Twelve species are described from a nonmarine facies, and 29 species from a "marine facies which occupies the outer or northern part of the exposed Gubik and extends 10–20 miles inland between the Colville River on the east and Point Barrow on the west." Four of the genera and 18 of the species described are new. Swain considered the Gubik to be of probable late Pleistocene age.

MICROFOSSIL ZONES IN CRETACEOUS ROCKS

Except for the Okpikruak Formation (Neocomian), most of the fossiliferous Cretaceous sediments of northern Alaska can be included within microfossil zones. In 1956, seven microfossil zones were named (Bergquist, 1956a) but were subsequently modified (Bergquist, 1956b, 1958a–e, 1959a, b). Two of these zones are of Albian age, one is Cenomanian, two are Turonian, and the youngest is Senonian. The oldest microfossil zone is used here to include all the Fortress Mountain Formation and the lower part of the Torok Formation, plus a part of the more or less contemporaneous "Oumalik" Formation of the subsurface. The extent of this zone within the two surface formations can only be inferred from available data because the stratigraphic position of many samples within the several thousand feet of sections could not be determined by the collectors and because considerable thicknesses of beds were unsampled. The younger zone of the Lower Cretaceous rocks includes the upper part of the Torok Formation and the Tuktu and Grandstand Formations. The Ninuluk Formation of Cenomanian age has a faunal zone dominated by two species of Foraminifera. The Seabee Formation of Turonian age has a distinctive local faunal zone of planktonic Foraminifera within the shale beds and a thin but distinctive zone of two species of Foraminifera in the younger Ayiyak Member. The Schrader Bluff Formation of Senonian age has a radiolarian zone in the Barrow Trail or middle member and a distinctive foraminferal zone in the overlying Sentinel Hill Member.

ALBIAN ROCKS

GAUDRYINA TAILLEURI FAUNAL ZONE

The *Gaudryina tailleuri* faunal zone (pl. 15), the oldest Cretaceous microfaunal zone, is of early Albian age and includes beds in the lower part of the Torok Formation and in the Fortress Mountain Formation, where a few species of arenaceous Foraminifera dominate a fauna of about 55 species. Some of the species are restricted to the formations indicated, but others are long ranging. Making up more than 27 percent of the fossils are specimens of *Haplophragmoides topagorukensis* Tappan, a species found throughout much of the Lower Cretaceous in northern Alaska. Next in relative abundance is *Gaudryina tailleuri* (Tappan), which accounts for more than 11 percent of the fauna and lends its name to this faunal zone. As originally identified (Bergquist, 1956a), the zone was designated by two species—namely, *Verneuilinoides tailleuri* Tappan from the Fortress Mountain Formation and *Dorothia chandlerensis* Tappan from the lower part of the Torok Formation. Inasmuch as these two species are now considered as conspecific by Mrs. Loeblich (Tappan, 1962, p. 149) and as they have been placed under *Gaudryina* and designated by the name *G. tailleuri*, this name is used in this report, but it should be noted that specimens showing characteristics of *Gaudryina* occur only in the Torok Formation, whereas specimens found in samples of the Fortress Mountain Formation are entirely triserial and have closely appressed low chambers, nearly horizontal sutures, and flattened sides. The latter specimens seem to belong to the genus *Verneuilinoides* as originally described, as none were seen to have the biserial stage characteristic of *Gaudryina.*

Gaudryina specimens found in the lower part of the Torok Formation have a short triserial stage and a long biserial stage. Such tests were found in about 24 percent of the fossiliferous samples from the lower part of the Torok Formation and are common to abundant in 16 of the occurrences. Tests showing only triserial form were found in only about 12 percent of the fossiliferous samples from the Fortress Mountain Formation. Specimens occurred in the lower 1,750 feet of the Fortress Mountain Formation along the Kiruktagiak River and in the lower part of the formation in the Autumn Creek area, whereas in the type section in the Castle Mountain area, some occurred in beds 5,500–7,000 feet above the base of the formation. A few occurrences of *Gaudryina tailleuri* from the Fortress Creek syncline area and the Horseshoe Mountain area are from unspecified parts of the formation.

From the above comments, it can be seen that there may actually be two faunal subzones within the *Gaudryina tailleuri* zone. A "*Gaudryina* stage" typified by *Gaudryina tailleuri* is most characteristic of the lower part of the Torok Formation, whereas a "*Verneuilinoides* stage" characterizes the Fortress Mountain Formation, although in some parts of the formation the typical *G. tailleuri* may possibly occur. Specimens in the Fortress Mountain Formation are referred to as "*Verneuilinoides tailleuri*" in table 3.

The "pebble shale" section in Avak test well 1 and in the South Barrow test wells seems to be in this faunal zone, but in the suites of specimens assigned to *G. tailleuri*, more than one species is probably present. In the Barrow area, specimens appear to be typical of *Gaudryina.* The triserial stage is usually short and is followed by a long biserial stage; a few specimens have elongated triserially arranged chambers, but all the specimens are slender and either parallel sided throughout or somewhat flared; the initial end is rounded. Specimens from Avak test well 1 seem to be of three kinds. In the upper beds down through 645 feet, the specimens are short and somewhat flared or twisted. In general, these tests are poorly preserved, are flattened or crushed, and have obscure sutures; some of the tests have relatively coarse grains on the surface. A second kind, which ranges from about 572 feet through the core at 1,082–1,092 feet, seems to be the same as specimens in the lower part of the Torok Formation, for the tests are elongate and have parallel sides. A third form, found in cores from 1,258–1,348 feet, is similar to the "*Verneuilinoides*" specimens in the Fortress Mountain Formation; specimens are triserial and well preserved, and some specimens are elongate and have about 8 whorls. Associated with the lowest group are coarse-textured specimens of *Ammobaculites* that are similar to specimens of species found in the Okpikruak Formation of the Kemik Creek area. Other specimens similar to those of the cited Okpikruak fauna belong to *Haplophragmoides* and *Glomospira* aff. *G. pattoni.*

If the faunal assemblage in outcrop samples of both formations is considered as an entity, certain generalities are noted. The distribution of most species is about the same. Five species of arenaceous Foraminifera make up more than 50 percent of the faunal count from a combined total of 386 fossiliferous outcrop samples. Two calcareous species make up more than 6 percent of the total count. The leading species and their abundance in percent are as follows:

	Percent
Haplophragmoides topagorukensis Tappan	>27
Gaudryina tailleuri (Tappan)	>11
Bathysiphon brosgei Tappan (mostly in Fortress Mountain Formation)	10
Bathysiphon vitta Nauss? (mostly in Fortress Mountain Formation)	08
Saccammina lathrami Tappan	>05
Trochammina eilete Tappan	>04
Ammodiscus rotalarius Loeblich and Tappan	>04
Conorboides umiatensis (Tappan)	>03
Pallaimorphina ruckerae Tappan (in Fortress Mountain Formation)	>03
Lithocampe? sp. (pyritic casts)	>03
Ammodiscus sp	>02
Glomospirella gaultina (Berthelin)	>02
Glomospira corona Cushman and Jarvis	01
Eponides morani Tappan (only two occurrences)	>01
Gavelinella awunensis Tappan (all in lower part of Torok Formation)	>01
Ammobaculites fragmentarius Cushman	>01
Trochammina sp	>01
Total	>87

The complete fauna that I have identified for the *G. tailleuri* zone includes about 21 arenaceous Foraminifera and 34 calcareous species, but the 16 species tabulated above make up about 87 percent of the total count. The total number of species identified is about the same as that given for the *G. tailleuri* zone by Mrs. Loeblich (Tappan, 1960, p. 283), but she lists only 12 arenaceous forms and has given 26 specific names not noted by me. Part of the difference is accounted for by the fact that 18 names on my faunal list (p. 129) are identified only by genera, whereas Mrs. Loeblich has listed specific names for all except two identifications. She also lists five genera which I did not find, but does not list *Bathysiphon vitta*? (which she may have included with *B. brosgei*), *Saccammina lathrami*, and *Ammodiscus rotalarius*, three species which account for 17 percent of the fauna. Also absent in Mrs. Loeblich's list is any indication of the relative ratio or abundance for the species; many of the species are not represented by more than one or two specimens each.

From the subsurface come the only specimens of *Gaudryina barrowensis* Tappan and most of the specimens of "*Tritaxia*" *athabascensis* Mellon and Wall. The latter species was extremely scarce in outcrop samples and seems to be prevalent in the subsurface only in the Avak and Barrow areas. Mrs. Loeblich (Tappan, 1960, p. 281) mentioned that specimens of *Haplophragmoides linki* Nauss characterize the zone, but she did not list the specimens. In this report, these forms are included under *H. topagorukensis* because the specimens initially considered as *H. linki* seem to be only a variant of *H. topagorukensis*, particularly in subsurface samples from which large numbers of the specimens were examined.

Of 410 microfossil samples collected from the Fortress Mountain Formation by the several field geologists working in the southern foothills, approximately 44 percent of the samples came from the Castle Mountain and Fortress Mountain areas between Chandler River and Kiruktagiak River south of the Tuktu Escarpment and adjacent to the type locality. A few samples came from the Siksikpuk River area and the Nanushuk River area south of Arc Mountain syncline. West from the type area, other samples were collected from along the Okokmilaga, Okpikruak, Oolamnagavik, Kurupa, Kiligwa, and Ipnavik Rivers and in the area west of Lake Noluck and north of Thunder Mountain. Very few of the samples in the western or eastern areas were fossiliferous, whereas samples from the Castle Mountain–Kiruktagiak area yielded nearly 70 percent of the total fossiliferous samples. The samples represent sections throughout the Fortress Mountain Formation, but no sections were sampled in detail.

Samples from both the eastern and the western parts of the southern foothills are from the lower part (2,400 ft or less) of the formation. Of the samples from the general area of the type locality, 33 percent are from the lower part (5,000 ft or less), 29 percent are from the upper part (5,500–8,950 ft) of the formation, and no stratigraphic data were furnished for 37 percent of the samples.

Examination of all the outcrop samples studied from the Fortress Mountain Formation indicates that 153 or approximately 37 percent were fossiliferous. Altogether these 153 samples yielded 48 species of Foraminifera and 2 species of Radiolaria. However, the fauna is relatively sparse: 27 of the species occurred in no more than 4 samples, and only 1–4 specimens of each species were found; 8 species occurred in 5–10 samples; 4 species occurred in 10–20 samples; and only 7 species occurred in 20 or more samples. (See table 1.) The two species of Radiolaria each occurred as only one or two specimens in two samples.

Of the seven species that are each represented in 20 or more samples from the Fortress Mountain Formation, three species—*Trochammina eilete* Tappan, *Conorboides umiatensis* (Tappan), and *Pallaimorphina ruckerae* Tappan—seem to be more characteristic of the Fortress Mountain Formation and the lower part of the Torok Formation than the Albian beds younger than this part of the section; *Conorboides umiatensis* and *Pallaimorphina ruckerae* occurred in several more samples from the Fortess Mountain Formation than from Torok shale.

Of the microfossil samples from the Torok Formation, a total of 441 came from the lower part, from the part that is more or less contemporaneous with the Fortress Mountain Formation. Of these samples 224 were fossiliferous. Stratigraphic data on the samples are either too general or not available; but most of the samples were collected from what would probably be the lower half of the lower part of the Torok Formation and all came from the southern foothills (table 4). The few samples taken east of the Siksikpuk River were nonfossiliferous, and no stratigraphic data are available. In the area of the Siksikpuk and Kiruktagiak Rivers south of the Ayiyak anticlinorium and southwest of Tuktu Bluff, 108 samples were collected from upper beds of the lower part of the formation, mostly above or below the *Subarcthoplites* zone of Imlay (1961, p. 8); Imlay determined this zone to be within the middle third of the Torok Formation and to be equivalent to the Clearwater Formation and the upper part of the Loon River Formation of Alberta. Of the 108 samples collected, 68 samples were fossiliferous. Twenty-six samples were collected along the Okokmilaga, Okpikruak, Killik, and Kurupa Rivers, south of the Ayiyak anticlinorium; but little or no stratigraphic data are available, and only 6 samples were fossiliferous. One hundred thirty-six samples were collected along the Etivluk, Kuna, and Nuka Rivers; only 28 samples were fossiliferous. No stratigraphic data are available on 94 of these samples, but 42 are from lower? (<3,000 ft) beds.

Eighty-three samples were collected in the western area along Noluck, Driftwood, and Adventure Creeks, on and adjacent to the Driftwood anticline, and 65 of them were fossiliferous. Although most of these samples are from the lower beds of the formation, 21 fossiliferous samples are from middle beds, and 7 fossiliferous samples are from upper beds of the lower part of the formation. The westernmost samples from this part of the Torok Formation were collected in the Iligluruk Creek area southeast of Poko Mountain. Of 42 samples from lower beds, 34 samples were fossiliferous.

The microfauna in the lower part of the Torok Formation is similar to that in samples from the Fortress Mountain beds, and it includes 48 species of Foraminifera and 2 species of Radiolaria. A few specimens of 28 species were found in 1–4 samples; 7 species, in 5–10 samples; 5 species, in 10–20 samples; and only 7 species occurred in more than 20 samples. Most of the last seven are about as numerous as those found in the Fortress Mountain Formation; but one, *Gavelinella awunensis* Tappan, was found only in the lower part of the Torok Formation, and it makes up only about

1 percent of the faunal count. Pyritic casts of Stichocorythidian Radiolaria (*Lithocampe*? sp. and *Dictyomitra*? sp.) are almost entirely confined to the lower part of the Torok Formation, and *Lithocampe*? accounts for about 3 percent of the entire fauna.

Most of the samples in which pyritic casts of *Lithocampe*? sp. and *Dictyomitra*? sp. occur came from the type section of the Torok Formation in the Ayiyak anticlinorium, on the north and south limbs of that structure along the Kiruktagiak and Ayiyak Rivers, and from the east along the Siksikpuk River. More than 30 occurrences of the casts of *Lithocampe*? sp. and 6 occurrences of pyritic casts of *Dictyomitra*? sp. were recorded from the samples. In five of the samples the pyritic casts of *Lithocampe*? sp. were common. Most of the occurrences of the Radiolaria seem to be within the middle third of the Torok Formation (upper part of the lower part of the formation) and are from sections containing specimens of *Subarcthoplites* sp., an Albian ammonite. Specimens of *Gaudryina tailleuri* are associated with the Radiolaria in several samples.

There were only two occurrences of pyritic casts of *Lithocampe*? sp. and five occurrences of *Dictyomitra*? sp. in samples from the Fortress Mountain Formation. Casts of *Lithocampe*? sp. and *Dictyomitra*? sp. have been found in the subsurface sections described as the Oumalik Formation and in some subsurface sections have been used to identify this formation. A few casts of *Lithocampe*? sp. were found in seven samples in the lower part of the "Oumalik" Formation (part of Torok Formation of this report) in Oumalik test well 1, and nine specimens of *Dictyomitra*? sp. were found in a core (10,233–10,240 ft) near the base of the beds penetrated.

The lower part of the Torok Formation in western Alaska seemingly has a relatively small microfauna, as suggested from 14 fossiliferous samples collected by Survey geologists along Adventure Creek on the south limb of Driftwood anticline and from a few samples collected along the Kokolik River. The species identified for the Utukok-Corwin region are listed by Chapman and Sable (1960, p. 79, 80, 82), together with my notations on the microfauna. The microfauna from the Driftwood anticline area is relatively small and consists mostly of very small flattened specimens of *Haplophragmoides topagorukensis* Tappan and fragmentary tests of *Bathysiphon brosgei* Tappan. Specimens of *H. topagorukensis* were common to abundant in nine samples. Flattened and distorted specimens of *Ammodiscus rotalarius* Loeblich and Tappan were found in several samples but were common to abundant in only two samples. Broken and twisted specimens of *Gaudryina tailleuri* (Tappan) (referred to as *Dorothia chandlerensis* by Chapman and Sable (1960)) were found infrequently but were common in one sample. The fauna in general is similar to that found in lower beds of the Torok Formation elsewhere in northern Alaska, but it lacks most of the species that identify the upper part of the formation. It also lacks pyritic casts of the radiolarian *Lithocampe*? sp., which is prevalent in samples from type exposures of the lower part of the formation.

Foraminifera and Radiolaria in Gaudryina tailleuri *zone*
[All very rare unless otherwise designated]

Foraminifera:
- *Bathysiphon brosgei* Tappan, very rare to common
  - *vitta* Nauss?, very rare to common
- *Hyperamminoides barksdalei* Tappan
- *Reophax* sp.
- *Ammodiscus rotalarius* Loeblich and Tappan, very rare to common
  - sp., very rare to common
- *Glomospira corona* Cushman and Jarvis, very rare to common
  - sp.
- *Glomospirella gaultina* (Berthelin)
- *Haplophragmoides topagorukensis* Tappan, very rare to abundant
  - aff. *H. kirki* Wickenden, very rare to common
  - sp.
- *Ammobaculites fragmentarius* Cushman, very rare to rare
- *Spiroplectammina*? sp.
- *Textularia*? sp.
- *Verneuilinoides* sp.
- "*Tritaxia*" *athabascensis* Mellon and Wall
- *Gaudryina barrowensis* Tappan
  - *subcretaea* Cushman
  - *tailleuri* (Tappan), very rare to common
- *Gaudryinella irregularis* Tappan
- *Miliammina subelliptica* Mellon and Wall?
- *Trochammina eilete* Tappan, very rare to abundant
  - sp., very rare to rare
- *Lenticulina erecta* (Perner)
  - *polygona* (Perner)
  - *topagorukensis* Tappan
  - sp.
- *Astacolus perstriatus* (Tappan)
  - *strombecki* (Reuss)
- *Marginulina acuticostata* Reuss?
  - *cephalotes* (Reuss)
  - *planiuscula* (Reuss)
  - sp.
- *Marginulinopsis collinsi* Mellon and Wall
  - sp.
- *Dentalina*? *dettermani* Tappan
- *Dentalina* sp.
- *Nodosarella barrowensis* Tappan
- *Nodosaria* cf. *N. concinna* Reuss
  - sp.
- *Saracenaria grandstandensis* Tappan
  - *trollopei* Mellon and Wall
  - sp.
- *Vaginulinopsis schlönbachi* (Reuss)
  - sp.

Foraminifera—Continued
- *Globulina lacrima* Reuss subsp. *canadensis* Mellon and Wall
  - *prisca* Reuss
  - sp.
- *Praebulimina nannina* (Tappan)
- *Gavelinella awunensis* Tappan, very rare to rare
- *Discorbis*? sp.
- *Conorboides umiatensis* (Tappan), very rare to rare
- *Valvulineria loetterlei* Tappan
- *Gyroidina* sp.
- *Eponides morani* Tappan
- *Globorotalites alaskensis* Tappan
- *Pallaimorphina ruckerae* Tappan, very rare to rare

Radiolaria:
- *Lithocampe*? sp. (pyritic casts)
- *Dictyomitra*? sp. (pyritic casts)

VERNEUILINOIDES BOREALIS FAUNAL ZONE

The *Verneuilinoides borealis* faunal zone is an Early Cretaceous microfossil zone of middle to late Albian age that includes several thousand feet of beds; it can be traced over areas of outcrop in the foothills region and throughout most of the subsurface of the coastal plain area. It occurs in the upper third (approx. 2,000 ft) of the Torok Formation, extends through the overlying Tuktu and Grandstand Formations of the Nanushuk Group, and is found in intertongues of the Grandstand and Chandler Formations. In the western part of northern Alaska this zone, embracing as much as 7,000 feet of section, includes the upper part of the Torok Formation, all the Kukpowruk Formation, and beds throughout much of the Corwin Formation.

The *Verneuilinoides borealis* zone, the most extensive faunal zone in the Cretaceous rocks of northern Alaska, is present in outcropping rocks throughout the foothills section and in most of the test wells. The zone was formally recognized in 1956 (Bergquist, 1956a) but had been used informally as the "*Verneuilinoides* F fauna" (Bergquist, 1951, 1952) during the geological investigations of Naval Petroleum Reserve No. 4. The zone was briefly described in connection with the Oumalik area and the Umiat field (Bergquist, 1956b, 1958a) and was further discussed in subsequent micropaleontological reports on several wells (Bergquist, 1958b–e, 1959a, b).

More than 100 species of Foraminifera have been found in the *Verneuilinoides borealis* zone, but most of the species occur only rarely and sporadically; many of them were found only in the coastal wells, especially in Simpson test well 1 and in Topagoruk test well 1, where the largest assemblage of Foraminifera occurs. Most of the specimens belong to 12 arenaceous species, but locally other species may be abundant. Some species are the same as forms found in beds of middle Albian age in Europe and Canada; many are new species which Mrs. Loeblich has described (Tappan, 1951a, 1957, 1960).

Several species of the *Verneuilinoides borealis* zone are relatively common and are restricted to the zone. Its dominant species, *Verneuilinoides borealis* Tappan, is not found throughout the entire vertical or horizontal extent of the faunal zone; no specimens of *V. borealis* were found in the upper part of the Torok Formation in western Alaska, but in other areas this species is diagnostic of the same beds.

Verneuilinoides borealis Tappan, the species for which the zone is named, is a broadly flaring triserial arenaceous species, the best preserved specimens of which are pyritized and have bulbous chambers and deeply incised sutures (fig. 34); most specimens, however, have not had the supporting medium of pyrite to retain their shape and are flattened, with a slight overlapping of chambers. Many specimens have a relatively smooth surface texture, but others, particularly the smaller tests found at certain horizons, have a rough, granular texture that makes the chambers and sutures barely discernible.

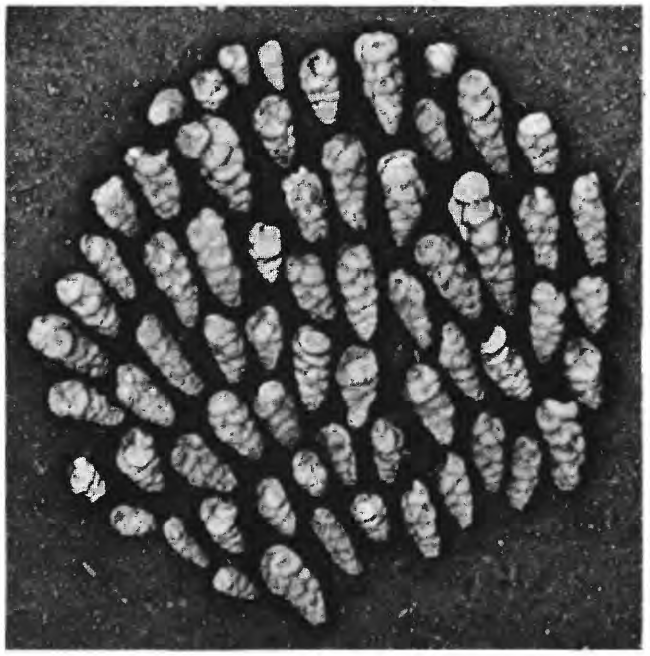
Approximately 30 of the total number of species of Foraminifera found in samples from the *Verneuilinoides borealis* faunal zones occur frequently (pl. 13), and 25 of these species are more or less indicative of the fauna. The other few species are long-ranging forms or forms found also in older Albian beds. Some of the species first appear in the lower part of the Torok Formation in the *Gaudryina tailleuri* zone and continue into the Grandstand Formation; but most are confined to the upper part of the Torok Formation and the Tuktu Formation, and only a very few of the species persist into the beds of the Grandstand Formation. *Haplophragmoides topagorukensis* Tappan, the most frequently occurring and abundant species of the entire fauna, appears first in beds of early Albian age, or possibly in the Neocomian Okpikruak Formation; it continues in abundance through the Tuktu Formation but occurs sparingly in the Grandstand Formation.

Verneuilinoides borealis is the dominant species, but other Foraminifera also diagnostic of the zone include *Psamminopelta bowsheri* Tappan, *Miliammina awunensis* Tappan, *Miliammina manitobensis* Wickenden, *Ammobaculites fragmentarius* Cushman, *Ammobaculites wenonahae* Tappan, *Textularia topagorukensis* Tappan, *Gaudryina nanushukensis* Tappan, "*Tritaxia*" *manitobensis* Wickenden, *Gavelinella stictata* (Tappan), *Marginulina planiuscula* (Reuss), *Lenticulina erecta* (Perner), *Lenticulina macrodisca* (Reuss), *Globorotalites alaskensis* Tappan, and two species of *Eurycheilostoma*, a high-spired rotalid described by Tappan (1957). Several of these species are not found in the Grandstand

Formation; some are most conspicuous in one formation or are only in one part of the faunal zone.

Microfossils in the *Verneuilinoides borealis* zone vary in their state of preservation. Foraminifera from outcrop and test-hole samples in the foothills region generally are dark brown. The tests of some are partly or completely filled by pyrite and may retain the original shape; nonpyritized specimens commonly are flattened, and many are distorted. Foraminifera from the subsurface section of the zone in the coastal plain area are generally light colored, and only locally are some specimens pyrite filled. Generally, the arenaceous specimens from the coastal wells are flattened by crushing but seem to be somewhat less distorted than specimens from the foothills area or the western area. Most of the Foraminifera from the Kukpowruk and Corwin Formations are dark colored, are distorted, and generally are poorly preserved.

The geographic extent and the thickness assigned to the *Verneuilinoides borealis* zone may seem too broad, but the data, compiled from a large number of samples and a multitude of specimens, indicate that this zone is



A

B

FIGURE 34.—Specimens of *Verneuilinoides borealis* Tappan showing variation in texture, shape, and size, Oumalik core test 1. *A*, Collapsed tests from core at 14–24 feet, × 20. *B*, Inflated pyrite-filled tests and at bottom, coarsely granular tests, from core at 87–97 feet, × 30.

extensive and cannot be subdivided unless there is closer control. Where close subsurface control was obtained from 11 test wells in the Umiat field, certain species of Foraminifera of the *V. borealis* zone and a worm tube (*Ditrupa cornu* Imlay) proved to be excellent markers. These species are within the Tuktu faunal facies of the Tuktu and Grandstand Formations undifferentiated and are conformable with the structural features of the field (pl. 16).

In the Umiat field the highest faunal horizon is approximately 125–150 feet below the top of the *Verneuilinoides borealis* zone at the highest occurrence of *Ammobaculites fragmentarius* Cushman (fig. 35), along with the small, smooth, slightly curved, and somewhat tapered, calcareous worm tubes *Ditrupa cornu* Imlay. Another horizon, approximately 500 feet below the top of the faunal zone, is marked by the first occurrence of *Ammobaculites wenonahae* Tappan (fig. 36), which differs from *A. fragmentarius* in having a larger initial whorl and only four or five broad chambers in the uniserial stage. Slightly lower in the section, or appearing along with *A. wenonahae* are specimens of *Trochammina umiatensis* Tappan (fig. 37), a trochoid species distinguished by four large bulbous chambers in the last whorl and a "*Globigerina*"-like appearance unlike that of any other *Trochammina* in the Cretaceous sediments of northern Alaska. *Trochammina umiatensis* seems to be restricted to a thin zone that is less than 100 feet thick in the Umiat area, and that zone apparently is also limited geographically. Although it occurs in each of the test wells of the Umiat field, it was not recognized elsewhere in the foothills region but was found in the two Gubik test wells and in Fish Creek test well 1.

The four fossils mentioned above proved to be reliable markers in the Umiat field. In drilling most of the later test wells in that field, the depths to each fossil marker could be estimated as soon as the top of the *Verneuilinoides borealis* zone had been recognized.

In many other subsurface sections of Early Creta-

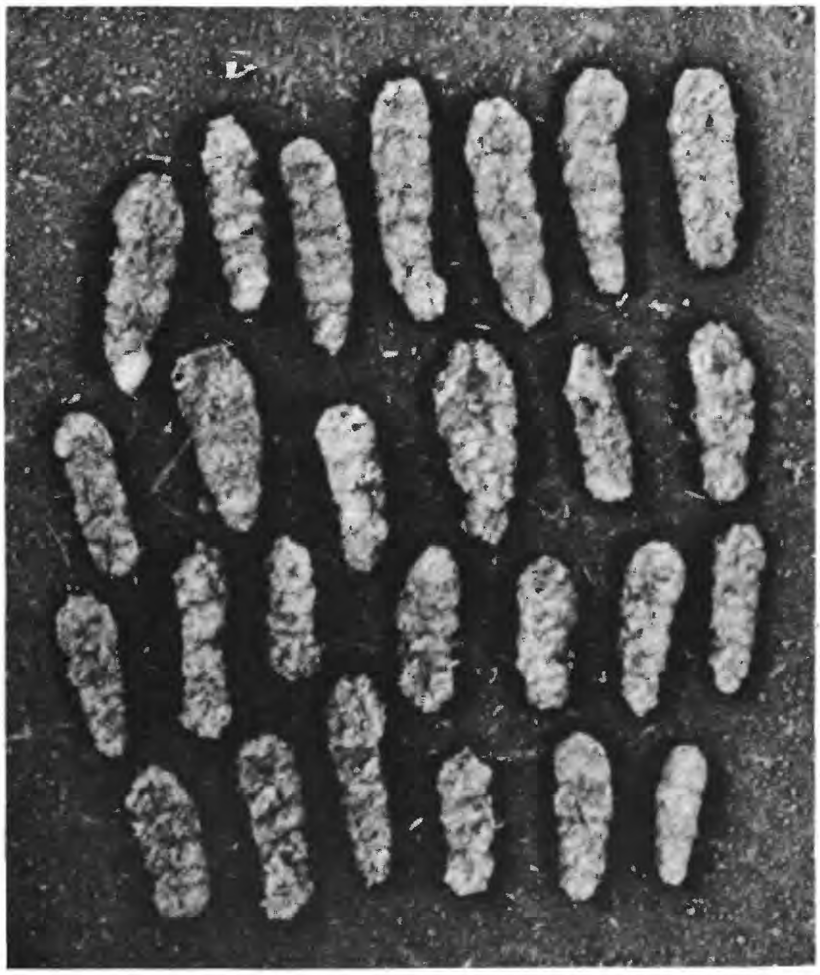


FIGURE 35.—*Ammobaculites fragmentarius* Cushman from Tuktu faunal facies of *Verneuilinoides borealis* faunal zone, Umiat test well 2, core at 465–475 feet, × 30.

A

B

FIGURE 36.—*Ammobaculites wenonahae* Tappan from Tuktu faunal facies of *Verneuilinoides borealis* faunal zone. *A*, Group of specimens from a core, at 2,365–2,370 feet, Umiat test well 1, × 20. *B*, Single specimen from a core, at 680–690 feet, Umiat test well 2, × 30.

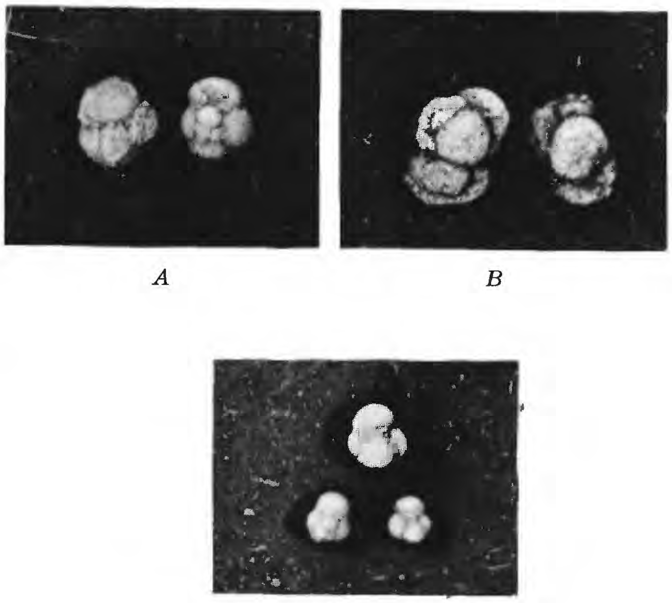
ceous rocks in northern Alaska, the tubes of *Ditrupa cornu* have been a very useful marker because they are commonly prevalent within the upper part of the *Verneuilinoides borealis* zone. These tubes are diagnostic of the Tuktu Formation because in the outcrop areas they occur almost exclusively in that formation and have been found only rarely in the Grandstand Formation (pl. 13).

Frequently associated with *Ditrupa cornu* in the upper part of the *Verneuilinoides borealis* zone are *Inoceramus* prisms and fragments of *Inoceramus* shells. Together the *Inoceramus* and *Ditrupa* virtually constitute a faunal subzone in the Barrow, Simpson, and Fish Creek areas. Earlier in the exploration of the Cretaceous rocks of northern Alaska, the *Ditrupa* tubes were considered to be scaphopods and were reported as *Laevidentalium* (Gryc and others, 1951, p. 163; Robinson, Rucker, Bergquist, 1956, p. 230; Detterman, 1956, p. 234). Imlay later identified them as worm tubes similar to forms found in the Albian beds of Spitzbergen and Russia, where they also were at one time referred to the Scaphopoda (Imlay, 1961, p. 40).

Fragments of a small crinoid that occurs in some of the Early Cretaceous microfossil samples have been identified as *Balanocrinus* sp. by A. L. Bowsher who found them to be confined to a zone approximately 100 feet thick in the uppermost part of the Tuktu Formation (Bowsher, written commun., 1957). Specimens of *Balanocrinus* have been found in subsurface core samples, where they are associated with tubes of *Ditrupa cornu* amid a microfauna containing *Ammobaculites fragmentarius*, "*Tritaxia*" *manitobensis*, *Miliammina manitobensis*, *Gavelinella stictata*, and two species of *Eurycheilostoma*, all species that are rarely found above the Tuktu Formation.

Gaudryina nanushukensis Tappan is a distinctive Foraminifera found in a few samples from the Tuktu Formation and in many samples from the upper part of the Torok Formation. The species seems to be more common in the subsurface than in outcrop samples, but few specimens have been found above the upper part of the Torok Formation in the subsurface. No specimens were found in outcropping beds of the Grandstand Formation. Thus the species seems to be a good marker for the middle part of the *Verneuilinoides borealis* zone. Most specimens of this arenaceous species have large triserial tests that are triangular in section and that commonly have sooty black specks of manganese oxide(?) on the surface of the chambers and along the sutures.

Glauconitic casts of a conical, striate radiolarian (*Dictyomitra* cf. *D. multicostata* Zittel) occur in a glauconite zone that can be traced extensively within the lower part of the *Verneuilinoides borealis* faunal zone in some of the core tests and test holes in the Cape Simpson and Barrow areas, in Topagoruk test well 1, and in shotholes in the Teshekpuk Lake region. The top of this glauconitic zone seems to be 400–500 feet below the lower or basal part of the zone in which *Inoceramus* shells and *Ditrupa cornu* are conspicuous. The thickness of the glauconitic zone is not known because the casts were found only in ditch samples and were scattered through a much greater interval of rocks than can possibly represent the true thickness of the zone.



A B

C

FIGURE 37.—*Trochammina umiatensis* Tappan from Tuktu faunal facies of the *Verneuilinoides borealis* faunal zone. *A* and *B*, Specimens from Umiat test well 1, core at 1,635–1,645 feet. *B*, Specimens crushed and distorted. *C*, Specimens from Umiat test well 8, cuttings at 1,190–1,195 feet. All × 20.

Specimens of *Textularia topagorukensis* Tappan (fig. 38) were found only in the lowermost part of the *Verneuilinoides borealis* faunal zone in lower beds of the upper part of the Torok Formation. The species seems to constitute a faunal subzone in coastal wells but was found only rarely in other wells and in only 28 outcrop samples. The delicate tests of this small biserial species are commonly flattened and occur in abundance below the main part of the microfauna.

FIGURE 38.—*Textularia topagorukensis* Tappan from a core at 256–264 feet, Skull Cliff core test 1, lower part of *Verneuilinoides borealis* faunal zone, upper part of the Torok Formation, × 20.

The subzone of *Textularia topagorukensis* extends through about 1,600–1,700 feet of section in the *Verneuilinoides borealis* faunal zone in the northern wells. It can be traced from the Skull Cliff-Barrow-Simpson area to Fish Creek test well 1 and occurs in the Topagoruk and Oumalik wells. The subzone is very poorly defined in the Umiat area.

Most specimens of *Textularia topagorukensis* have slender tapered flattened tests, but there is a shorter form that has a more flared later part of the test and in some specimens an initial coiling. This initially coiled form was originally described as *Spiroplectammina koveri* Tappan (Tappan, 1957, p. 205) but was subsequently regarded by Mrs. Loeblich as a microspheric form of *T. topagorukensis* (Tappan, 1962, p. 141, 142).

In Skull Cliff core test 1, the short flared form of *Textularia topagorukensis* was found in abundance at 256 feet and extended to 411 feet. In South Barrow test well 1, it occurred only at 1,140–1,150 feet; in Simpson test well 1, it ranged from 2,235–2,540 feet; but in Oumalik test well 1, it extended through an interval of more than 900 feet (2,790–3,710 ft).

The slender form of *Textularia topagorukensis* can be traced in all the northern wells, including North Simpson test well 1. The subzone occupies a thick interval (2,939–3,996 ft.) in Simpson test well 1 but only a thin interval below 4,420 feet in Oumalik test well 1. There is accordingly a thickening of the interval occupied by the flared form from Skull Cliff-Simpson area to Oumalik test well 1 and a corresponding thinning of the interval occupied by the slender form from Simpson to Oumalik.

Although locally the subzone of *Textularia topagorukensis* has abundant tests of "*Tritaxia*" *manitobensis*, relatively few specimens of *Miliammina* are found, and specimens of *Psamminopelta* are conspicuously absent from this part of the *Verneuilinoides borealis* zone. Specimens of *Ammobaculites* also seem to be absent, except possibly for a few very rare occurrences of segments of uniserial-chambered tests in the Torok Formation of the Driftwood anticline area. These uniserial segments, however, may be segments of *Reophax*.

Other than the markers and subzones mentioned above, the *Verneuilinoides borealis* faunal zone of northern Alaska does not seem to be further divisible, whereas in western Canada seven microfossil zones are recognized in the Albian Formations of the Fort St. John Group (Stelck, Wall, Bahan, and Martin, 1956). Beds that are approximately equivalent to those of the Fort St. John Group include all the *Gaudryina tailleuri* zone

(Fortress Mountain Formation and the lower part of the Torok Formation) and the *V. borealis* faunal zone.

The *Verneuilinoides borealis* faunal zone is economically important in northern Alaska because it includes the producing sand section of the Umiat field and most of the oil sands penetrated in the Early Cretaceous sections. It is also the most widespread faunal zone and is thicker in the subsurface than in the areas of outcrop, except perhaps in the western part of northern Alaska. The greatest subsurface thickness of the zone, nearly 5,000 feet, is in Oumalik test well 1. However, the largest fauna and largest number of specimens of Foraminifera of this zone occurred in Simpson test well 1 and in Topagoruk test well 1.

RELATION TO MEGAFOSSIL ZONES

From his study of Lower Cretaceous ammonites from northern Alaska, Ralph Imlay concluded that the upper third of the Torok Formation and the entire Tuktu Formation can be correlated with beds of middle Albian age in Europe (Imlay, 1961, p. 4). The sequence of beds considered ranges in thickness from 1,000 feet to nearly 4,000 feet and is characterized by the ammonites *Gastroplites* and *Paragastroplites* in association with other mollusks. Imlay (1961, p. 9–10) named this the *Gastroplites kingi* zone. As such, this zone would correspond to the most fossiliferous part of the *Verneuilinoides borealis* faunal zone, but many of the mollusks associated with the ammonite zone have the same range as do individual microfossil species of the *V. borealis* zone, that is, they range through the Grandstand Formation and its intertongues.

STATISTICAL SUMMARY

Approximately 127 microfossil samples were collected from the Tuktu Formation from 18 localities over a distance of 80–120 miles in the northern foothills section south of the Colville River (table 6). Of these samples, 92 were fossiliferous. Six samples were obtained from the type locality of the formation at Tuktu Bluff; in the 1,030-foot section, which is preponderantly sandstone with only minor silty shale beds, all the samples came from the lower 275 feet of the section. The largest number of samples from one locality is in a collection of 18 samples obtained by Detterman and Gryc along the Chandler River from a 300-foot section of the formation in the area from the Niakogon syncline to the Big Bend anticline. Some of the best preserved microfossils in the formation, however, were found in 14 samples from 1,360 feet of beds exposed below the Grandstand Formation on the Colville River between Ninuluk Creek and Umiat Mountain. This exposure of the Tuktu Formation was the thickest sampled; it yielded such diagnostic species as *Verneuilinoides borealis*, *Psamminopelta bowsheri*, *Miliammina manitobensis* and *Ammobaculites fragmentarius.* These species, together with tubes of *Ditrupa cornu*, occur most commonly and frequently in the samples from other localities. Occurring less frequently are specimens of *Miliammina awunensis*, *Ammobaculites wenonahae*, "*Tritaxia*" *manitobensis*, *Gaudryina nanushukensis*, and *Gavelinella stictata*. Several of these species were not found above the Tuktu Formation. (See pl. 13.)

A total of 38 species of Foraminifera have been identified from the outcrop samples of the Tuktu Formation, but specimens of 19 of these species were extremely rare in occurrence. In individual samples, generally only a few species are found, but specimens range from very rare to abundant. Many specimens are flattened and distorted; others although flattened, are fairly well preserved.

The dominant microfossil in the Tuktu Formation is *Verneuilinoides borealis*, which was found in 82 percent of the fossiliferous samples. Next most frequently found are *Haplophragmoides topagorukensis* Tappan and *Ammobaculites fragmentarius* Cushman; these species are closely followed in abundance by the long-ranging species *Saccammina lathrami* Tappan and by *Psamminopelta bowsheri* Tappan and *Miliammina manitobensis* Wickenden. *Ditrupa cornu* Imlay occurred in 31 samples from nine localities. *Gaudryina nanushukensis* was found only in seven of the samples; these came from the thick section in the Ninuluk Creek-Umiat Mountain area.

One hundred and ten samples of the Grandstand Formation were collected at 16 localities during five field seasons. The samples came from a region in the northern foothills, about 140 miles in east-west extent, south of the Colville River, and they were collected along the Colville River from the Ipnavik River eastward to the Kurupa River; along the Kurupa and Oolamnagavik Rivers; along Fossil Creek; along the Colville River between Ninuluk Creek and Umiat Mountain; and along the Chandler River at the Big Bend anticline and the Grandstand anticline (table 7). A few miscellaneous samples came from outcrops along the Nanushuk and Anaktuvuk Rivers. Approximately 71 samples came from beds intertongued with the nonmarine Chandler Formation. Of the samples collected, 77 were fossiliferous; and of these, 44 were from intertonguing sections.

Some microfossils came from each of the localities where the Grandstand Formation was sampled, but the number of species generally is very rare to rare in each sample. The number of specimens in a sample, however, ranges from very rare to very abundant. Generally the specimens are flattened, and preservation ranges from poor, which makes identification difficult, to good in the intertonguing sections and from fair to good in the main part of the formation.

Verneuilinoides borealis was found in about 60 percent of the samples and at all localities, with the exception of two samples from a section interbedded with the Killik Tongue of the Chandler Formation. Its abundance is about equaled by *Haplophragmoides topagorukensis*, but that species occurs also in lower Albian beds. In the majority of the samples, *Psamminopelta bowsheri* and *Miliammina awunensis* are diagnostic species of the *Verneuilinoides borealis* fauna. Tubes of *Ditrupa cornu* were found only in the Fossil Creek area in two samples from the upper part of the formation. This species is relatively common in the microfossil samples from the Tuktu Formation and in the samples of the Tuktu and Grandstand Formations undifferentiated in the subsurface; but, oddly enough, none were found in the microfossil samples from the interbedded Grandstand and Killik beds nor from the lower part of the Grandstand Formation although the species was identified in two megafossil collections from beds 100–200 feet above the Tuktu Formation (Imlay, 1961, p. 40).

About 30 species of Foraminifera of the *Verneuilinoides borealis* faunal zone were found in samples from the Kukpowruk and Corwin Formations in western Alaska. Check lists of the species found in these formations in the Utukok-Corwin region, together with my notations on the microfauna, are given by Chapman and Sable (1960, p. 78–81, 100, 125) in their report on the geology of northwestern Alaska. Foraminifera in the Kukpowruk Formation of that area are principally *Verneuilinoides borealis*, *Haplophragmoides topagorukensis*, *Ammobaculites wenonahae*, "*Tritaxia*" *manitobensis*, *Gaudryina* sp., *Pallaimorphina ruckerae*, *Gavelinella stictata*, *Conorboides umiatensis*, *Eurycheilostoma grandstandensis*, *Marginulina planiuscula*, *Lenticulina macrodisca*, and *Globulina lacrima*. Specimens are generally more poorly preserved than those found in the *V. borealis* zone in most other areas in that almost all the arenaceous specimens are distorted by compression and many are severely flattened; most are dark tan or brown. The calcareous Foraminifera, however, are rarely distorted; tests are filled with calcite or rarely with pyrite, and all have a weathered or "frosty" appearance. Some arenaceous foraminifers from the Kukpowruk Formation in the Utukok-Corwin region seem to be dwarfed as compared to the robust specimens frequently found in samples from other areas. This is particularly true of *V. borealis*, but some specimens of "*Tritaxia*" *manitobensis* are relatively large for the species. Farther east, in the area of the Awuna syncline, however, many of the Foraminifera from the Kukpowruk Formation are of normal size or are large for the species.

Microfossils were found in less than 32 percent of the samples collected from the Corwin Formation; about one-third of the fossiliferous samples yielded only charophytes (table 15). Foraminifera are exceedingly rare; although the entire assemblage includes *Verneuilinoides borealis*, *Haplophragmoides topagorukensis*, *Miliammina awunensis*, *Psamminopelta bowsheri*, *Gaudryina canadensis*, "*Tritaxia*" *manitobensis*, and *Saccammina lathrami*, generally only one to three species occur in a sample, and the specimens of each species are few in number. In a few samples, one or two species are common.

The Corwin Formation was not thoroughly or critically sampled for microfossils, however, as samples are separated stratigraphically by several hundred to a few thousand feet of section. Twenty samples were collected in 1953 from the lowest 7,800 feet of the 15,494-foot type section in the bluffs bordering the Chukchi Sea, and 22 samples were collected from the upper half of the section. Of these samples, only seven had any microfossil material, and only charophytes were found in six of these. The only Foraminifera were two specimens of *Haplophragmoides topagorukensis?* from a sample near the top of the section. An earlier collection of 22 samples from the type section yielded a total of 18 specimens (6 species) of Foraminifera, and 1 charophyte from 8 samples. Twenty-six other samples from the Corwin Formation were collected by various geologists along the Utukok, Kokolik, and Kukpowruk Rivers; of these, 14 were fossiliferous and yielded most of the microfossils known from the formation.

In the Awuna syncline area, the Corwin Formation is somewhat more fossiliferous, as 40 percent of the total samples examined yielded microfossils. On the flanks of the Awuna syncline, where 69 samples were collected through about 1,700 feet of section, more than 62 percent of the samples examined yielded Foraminifera. There too, the species and specimens were more numerous than in the samples from the Utukok-Corwin region.

PROBLEMS OF SPECIFIC IDENTIFICATION

Mrs. Loeblich (Tappan, 1960) listed a number of species of Foraminifera for the Cretaceous microfaunas of northern Alaska that I have not found in any of the material. For example, I have identified 45 species in the 620 fossiliferous surface samples from the *Verneuilinoides borealis* faunal zone and 60–70 species from the subsurface sections in the same zone. Mrs. Loeblich, however, listed 93 species for this zone (Tappan, 1960, p. 283), but she included many calcareous Foraminifera which are represented by only one or two specimens and were not found by me. Many of these calcareous species were found in samples from Simpson test well 1, South Barrow test wells 1 and 2, and Umiat test wells 1 and 2; these wells yielded more species than did many from later wells. I have included the names of these species and the approximate number of specimens from Mrs. Loeblich's collections in the faunal charts of this report but some may have been overlooked.

The arenaceous Foraminifera, however, present a different aspect. It is often extremely difficult to identify poorly preserved specimens, and different people may not always agree on certain identifications; thus I have identified some arenaceous species differently than Mrs. Loeblich has. This seems to be particularly true for the Trochamminas, for which I have introduced three or four names from the Canadian Cretaceous that have not been used by Mrs. Loeblich; I, also, do not use some of the specific names that she does. Other arenaceous Foraminifera that I identify differently are indicated in the various sections of this report. Certain of the following misidentifications noted on some of the Tappan type slides from the Alaskan collection may be due to poor preservation of specimens.

The hypotype specimens of *Gaudryina cushmani* Tappan identified from northern Alaska are not the species described from the Grayson Formation of Texas, and *G. cushmani* should not be considered as part of the *Verneuilinoides borealis* fauna although it has been listed as such (Tappan, 1960, p. 283) and although it has been described in the taxonomic work on the Alaskan Cretaceous (Tappan, 1962, p. 147). Unfigured hypotypes labeled USNM P6167 from sample 47A Tr 115 are calcareous and apparently are specimens of *Eurycheilostoma robinsonae* Tappan. Figured and unfigured hypotypes labeled USNM P6165 from sample 47A Wh 160 represent two different forms. One specimen seems to be a distorted calcareous test of *E. robinsonae*, and another is a tiny immature triserial arenaceous test which I believe is a specimen of *Verneuilinoides borealis* that is flattened at the apertural end. Unfigured hypotype USNM P6166 from a core at 4,087–4,097 feet in Umiat test well 2 is a specimen of *V. borealis*.

Reophax troyeri Tappan is another species which I have not identified in collections from outcrop sections, but it may occur sparingly in the subsurface in the *Verneuilinoides borealis* faunal zone. Some of the specimens selected as types, however, appear to be *Ammobaculites*. Unfigured paratypes (USNM P5999) identified as *R. troyeri* Tappan from a core at 2,535–2,540 feet in Simpson test well 1 (Tappan, 1962, p. 133) are specimens of *Ammobaculites fragmentarius* Cushman. One specimen on the type slide has an initial coiled end; the other specimen is [illegible]. The core yielded several specimens of *A. fragmentarius* but none of *R. troyeri*. Unfigured paratypes USNM P6000 from cuttings at 4,000–4,010 feet in the same well are more likely specimens of *Ammobaculites* than of *Reophax*. Unfigured paratype USNM P5997 identified as *R. troyeri* from cuttings at 1,319–1,329 feet in the Arcon Point Barrow core test 1 appears to be a specimen of *Gaudryina* that is compressed axially; it is biserial throughout most of the test and apparently is triserial in the initial portion. Figured paratype USNM P5996 from the same sample is also compressed axially, but it could be a specimen of *Ammobaculites*, as could unfigured paratype USNM P5995 from well cuttings at 2,820–2,830 feet in the Barrow core test. Also doubtful is the validity of unfigured paratype USNM P5993 from well cuttings at 1,500–1,510 feet in South Barrow test well 1 and of unfigured paratype USNM P5994 from cuttings at 2,340–2,350 feet in the same well. The specimens could all be *Ammobaculites*; the specimen from cuttings at 1,319–1,329 feet in particular has a suggestion of being coiled in the initial part, and the terminal end is produced in a manner that is more pronounced than is characteristic of *Reophax*.

Specimens of *Gaudryina nanushukensis* Tappan are usually readily identified in the *Verneuilinoides borealis* zone, but an unfigured hypotype (USNM P6186) labeled *G. nanushukensis* from sample 47A Z 604 (Tappan, 1962, p. 149) is a specimen of *V. borealis* Tappan. *V. borealis* is a common species in the sample. Furthermore, no specimens of *G. nanushukensis* were found in that sample or in the suite of samples associated with it from the section of the Tuktu Formation on the Kurupa anticline.

THE PROBLEM OF "TRITAXIA" MANITOBENSIS

In a recent publication, Mrs. Loeblich lists *Uvigerinammina manitobensis* (Wickenden) as a species of the *Verneuilinoides borealis* faunal zone (Tappan, 1960). Previously she described this species (Tappan, 1951a) as *Tritaxia manitobensis* Wickenden, and as such it has been listed or cited by myself and others in several subsequent publications on northern Alaska. No explanation for the generic change was given by Mrs. Loeblich, but later (Tappan, 1962, p. 144) she indicated that this was done because this species and *T. athabascensis* Mellon and Wall are trochoid instead of triserial and because specimens of *T. manitobensis* from Alaska and Canada appear to be generically comparable to specimens of *Uvigerinammina jankoi* Majzon. Specimens of *U. jankoi* were supplied to Mrs. Loeblich by

S. Geroch from Upper Cretaceous and Paleogene sediments of the northern and central Carpathians, the area from which the genus was described.

I have not seen the specimens of *Uvigerinammina* studied by Mrs. Loeblich, but I have carefully studied Geroch's figures and description of *Uvigerinammina jankoi* Majzon (Geroch, 1957) and have examined all the available specimens of "*Tritaxia*" *manitobensis* from northern Alaska. I agree with Mrs. Loeblich that the Alaskan forms are not typical of the genus *Tritaxia*, but I question the assignment of them to the genus *Uvigerinammina*; therefore, in this report I have used the name "*Tritaxia*" in quotation marks.

Tests of *Uvigerinammina* are round or indistinctly triangular in cross section and are pear shaped in side view. According to Geroch (1957), when well-preserved specimens are immersed in clove oil, the internal structure shows up, and the chambers are seen to be in a trochoid spire, usually in three to four whorls with three chambers in each of the whorls. The last three chambers occupy more than half the test, and the aperture is on an elevated terminal face but is without a distinct neck; the surface is rather coarse. Geroch indicated that there is variability in the size and shape of the test and that there is a tendency to a biserial arrangement of chambers in some specimens but not in typically formed specimens. No mention is made of flattening or distortion of specimens, whereas the Alaskan specimens identified as "*Tritaxia*" *manitobensis* in this report and as *Uvigerinammina manitobensis* by Tappan (1960, 1962) show various gradations of distortion and flattening (fig. 39).

Study of "*Tritaxia*" *manitobensis* has led me to the conclusion that the tests are biserial but that they can suggest a triserial arrangement if specimens are flattened in certain directions. The undistorted form of "*Tritaxia*" *manitobensis* could be *Siphotextularia? rayi* Tappan, a biserial agglutinate species which has a smooth arenaceous texture identical to that of "*Tritaxia*" *manitobensis*. It usually has 4–6 chambers on a side but may have as many as 10, each succeeding chamber being increasingly inflated. Few specimens of *Siphotextularia? rayi* were found, perhaps because they are recognized only as an undistorted form, but it is important to note that they occur only in the same part of the section as "*Tritaxia*" *manitobensis* and that the two are usually found together in a sample. Specimens of *Siphotextularia? rayi* also show gradations to forms that separately would be considered as "*Tritaxia*" *manitobensis* and "*T*". *athabascensis*. This relationship can be shown experimentally by compressing plasticine models of *Siphotextularia? rayi* tangentially.

A

B

FIGURE 39.—"*Tritaxia*" *manitobensis* Wickenden from *Verneuilinoides borealis* faunal zone, upper part of Torok Formation. *A*, Group of specimens from cuttings at 1,140–1,150 feet, South Barrow test well 1. *B*, Group of specimens from sample 47A Tr 166, north flank of Awuna anticline. All specimens show some degree of flattening and distortion. × 20.

The resultant "chamber" arrangement on the flattened models is similar to that on many specimens of "*T*". *manitobensis*. In contrast, if plasticine models of trochoid or triserially chambered specimens are compressed tangentially, the pattern arrangement of chambers is still triserial and is similar to that of Geroch's (1957) illustrations of *Uvigerinammina*.

A compressed specimen of "*Tritaxia*" *manitobensis* found in cuttings from 300–310 feet in South Barrow test well 1 shows definite biserial arrangement of chambers and also an affinity to *Siphotextularia? rayi*. Two specimens of "*T*". *manitobensis* from cuttings at 365–375 feet from the same well are also biserial but from other characteristics would be identified as "*Tritaxia*" *manitobensis*. The chamber arrangement on these two specimens are the same as those duplicated in tangentially compressed models of *Siphotextularia? rayi.*

Numerous specimens of "*Tritaxia*" *manitobensis* were found in the upper part of Skull Cliff core test 1; many of these specimens have six chambers visible and are definitely biserial, whereas other specimens appear to have a triserial or trochoid arrangement of chambers because the test is distorted. Several specimens from Skull Cliff core test 1 were embedded in bakelite, sectioned, and checked in clove oil, but none showed any indication of the trochoid spire or internal chamber arrangement noted by Geroch (1957, p. 240) for the genus *Uvigerinammina.*

The apertures of specimens of "*Tritaxia*" *manitobensis*, "*T*". *athabascensis*, and *Siphotextularia? rayi* show considerable variation. Some specimens of "*T*". *manitobensis* and "*T*". *athabascensis* have a terminal slit instead of a neck, whereas some specimens of *Siphotextularia? rayi* have a slight neck instead of the usual slit. In general, specimens from western exposures of the Kukpowruk Formation show only an ovate or protruding slit. Although specimens found in the Kukpowruk Formation of the Awuna area show both apertural forms, most have an elliptical slit, and in only a few specimens is a neck or collar seen. Thus it is sometimes difficult to determine whether certain specimens should be identified as "*Tritaxia*" *manitobensis* or as *Siphotextularia? rayi.* Invariably both forms are associated. On some undistorted specimens of the three species considered above, there is a suggestion of apertures being invaginated; this part might be partly extruded into a short neck by pressure on a pliable test at the time of compaction of sediments.

Most specimens of "*Tritaxia*" *manitobensis* that were found in outcropping rocks within the *Verneuilinoides borealis* faunal zone came from the Tuktu Formation, the upper part of the Torok Formation, and the Kukpowruk Formation. Very few specimens were found in the Grandstand Formation, and they are questionably referred to the species in the Corwin Formation. *Siphotextularia? rayi* was not identified as such in the Grandstand and Tuktu Formations, and very few specimens were found in the upper part of the Torok Formation and the Kukpowruk Formation. I have not found *Siphotextularia? rayi* above beds of Albian age in the Alaskan section. Mrs. Loeblich (Tappan, 1962, p. 142) listed an unfigured paratype of the species (USNM P6110) from the Ninuluk Formation from sample 47A Wb 372, but this sample has not yielded any specimens which could be regarded as *Siphotextularia? rayi.*

In the subsurface, "*Tritaxia*" *manitobensis* was found in relative abandance in the Tuktu and Torok Formations of the Barrow wells, Simpson test well 1, Fish Creek test well 1, and Skull Cliff core test 1. It was not found in the Umiat wells nor in Gubik test well 2. In undifferentiated beds of the Tuktu and Grandstand Formations in Gubik test well 1, two small distorted specimens of "*T*". *manitobensis* were found in a core sample from 3,900–3,910 feet, but the same core yielded three specimens of questioned *Siphotextularia? rayi.* A few poorly preserved specimens of "*T*". *manitobensis* came from cuttings, and three tiny specimens came from a core in the upper part of the Torok Formation at 5,100–5,115 feet.

A few small pyritic casts of a biserial form that may be *Siphotextularia? rayi* came from a core at 619–629 feet in Grandstand test well 1, and similar specimens came from cores and cuttings below 2,690 feet. The specimens from the upper core are from the Grandstand Formation; lower specimens are from the Torok Formation. A core at 6,367–6,387 feet in Kaolak test well 1, from beds that are probably part of the Kukpowruk Formation, yielded specimens identified as *Siphotextularia? rayi*, and five flattened specimens that are questionably identified as "*Tritaxia*" *manitobensis.* These five specimens are gradational into *S.? rayi*, and perhaps all should be considered one species. They are, however, listed separately on the faunal chart of the Kaolak test well.

Specimens that are identified as "*Tritaxia*" *manitobensis* were found in Meade test well 1 in numerous ditch samples below 1,400 feet and in a core from 3,825–3,830 feet, but only one or two specimens came from each sample. Some specimens have a flattened ovoid shape. Many specimens do not have a neck such as is characteristic of "*Tritaxia*" *manitobensis*, and the aperture is usually a bulged terminal opening. Some flattened specimens have a neck or protuberance around the aperture in the manner of "*Tritaxia*" *manitobensis* but show features also characteristic of *Siphotextularia? rayi.* It is thus very difficult to identify these specimens because the physical characteristics are similar.

Eicher (1960, p. 66, 67) included *Siphotextularia? rayi* Tappan under the genus *Bimonilina*, which he described as biserial throughout, having a false appearance of becoming uniserial, and having a terminal aperture. He also suggested that *Tritaxia athabaskensis* Mellon and Wall should be included in the genus *Bimonilina.*

RELATIONSHIP OF MICROFOSSILS TO DEPOSITIONAL ENVIRONMENT

Possible environments of deposition of Cretaceous sediments in northern Alaska were described by Mrs. Loeblich (Tappan, 1960), who classified the deposits as fluviatile inland facies, supralittoral and littoral coastal facies, and offshore facies, the offshore facies being further divided into inner sublittoral, outer sublittoral, and open-sea deposits. These facies are modifications of Payne's proposed inland and coastal facies of nonmarine sediments and inshore and offshore facies of marine sediments (Payne and others, 1951). In the same paper, Mrs. Loeblich considered the size of tests of arenaceous Foraminifera to be dependent on the environment of deposition (Tappan, 1960, p. 276–277), and she suggested that large, robust tests are characteristic of inner sublittoral zone deposits of an offshore facies and that stunted forms are indicative of intertidal or littoral zone deposits of a coastal facies. The intertongues of the southernmost beds of the Grandstand Formation and the Killik Tongue of the Chandler Formation are cited as an example of the coastal facies. However, I have observed that, within the *Verneuilinoides borealis* faunal zone, some of the largest and best specimens of *Verneuilinoides borealis* occurred in intertongues of the Grandstand Formation and that some of the smallest forms in this faunal zone were in coastal well sections which Mrs. Loeblich would classify as offshore outer sublittoral zone deposits. In samples from the *Verneuilinoides borealis* faunal zone in the coastal wells, it was not uncommon to find stunted forms above or below samples containing specimens of average or large size. For example, both large and small tests of *Miliammina manitobensis* were found in the same section that yielded small specimens of the species in other samples.

Although the environment of deposition is probably a factor in determining size of foraminiferal tests, only generalizations can be made for the Cretaceous environment of northern Alaska. For example, the Corwin Formation of the Corwin Bluff region is reported to have characteristic stunted arenaceous Foraminifera of the intertidal (littoral) facies of the *Verneuilinoides borealis* zone (Tappan, 1960, p. 280), but Foraminifera are so scarce in the relatively small number of microfossils collected in that area that it is difficult to give any true evaluation of the fauna or assess whether or not the species are stunted. Furthermore, some of the Foraminifera from samples collected from the Corwin Formation along the Utukok, Kokolik, and Kukpowruk Rivers are of average or normal size.

Samples examined from the Corwin Formation from the Awuna-Kigalik area are available; some carried little or no fauna, but in others microfossils were fairly numerous. Interestingly enough, the percentage of large specimens of arenaceous Foraminifera exceeds that of so-called stunted forms.

Further indication that only generalizations can be made regarding size of tests in relation to environment is in the consideration of "*Tritaxia*" *manitobensis* which was listed by Mrs. Loeblich under the genus *Uvigerinammina* as one of a few species that is characteristically large and robust in deposits of the inner sublittoral zone (Tappan, 1960, p. 277). This species, however, does not follow a predictable pattern as to occurrence or size of specimens. The species seems to be more common in the outcropping Kukpowruk Formation (presumably inner sublittoral zone) and the upper part of the Torok Formation of the Awuna area than in any other formations, but in the subsurface it is more erratic. The species is very scarce in the *Verneuilinoides borealis* zone in the Umiat wells, in beds which would probably be classed as deposits of the inner sublittoral environment. In contrast, large tests of the species are common in samples from Skull Cliff core test 1 and Simpson test well 1 in sections which would be classified by Mrs. Loeblich as outer sublittoral environment deposits (Tappan, 1960, p. 280). Also noteworthy is the fact that about 63 percent of the Foraminifera recovered from these sections are calcareous and that the number of specimens of many species is greater than the number of specimens of species occurring in Mrs. Loeblich's inner sublittoral environment, although she (Tappan, 1960, p. 277) indicated that "increased competition resulted in fewer specimens of each species than in the preceding [inner sublittoral] facies."

In another coastal plain well (Fish Creek test well 1), few specimens of "*Tritaxia*" *manitobensis* are found in beds that Mrs. Loeblich would classify as outer sublittoral deposits. Perhaps the deposits should be considered as inner sublittoral zone about equivalent to the *Verneuilinoides borealis* zone of the Umiat wells as some of Mrs. Loeblich's list of characteristic environment fossils of that zone are present.

CENOMANIAN ROCKS

GAUDRYINA IRENENSIS–TROCHAMMINA RUTHERFORDI FAUNAL ZONE

Few of the foraminiferal genera in beds of Albian age in northern Alaska continue into the younger sediments, and only a small assemblage composed predominantly of species of *Trochammina* and *Gaudryina* occurs in the Ninuluk Formation. This assemblage was described or referred to as the *Gaudryina canadensis*–*Trochammina rutherfordi* zone in previous publications (Bergquist, 1958a, 1959a, b). From detailed studies of all available specimens of *Gaudryina* from the Cretaceous rocks of Alaska, however, it became apparent that most of the well-preserved specimens from the Ninuluk Formation had a longer biserial stage than is characteristic of *G. canadensis* from the rocks of Albian age, and these specimens seemed to be the same as *G. irenensis* Stelck and Wall from the lower part of the Kaskapau Formation of Cenomanian age in western Canada. Mrs. Loeblich (oral commun., 1959) concurred in this interpretation. In accord with this change in identification, the name of the faunal zone in the Ninuluk Formation is here corrected to the *Gaudryina irenensis–Trochammina rutherfordi* zone although Mrs. Loeblich (Tappan, 1960, p. 284) regarded the Early Cretaceous *T. rutherfordi* Stelck and Wall as a subspecies of the Late Cretaceous *T. ribstonensis* Wickenden. To use the triple name in the nomenclature of the faunal zone would be somewhat cumbersome however.

The faunal zone within the Ninuluk Formation is best known from microfossil samples collected by Charles Kirschner and R. L. Detterman in 1945 and 1947 from the type locality of the Ninuluk Formation in the southwest end of Ninuluk Bluff on the right bank of the Colville River, 20 miles downstream from the mouth of the Killik River. The samples represent about 800 feet of combined beds of the Ninuluk Formation and the Niakogon Tongue of the Chandler Formation; fossils were found in 26 of the 44 samples collected.

Four species of arenaceous Foraminifera were found in samples from the type section of the Ninuluk Formation, and these species in order of relative abundance are *Trochammina ribstonensis* Wickenden subsp. *rutherfordi* Stelck and Wall, *Gaudryina irenensis* Stelck and Wall, *Saccammina lathrami* Tappan, and *Trochammina wetteri* Stelck and Wall. Most of the Foraminifera are from the upper beds of the Ninuluk Formation which overlie part of the Niakogon Tongue. In fact, elsewhere in the type section of the Ninuluk Formation, few Foraminifera were found except for abundant *Trochammina ribstonensis rutherfordi* in a few samples below the upper part of the Niakogon Tongue. In the lowest beds of the type locality, microfossils are seemingly very few, but *T. ribstonensis rutherfordi* was very abundant in one sample and *Saccammina lathrami* was abundant in another. A few charophytes came from the Niakogon beds.

Microfossil data from the type section of the Ninuluk Formation thus suggest that the *Gaudryina-Trochammina* fauna is largely in the uppermost part, but I have generally regarded the fossils as characteristic of the entire formation and have made no attempt to delimit parts based on the absence of one of the characteristic species.

Samples from the Ninuluk Formation of areas other than the type locality have furnished a few other Foraminifera: *Haplophragmoides rota* Nauss, *Verneuilinoides fischeri* Tappan?, *Textularia* cf. *T. rollaensis* Stelck and Wall, *Trochammina diagonis* Carsey? and *Praebulimina seabeensis* Tappan. Most of these species are of only minor occurrence.

A

B

FIGURE 40.—*Trochammina wetteri* Stelck and Wall from sample 47A Dt 58, Ninuluk Formation, south side of the Colville River, southwest end of Ninuluk Bluff, approximately 32 miles air line southwest of Umiat, Alaska. *A*, Flattened specimens; *B*, Normal specimens. × 20.

Siphotextularia? *rayi* Tappan and *Trochammina rainwateri* Cushman and Applin were listed by Mrs. Loeblich (Tappan, 1960, p. 284) as components of this fauna. However, I have not found *S.*? *rayi* in any of the Ninuluk samples and doubt that it contained beyond the late Albian. The specimens which Mrs. Loeblich referred to *Trochammina rainwateri* may be what I have identified as *T. wetteri* Stelck and Wall (fig. 40). *T. wetteri* is a low-spired form composed of four whorls with five globular chambers in each of the last three whorls; it has a lobulate periphery, sutures similar to those of *T. rainwateri*, but fewer chambers in the later whorls; many of the specimens are in part pyritized. *T. wetteri* was described from rocks of the lower part of the Kaskapau Formation of the Peace River area, Western Canada.

The Foraminifera of the Ninuluk Formation are for the most part species that have been described from rocks of Cenomanian age in Canada. This age is corroborated by the following megafossils, which were identified by Ralph Imlay: *Inoceramus athabascensis* McLearn, *I. dunveganensis* McLearn, *Panope dunveganensis* Warren, and *Arctica dowlingi* (McLearn), all species that were described from rocks of Cenomanian age in western Canada (R. W. Imlay, written commun., 1954).

The environment of the deposition of sediments of the Ninuluk Formation is regarded by Mrs. Loeblich as largely very nearshore to intertidal, and the fauna is regarded as stunted (Tappan, 1960, p. 280). Mrs. Loeblich's interpretation of the environment of deposition seems to be correct, but I do not consider the species present to be stunted.

The *Gaudryina irenensis–Trochammina rutherfordi* zone of the Ninuluk Formation is known from several wells in the foothills region, but was not recognized in the subsurface of the coastal plain. The faunal zone is sparingly present in four of the wells in the Umiat field. It was identified in test well 6, where specimens of *Trochammina wetteri* were found, and it possibly occurs in test well 9. In test well 10, the faunal zone is recognized at two levels owing to faulting, but most of the few specimens found are *T. wetteri.* In test well 11, *T. ribstonensis rutherfordi* was abundant in one sample.

In Wolf Creek test wells 1 and 2 and in Square Lake test well 1, the zone is recognized from sparse occurrences of *Gaudryina irenensis* and *Trochammina ribstonensis rutherfordi;* in Wolf Creek test well 3 these species are fairly numerous, and *T. ribstonensis rutherfordi* is common to abundant in nearly one-third of the samples through nearly 500 feet of section (Bergquist, 1959a).

Specimens of *Gaudryina irenensis* and *Trochammina ribstonensis rutherfordi* were found in most of the samples from the upper 500 feet in Titaluk test well 1 and attest to the presence of the faunal zone in that well.

Flattened and distorted specimens of *Gaudryina irenensis?* occur in Gubik test wells 1 and 2, in beds referred to the Ninuluk Formation. The zone is very thin, however, and the presence of the formation cannot be determined from the fauna.

From the foregoing statements, it seems that the *Gaudryina irenensis–Trochamina rutherfordi* faunal zone of the Ninuluk Formation is restricted geographically. It is best represented in the upper part of the Ninuluk Formation at the type locality and in the subsurface in Titaluk test well 1. It is poorly represented in several subsurface sections where it seemingly might underlie the Seabee Formation of Turonian age. In certain of the coastal plain test wells (Simpson Seeps area, Fish Creek test well 1, and others), the zone is absent; if rocks of Cenomanian age are present there, they could only be part of the nonmarine Niakogon Tongue of the Chandler Formation.

TURONIAN ROCKS

In some areas of outcrop of the lower part of the Shale Wall Member of the Seabee Formation, there is a concentration of *Haphlophragmoides rota* Nauss, *Gaudryina?* sp. (possibly some of these are *Gaudryina irenensis* Stelck and Wall), *Textularia* sp., *Trochammina diagonis* Carsey, *T. ribstonensis* Wickenden, and *T. whittingtoni* Tappan. In the subsurface, some of the elongate coiled forms found in the lower part of the Seabee Formation may be *Gaudryina irenensis.* Several of the above-mentioned species range upward into the Schrader Bluff Formation, but species of *Textularia* (*Textularia* cf. *T. gravenori* Stelck and Wall and *T. rollaensis* Stelck and Wall) and medially depressed, discoidal pyritic objects that may be Radiolaria ("*Zonodiscus*" sp. A) (fig. 41) are restricted to the Seabee Formation.

A thin zone of pelagic Foraminifera, *Hedbergella loetterlei* (Nauss) and *Heterohelix globulosa* (Ehrenberg), and abundant Radiolaria were found in the upper part of the Shale Wall Member of the Seabee Formation in certain core tests in the Cape Simpson area. The two species of Foraminifera are part of a

FIGURE 41.—Pyritic casts of "*Zonodiscus*" sp. A from Ayiyak Member of the Seabee Formation (*Pseudoclavulina hastata–Arenobulimina torula* faunal zone), Gubik test well 2, core at 2,180–2,190 feet. × 20.

widespread zone in beds of Turonian age in western Canada and the northwestern United States. Associated with these pelagic Foraminifera in Alaska is a small ammonite (*Borissiakoceras*).

Another thin but distinctive microfossil zone occurs in shale and sandstone beds of the Ayiyak Member of the Seabee Formation in the southern foothills. The zone is characterized by only two Foraminifera, *Pseudoclavulina hastata* (Cushman) and *Arenobulimina torula* Tappan and is known from a few outcrop samples and two subsurface areas.

HEDBERGELLA LOETTERLEI–HETEROHELIX GLOBULOSA FAUNAL ZONE

The thin *Hedbergella loetterlei–Heterohelix globulosa* zone of Radiolaria and pelagic Foraminifera was found within beds assigned to the upper part of the Shale Wall Member of the Seabee Formation in Simpson core tests 13, 15, 16, 26, 27, and 30. The zone was noted only in the subsurface of this northern area and was not found in the type section of the Seabee Formation, nor is it known from the outcrop. The two Foraminifera are seemingly associated with a few species of nasselline and spumelline Radiolaria. The two pelagic Foraminifera were reported by Mrs. Loeblich (Tappan, 1960, p. 289) as occurring in the "central Kaskapau" of Stelck and Wall in the Peace River area and the upper part of the Lloydminster Shale in Alberta, in the Favel Formation of Manitoba and Saskatchewan, and in the Frontier Formation of Montana. Nauss (1947, p. 336), in his description of "*Globigerina loetterlei*", reported it as occurring in "floods" in the central part of the Lloydminster Shale in association with a few specimens of "*Gümbelina globulosa*", and he found it as a zone in wells in the Vermillian area in southern Alberta.

In Alaska, *Hedbergella loetterlei* was found in abundance in a core sample from 655 feet in Simpson core test 13 with specimens of *Heterohelix globulosa*, which were common. Radiolaria were rare in that sample, but in Simpson core tests 15 and 16 the reverse was true, as radiolarian species of *Cenosphaera*, *Spongodiscus*, and *Dictyomitra* were abundant and the pelagic Foraminifera were represented by only one specimen of *H. loetterlei* from each core test. Only Radiolaria were found in Simpson core tests 26 and 27, but genera other than those cited above were also present in lesser numbers. Radiolaria were numerous through 100 feet of section (143–243 feet) in Simpson core test 30, and a few specimens of *H. loetterlei* and *H. globulosa* were found in one sample (153–162 feet). Imprints of *Borissiakoceras* sp. were associated with the zone in some of the core tests.

PSEUDOCLAVULINA HASTATA–ARENOBULIMINA TORULA FAUNAL ZONE

Within the Ayiyak Member of the Seabee Formation, a thin microfossil zone is characterized by two species of Foraminifera: *Pseudoclavulina hastata* (Cushman) (fig. 42) and *Arenobulimina torula* Tappan (fig. 43). The former was described from beds of Turonian age in Canada and is distinguished by a short triserial initial stage followed by a long uniserial stage. It is the only species of this genus known from the

FIGURE 42.—*Pseudoclavulina hastata* (Cushman) from sample 47A Wb 428 from upper 100–125 feet of Ayiyak Member of Seabee Formation, at Schrader Bluff on the Anaktuvuk River. × 30.

FIGURE 43.—*Arenobulimina torula* Tappan from Ayiyak Member of the Seabee Formation, Gubik test well 2, core at 2,200–2,210 feet. × 20.

Cretaceous of Alaska. *A. torula* is a trochoid form with a high-coiled spire that is distinctive even on flattened specimens. The two species were found in about half of the 41 outcrop samples collected from the Ayiyak Member of the Seabee Formation (table 10); the Ayiyak Member is restricted to the southernmost exposures of the formation south of the Umiat-Maybe Creek area (Detterman, 1956, p. 253). The species were also found in stratigraphically equivalent beds in sections of the Seabee Formation in Umiat test well 11 and in the Gubik test wells. Neither of these species are known from the remainder of the Seabee Formation, and the zone as such was not found in subsurface sections of the formation in the coastal plain area. Specimens of *A. torula*, however, were found in samples from seismograph shot holes in the Shaviovik area in rocks identified as being in the upper part of the Ignek Formation.

The presence of *Arenobuliminia torula* in the upper part of the Ignek Formation does not necessarily indicate that the beds are the equivalent of the Ayiyak Member of the Seabee Formation, but it does suggest a similar stratigraphic position. An excellently preserved specimen selected as holotype for the species (Tappan, 1957, p. 209) came from a seismograph shot hole (No. 6, line 4–53–144) on the east end of the south flank of the Shaviovik anticline, about 2 miles S. 60° W. of the junction of Fin and Juniper Creeks (approx. lat 69°34′15″, N. long 147°33′45″ W.). (Note: for location of seismograph line see Keller and others, 1961.) Other specimens of *A. torula* from seismograph holes in the Shaviovik area are listed as unfigured paratypes by Mrs. Loeblich (Tappan, 1957).

Microfossils associated with *Pseudoclavulina hastata* and *Arenobulimina torula* include elongate coiled forms referred to *Dorothia*? sp. and *Gaudryina*? sp.; these forms, which are known from only nine occurrences, are crushed and too poorly preserved for positive identification. A few specimens of *Saccammina lathrami* Tappan and of pyritic discoidal Radiolaria ("*Zonodiscus*"? sp.) constitute the rest of the Ayiyak fauna.

The *Pseudoclavulina hastata–Arenobulimina torula* faunal zone was first recorded in 1956 (Bergquist, 1956a) and was later defined (Bergquist, 1958b) as occurring in the upper 200 feet of the Ayiyak Member of the Seabee Formation. Mrs. Loeblich suggested that the zone should be expanded to include the remainder of the Seabee Formation also (Tappan, 1960, p. 284). I do not concur with this suggestion, however, because the two distinctive fossils are restricted stratigraphically. I regard the zone, as originally defined, to be limited to the Ayiyak Member of the Seabee Formation.

SENONIAN ROCKS

NEOBULIMINA CANADENSIS FAUNAL ZONE

A number of microfossil species are restricted to the Schrader Bluff Formation, and analysis of outcrop and subsurface samples leads to some difficulty in selecting one or more Foraminifera that can be considered characteristic. A dual name of *Trochammina ribstonensis–Neobulimina canadensis* was proposed as a faunal zone by Mrs. Loeblich (Tappan, 1960, p. 285), who stated that *Trochammina ribstonensis* Wickenden occurs rarely in the underlying zone but is most characteristic of the Schrader Bluff Formation. I do not agree entirely with this as my data indicate that *T. ribstonensis* is as equally distributed in the Seabee Formation as it is in the Schrader Bluff Formation. The choice of *Neobulimina canadensis* Cushman and Wickenden is acceptable, but *Gavelinella ammonoides* (Reuss) and *Anomalinoides talaria* (Nauss) are also of equal or greater abundance in the formation. In addition, such species as *Nonionella taylorensis* Hofker, *Quinqueloculina sphaera* Nauss, and *Vaginulina schraderensis* Tappan are also characteristic but are not as frequent in occurrence. Two of the above-mentioned species, *Gavelinella ammonoides* and *Nonionella taylorensis*, along with *Ammodiscus cretaceus* (Reuss) are among eight species that Mrs. Loeblich cited as restricted to the Sentinel Hill Member (Tappan, 1960, p. 285), but they occur in all three members of the Schrader Bluff Formation.

Neobulimina canadensis is sparingly present in samples from the Schrader Bluff Formation in North Simpson test well 1 but was not found in any of the members of the Schrader Bluff Formation in Fish Creek test well 1, where the best subsurface section was penetrated.

Because the name *Neobulimina canadensis* has already been proposed for the faunal zone and because the species is as characteristic as others in some sections, the name is retained here, but *Trochammina ribstonensis* is not desirable as part of a dual name for the zone because of its equal distribution in the Seabee Formation.

Some Foraminifera are conspicuous enough within parts of the Schrader Bluff Formation to comprise faunal subzones. For example, *Praebulimina venusae* (Nauss) is characteristic of the Barrow Trail Member, and the large *Trochammina stefanssoni* Tappan is characteristic of both the Barrow Trail and Sentinel Hill Members. A particularly conspicuous foraminifer in the Sentinel Hill Member is *Eoeponidella strombodes* Tappan, a species belonging to a genus having a stellate pattern on the ventral surface of the test, similar to the genus *Asterigerina* of the Tertiary. The genus *Eoeponidella*, however, is seemingly confined to beds of late

Senonian age and as such is a good indicator of the youngest beds of the northern Alaskan Late Cretaceous section in which two species (*E. linki* Wickenden and *E. strombodes* Tappan) have been found. *E. strombodes* was proposed as the name of a faunal zone delineated in the Sentinel Hill Member of the Schrader Bluff Formation (Bergquist, 1956a) as it is very useful to identify the lower 400 feet of the member. It is now regarded as a subzone of the *Neobulimina canadensis* zone. None of the microfossils of the Schrader Bluff Formation seem to be characteristic of the Rogers Creek Member.

Locally in the subsurface of the coastal plain, a radiolarian zone is conspicuous in the lower part of the Sentinel Hill Member and in the Barrow Trail Member. This zone occurs most extensively in Fish Creek test well 1 and to a lesser extent in North Simpson test well 1. At least a score of radiolarian species, some of unusually large size, were found in the Fish Creek well. Clear volcanic glass shards occur in the same section but were not found in beds carrying the Radiolaria.

Foraminifera of the Schrader Bluff Formation were listed by Mrs. Loeblich (Tappan, 1960, p. 285), but she gave no data on the relative abundance of each species. Some species are relatively numerous, but many are of rare occurrence. The relative abundance of most species of Foraminifera and Radiolaria found in 165 outcrop samples from the formation is summarized on plate 14. Some of my identifications differ from those of Mrs. Loeblich. For example, I found *Praebulimina cushmani* (Sandidge) and *Aeolostreptis vitrea* (Cushman and Parker) only in subsurface samples and do not recognize *Gaudryina irenensis* Stelck and Wall, as recorded by Mrs. Loeblich, in any of the samples from the Schrader Bluff Formation. However, I have listed *Gaudryina?* sp. and *Dorothia?* sp. on the faunal chart and have maintained the same usage in identifications of subsurface material. These species may be comparable to *G. irenensis* of Mrs. Loeblich, but because most elongate coiled specimens found in the Schrader Bluff Formation are crushed and poorly preserved, I do not believe a positive identification can be made; I could find no specimens that could be specifically identified.

A species which I would completely exclude from a list of Foraminifera in the Schrader Bluff Formation is *Pseudoclavulina hastata* (Cushman). Its inclusion in the Schrader Bluff Formation by Mrs. Loeblich was probably based on the unfigured hypotype of the species which she listed (Tappan, 1962, p. 151) from a sample of the Rogers Creek Member from the Schrader Bluff locality on Anaktuvuk River. The specimen is the only one of its kind found in a suite of 15 samples collected at that locality, whereas the species was common to abundant in two samples and rare in three samples from the Ayiyak Member of the Seabee Formation of the same area. Furthermore, the specimen cited from the Rogers Creek Member is the only one found in more than 160 fossiliferous samples of the Schrader Bluff Formation. The sample from which it was reported was collected 435 feet above the top of the Ayiyak Member of the Seabee Formation and this position places doubt on its validity as no other specimens of *P. hastata* were found above the Ayiyak. Possibly the specimen was introduced into the sample by screen contamination as all samples collected from the Schrader Bluff locality were processed in the laboratory during one day's run.

Foraminifera of the Schrader Bluff Formation suggest a Senonian age. Several species were originally described from the Bearpaw and Lea Park Shales and Belly River Formation of Alberta and from the Morden beds of Manitoba. A correlation of the Alaskan and Canadian sections of Senonian age was given by Mrs. Loeblich (Tappan, 1960, fig. 6, p. 286). However, the suggestion made by Jones and Gryc (1960, p. 153) that beds of Coniacian age may be missing in northern Alaska may be somewhat substantiated by the fact that the microfauna of the Schrader Bluff Formation is for the most part distinctly different from that of the Seabee Formation.

SUBSURFACE STUDIES

The following part of this report discusses the micropaleontology of selected core tests and all test wells drilled in northern Alaska during the Navy's exploration program. Although much of the data concerns the microfaunal zones recognized in the Cretaceous rocks, the paleontology of the Jurassic and Triassic sections penetrated in the Avak-Barrow area, in Simpson test well 1, and in Topagoruk test well 1, is also included.

Microfossil samples were washed and studied in the Geological Survey laboratory at Fairbanks. Inasmuch as samples were processed concurrently with the drilling and exploration, large samples were seldom processed merely to secure large population counts. Generally about 6 grams of each washed sample was picked for microfossils, and faunal counts are based on this average amount, but if the washed sample consisted of only a few grams, the entire amount was picked for microfossils. The wells are discussed in roughly geographic order, from northwest to southeast.

SKULL CLIFF CORE TEST 1

Skull Cliff core test 1 was a stratigraphic test drilled near an oil seep, about 1¼ miles inland from the Arctic Ocean and about 40 miles southwest of Point Barrow. Originally a 1,500-foot test was considered, but mechanical difficulties necessitated abandonment at 779 feet. Coring was continuous from 100 to 776 feet. The recovered cores and cuttings have been described by Collins (1961, p. 576–579) who considered the section between 50 and 450 feet to be part of the Grandstand Formation and the remainder of the beds penetrated to be in the Topagoruk Formation. This designation was probably made because sandstone makes up about 54 percent of the upper beds, particularly in the upper 200 feet of section. The microfossils, however, suggest that the entire section is within the Torok Formation inasmuch as the section below 256 feet is part of the *Textularia topagorukensis* faunal subzone of the lower part of the *Verneuilinoides borealis* faunal zone. As indicated earlier in the discussion of the *V. borealis* faunal zone, the *T. topagorukensis* subzone seems to be entirely confined to the upper part of the Torok Formation and is especially well represented in the northern test wells, where it extends through about 1,600–1,700 feet of section. The faunal summary of microfossils recovered from the Skull Cliff core test is shown on plate 17. Arcon core test 1 (total depth 1,442 ft) yielded microfossils of the *V. borealis* zone that are similar to those from the upper part of South Barrow test well 1.

SOUTH BARROW TEST WELL 1

South Barrow test well 1, about 1 mile southwest of the Barrow camp, penetrated 70 feet of Pleistocene sediments (Gubik Formation) and approximately 3,320 feet of sandstone, siltstone, clay shale, and claystone of Albian age. The lowest 560 feet of the Albian beds is predominantly claystone containing pebbles of quartz and gray to black chert. Fossiliferous beds occurred in the upper 1,600 feet of section and in the pebble shale beds between 2,847 and 3,385 feet. The stratigraphic distribution of the microfossils is shown on plate 17. Argillite is present below 3,385 feet. The first core came from 1,200–1,210 feet; 5 other cores were taken between that depth and 2,847 feet, which is the top of the first of 39 cores from the pebble shale section. Six cores came from the argillite.

The Cretaceous fossils found in samples from this test hole are all of Albian age. The upper beds carry a *Verneuilinoides borealis* fauna of 47 species of the same species found in the Tuktu Formation and upper part of the Torok Formation; thus the predominantly sandstone section from 70 to 390 feet is here considered the age equivalent of the Tuktu Formation, and the fossiliferous shale section down to approximately 1,600 feet is equivalent to the upper part of the Torok Formation. Sparingly fossiliferous beds from 1,600 feet to the pebble shale section at 2,825 feet may represent middle beds of the Torok Formation. Below 2,825 feet, in the pebble shale section, most of the cores and some of the ditch sampels carried a fairly prolific fauna of the *Gaudryina tailleuri* zone.

MIDDLE TO UPPER ALBIAN ROCKS

VERNEUILINOIDES BOREALIS FAUNAL ZONE (70–2,825 FT)

Gubik microfossils occurred in most samples through 190 feet, but *Inoceramus* prisms in a sample from 100–110 feet indicate Cretaceous rocks. Between 100 and 260 feet, however, only two or three specimens of Cretaceous Foraminifera were found; samples through that interval and down to a depth of 620 feet carried an abundance of *Inoceramus* prisms and tubes of *Ditrupa cornu* Imlay. Below the depth of 260 feet and probably extending at least through 1,040–1,050 feet, a small fauna of the *Verneuilinoides borealis* faunal zone occurred. This fauna consisted of frequent and some abundant occurrences of specimens of *Haplophragmoides topagorukensis* Tappan, frequent occurrences of specimens of *Bathysiphon vitta* Nauss? (fig. 44), *V. borealis* Tappan, *Miliammina manitobensis* Wickenden, "*Tritaxia*" *manitobensis* Wickenden, and *Gavelinella stictata* (Tappan), and infrequent occurrences of *Saccammina lathrami* Tappan, *Ammodiscus mangusi* (Tappan), *Ammobaculities wenonahae* Tappan, *Lenticulina macrodisca* (Reuss), and *Eurycheilostoma grandstandensis* Tappan. A few other species occurred very rarely.

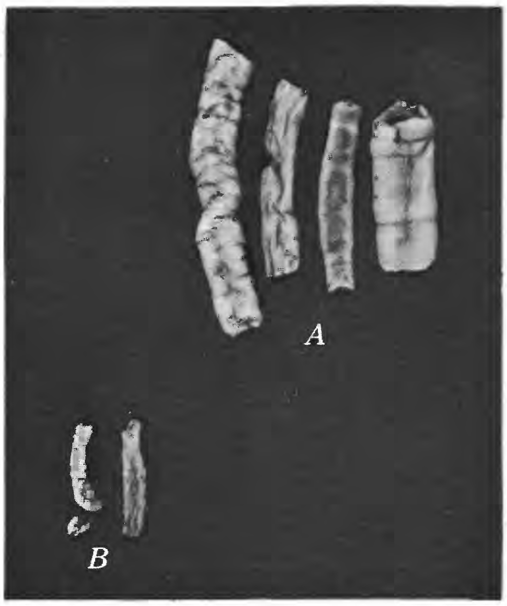


FIGURE 44.—*A*, Specimens of *Bathysiphon vitta* Nauss?. *B*, Specimens of *Bathysiphon brosgei* Tappan, from Torok Formation, South Barrow test well 1, cuttings at 1,640–1,650 feet. × 10.

In addition to these species, fossils fragments of a minute crinoid, *Balanocrinus* sp., which first appeared in a sample at 280–290 feet, were scattered in samples through the depth of 570 feet. This fossil, plus the preceding assemblage of microfossils and *Ditrupa cornu* indicate an Albian age and may be a part of the Tuktu Formation; they are similar to the Albian assemblage found in the upper part of Simpson test well 1 and suggest that the section in South Barrow test well 1 may be about 600 feet lower stratigraphically.

The beds at 1,060–1,070 feet are marked by common specimens of *Gaudryina nanushukensis* Tappan and a few of *Textularia topagorukensis* Tappan, *Psamminopelta bowsheri* Tappan, and glauconitic casts of *Dictyomitra* sp. The glauconitic casts of *Dictyomitra* sp. are conspicuous in the lower part of the *Verneuilinoides borealis* faunal zone throughout the Barrow-Simpson-Topagoruk area, and the casts occur in South Barrow test well 2 along with *G. nanushukensis* and *T. topagorukensis*. Specimens of *T. topagorukensis* were common in cores at 1,200–1,210 feet and 1,600–1,610 feet in South Barrow test well 1.

Through the interval 1,200–1,800 feet, the ditch samples carried numerous specimens of the *Verneuilinoides borealis* fauna, but many of these specimens could be contamination from the higher beds. Contamination is definitely conspicuous at lower depths throughout the hole as many ditch samples carried the *V. borealis* fauna found in the upper 1,200 feet of section, whereas the cores from 1,906–1,916 feet and 2,094–2,100 feet yielded very few Foraminifera and the cores from 2,352–2,360 feet and 2,625–2,635 feet were barren. An example of this contamination is the occurrence of specimens of *Balanocrinus* sp. in samples as low as 2,830–2,840 feet, within the pebble shale section of the lower part of the Torok Formation; all data indicate that *Balanocrinus* sp. is never found lower than the upper part of that formation and that it occurs principally in the Tuktu Formation. Cores from the pebble shale section carry a different fauna from that of the *V. borealis* zone.

Specimens of *Verneuilinoides borealis* in the samples from the upper beds are flattened and granular, and they have their sutures and chambers somewhat obscured; in general they are very tiny, and all are white in all samples to a depth of 470 feet. Below 470 feet the tests of *V. borealis* are somewhat elongated, and the flattened chambers are overlapped. Few specimens are free of flattening or distortion. In the same section, tests of *Haplophragmoides topagorukensis* are granular to fine textured and have smooth surfaces; most are flattened and show some distortion. Some tests have a simulated ribbed appearance because the walls of the chambers are sunken.

775–799 O—66——6

Specimens of "*Tritaxia*" *manitobensis* are white, and all are compressed. Many of these specimens have multiple chambers which may be overlapped, but others, such as those from the core at 1,200–1,210 feet, are large and baglike and the chambers are scarcely visible. All have an aperture at the end of a short thick neck.

LOWER ALBIAN ROCKS

GAUDRYINA TAILLEURI FAUNAL ZONE (2,825–3,385? FT)

The cores from the pebble shale section yielded a microfauna of about 22 species characterized by *Gaudryina tailleuri* (Tappan) and other species limited to the lower part of the Torok Formation or equivalent rocks. A few species in the samples are the same as those of the *Verneuilinoides borealis* zone, but most of those characteristic of the younger Albian beds are absent. The lower Albian arenaceous specimens also differ in preservation from those of the *V. borealis* zone, chiefly in being grayish-green instead of white, and in general they are less flattened or distorted than are the specimens from the younger beds.

In the abundance of specimens of *Haplophragmoides topagorukensis*, the fauna is similar to that of the *Verneuilinoides borealis* zone; but the specimens of *H. topagorukensis* are gray, and many have sutures that are darker gray than the chamber walls, which simulates transverse banding on the tests. The most conspicuous fossil is *Gaudryina tailleuri*. This elongated form has a short triserial part and a long biserial part; generally the specimens are well preserved. Another species of *Gaudryina* that seems to be limited entirely to the lower Albian beds is *G. barrowensis* Tappan. Specimens resemble *G. nanushukensis* of the *V. borealis* zone, but they are smaller and have lower and more closely appressed chambers; the sides are more excavated, causing the angles of the tests to be sharper and more acute. Specimens of *G. barrowensis* occurred much less frequently than those of *G. tailleuri*. Incomplete tests of *Ammobaculites fragmentarius* Cushman were found in many cores, and a few tests of a large "*Tritaxia*" ("*T.*" *athabascensis* Mellon and Wall) occurred in several cores. The "Tritaxias" apparently are the same species as that described from the Clearwater Formation of Alberta (Mellon and Wall, 1956). Tests are larger and have more chambers than do those of the younger species, "*T.*" *manitobensis* Wickenden, which occurs in the *V. borealis* zone of Alaska and the Ashville Formation of Manitoba (Wickenden, 1945).

Miliammina awunensis Tappan and *Saccammina lathrami* Tappan, two species that occur in younger Albian beds, are found infrequently in samples from the pebble shale section. Specimens identified as *Trochammina gatesensis* Stelck and Wall are rare.

Calcareous species of Foraminifera are generally well preserved in the pebble shale section, and several species of infrequent occurrence were found. Most of them can be identified with European Albian forms; usually only one or two specimens were found in a sample, or only a single occurrence was noted in the entire section. The most frequently occurring calcareous species are *Gavelinella awunensis* (Tappan), *Conorboides umiatensis* (Tappan), and *Saracenaria trollopei* Mellon and Wall. *S. trollopei* was described from the Clearwater Formation of Alberta and has been reported from the Moosebar Formation of British Columbia (Mellon and Wall, 1956).

A few pelecypod and gastropod shells in cores from the *G. tailleuri* zone were identified by Ralph Imlay and reported by Collins (1961, p. 589), but only one form could be given specific identification. This is *Thracia kissoumi* McLearn which occurs in Alberta in the lower part of the lower sandstone member of the Peace River Formation and in the Clearwater and Loon River Formations, all of early Albian age (Imlay, 1961).

Collins (1961, p. 590) reported the presence of argillite in a core from 3,355–3,360 feet and recovery of only drilling mud and claystone fragments from cores at the following depths: 3,368–3,374 feet, 3,374–3,776 feet, 3,382–3,382½ feet, and 3,402–3,410 feet. Washed samples of each of the cores recovered from the footages cited yielded the microfossils of the *Gaudryina tailleuri* zone which are listed on plate 17. These samples were processed in October 1948 and were never rerun to determine whether or not the fossils were carried by the drilling mud from the beds between 2,825 and 3,346 feet where the *G. tailleuri* zone is more clearly defined or were actually from the claystone fragments. The section from which these lower cores came may be fractured or crumpled and may not represent a clearly defined Cretaceous section. Thus the top of the basement argillite has been questionably placed at 3,385 feet by Collins (1961, p. 589); below that depth the argillite is continuous to the bottom of the hole.

PALEOZOIC(?) ROCKS

ARGILLITE (3,385?–3,553 FT, TOTAL DEPTH)

Hard, siliceous, bluish-gray to black argillite was penetrated at 3,385 feet and drilled to 3,553 feet, but Collins (1961, p. 586) reported that the rock dips steeply and that actually not more than 80 feet of argillite may have been penetrated. The black beds of argillite are somewhat carbonaceous. An origin from organic marine sediment in which siliceous organisms (Radiolaria) predominated is suggested by Charles Milton of the Geological Survey for a siliceous black argillite at 3,451 feet and a light-gray siliceous rock at 3,495 feet (Collins, 1961, p. 590). To date Radiolaria have been noted only rarely in the pre-Mesozoic rocks in northern Alaska, and the widespread paucity of these organisms in unmetamorphosed Paleozoic rocks from the area seems to largely refute the possibility that they could have been abundant in the rock from which the argillite was formed.

SOUTH BARROW TEST WELL 2

South Barrow test well 2 was drilled on a high point of the Barrow structure about 5 miles south of Barrow camp, and the well produced gas for the camp from April 1949 until it burned and was abandoned in March 1950. Less than 100 feet of Pleistocene sediments of the Gubik Formation mantle the area of this test well, and beneath them the drill penetrated only a little more than 2,200 feet of Lower Cretaceous Albian beds and about 100 feet of Lower Jurassic rocks. The test bottomed in black argillite, which was penetrated at 2,443 feet, approximately 942 feet higher than in South Barrow test well 1.

The site of the well is 700–800 feet structurally higher than that of South Barrow test well 1; therefore beds equivalent to the Tuktu Formation are missing, and the Cretaceous rocks are all part of the Torok Formation. These rocks are predominantly shale down to 1,930 feet and claystone or pebble shale from 1,930 to 2,328 feet. Microfossils of the *Verneuilinoides borealis* zone occurred to some extent in samples through 1,435 feet, but most species and specimens came from beds above 670 feet; through the succeeding 400 feet of section, the number of species is reduced. Except for *Textularia topagorukensis* Tappan, common in a core from 1,169–1,179 feet, only a few microfossils occurred in the section between 1,000 and 1,435 feet (pl. 17). This section and the overlying more fossiliferous beds are all within the upper part of the Torok Formation. A section of relatively unfossiliferous and barren beds between 1,435 and 1,930 feet is approximately equivalent to beds of the middle part of the Torok Formation, and the fossiliferous pebble shale section (1,930–2,328 feet) may in part represent the lower part of the Torok Formation.

A total of 70 cores were taken from this test hole. These cores represent 488 feet of continuous coring from 965 to 1,453 feet within the *Verneuilinoides borealis* faunal zone, and 496 feet of continuous coring from 1,950 to 2,446 feet in the pebble shale and Jurassic section. Four cores were taken in the argillite.

MIDDLE TO UPPER ALBIAN ROCKS

VERNEUILINOIDES BOREALIS FAUNAL ZONE (100–1,930 FT)

Albian microfossils of the *Verneuilinoides borealis* faunal zone occurred in every sample beginning at 100–110 feet and extending through the core at 1,103–1,111 feet. Some of the upper cores yielded more fossils than were found in ditch samples. Of the fossils found, 25 species of Foraminifera and 1 species of Radiolaria were identified, but only *Haplophragmoides topagorukensis* Tappan, *Bathysiphon vitta* Nauss?, *V. borealis* Tappan, "*Tritaxia*" *manitobensis* Wickenden, and *Miliammina manitobensis* Wickenden occurred in most of the samples. Other species were common or abundant in a single core, but only *H. topagorukensis* was common in several samples. In the first core at 459–469 feet, *H. topagorukensis*, *V. borealis*, and "*T.*" *manitobensis* were each common, and *Textularia topagorukensis* Tappan was abundant. In the second core, from 660–670 feet, *H. topagorukensis* was very abundant, and *B. vitta?*, *V. borealis*, *Ammobaculities wenonahae* Tappan?, and "*T.*" *manitobensis* were common. *H. topagorukensis*, *T. topagorukensis*, and *Hyperamminoides barksdalei* Tappan were each common in the core from 860–870 feet, but fewer fossils occurred in the core samples from the lower beds of the *V. borealis* zone. Calcareous species of Foraminifera were relatively rare in samples from the *V. borealis* zone in this test well; only 7 species were found in contrast to 18 arenaceous species.

Tests of *Gaudryina nanushukensis* Tappan and glauconitic casts of *Dictyomitra* sp. occurred in a few samples beginning at 240–250 feet and seem to constitute a zone that has a top occurrence at 1,060–1,070 feet in South Barrow test well 1. This correlation places the section in South Barrow test well 2 approximately 800 feet structurally lower than that in South Barrow test well 1.

Only one specimen each of *Ditrupa cornu* Imlay and *Balanocrinus* sp. was found between 420 and 450 feet in this test hole, whereas both species occurred in South Barrow test well 1 in the upper beds and as contamination in lower samples. Probably the two specimens found in test well 2 actually came from beds somewhat higher in the section, and the limited occurrence supports the conclusion that these two fossils are chiefly species of the Tuktu Formation and occur only rarely in the upper part of the Torok Formation.

Verneuilinoides borealis and *Gaudryina nanushukensis* did not occur in the lower part of the *V. borealis* zone in cores from 954–1,435 feet; the small fauna occurring there consists mainly of *Haplophragmoides topagorukensis* and *Textularia topagorukensis*, although a few other species did occur.

Tests of the arenaceous Foraminifera found in the *Verneuilinoides borealis* zone of this well are generally white to buff and are small, crushed, and distorted. Specimens of *Haplophragmoides topagorukensis* are usually crushed; some specimens have been flattened or compressed into discs, and others have been considerably distorted. Tests of *Verneuilinoides borealis* are crushed, and very few show inflated chambers and well-defined sutures. Specimens of *Textularia topagorukensis* are flattened, thin, and rather delicate. Tests of *Ammobaculites wenonahae* are thin and have rough exteriors. Specimens of *Gaudryina nanushukensis* are crushed and have scattered specks of black manganiferous(?) material on them.

Pelecypods from a core at about 1,353–1,354 feet were identified by Imlay (1961, table 14) as *Yoldia* cf. *Y. kissoumi* McLearn, which in Alberta, Canada, occurs in beds of early Albian age but in Alaska apparently also ranges into rocks of middle Albian age.

LOWER ALBIAN ROCKS

GAUDRYINA TAILLEURI FAUNAL ZONE (1,930–2,328 FT)

The pebble shale section cored in test well 2 is the most complete in the Barrow wells. Continuous cores were taken for 278 feet of the 298-foot section (1,930–2,228 ft) drilled, and there were fossils in each of the cores. About 30 species of Foraminifera were found, which makes this the largest microfauna obtained from the pebble shale. Arenaceous Foraminifera predominate in this fauna, and several are the same as occur in the younger Albian beds that carry the *Verneuilinoides borealis* faunal zone. The pebble shale beds, however, are correlative with the lower part of the Torok Formation and are of early Albian age. Excellent elongate specimens of *Gaudryina tailleuri* (Tappan) characterize the beds and occur throughout the section in test well 2, but specimens of *Haplophragmoides topagorukensis* occur most abundantly and frequently as they do in the same section of test well 1. Specimens of *Ammobaculites fragmentarius* Cushman, "*Tritaxia*" *athabascensis* Mellon and Wall and *Trochammina eilete* Tappan? occur less frequently in this section. *Gaudryina barrowensis* Tappan occurs rarely. In numerous samples are flattened specimens of *Haplophragmoides* sp. aff. *H. kirki* Wickenden. These specimens are of medium to large size and have four chambers in the final whorl. All are compressed, and the slightly distorted specimens suggest *Trochammina umiatensis* Tappan of the Tuktu Formation. Except for the seemingly larger size, the specimens appear to be much like the species described by Stelck and Wall (Stelck, Wall, Bahan, and Martin, 1956, p. 36) as *Haplophragmoides* cf. *H. kirki* Wickenden from St. John shales of the middle Albian, north bank of Peace River, British Columbia, Canada.

Of the numerous species of calcareous Foraminifera in the cores from the pebble shale, the most frequently occurring species is *Gavelinella awunensis* (Tappan), but 12 or 13 species of Lagenidae occurred erratically; few specimens of these species are found. (See pl. 17.)

A few pyritic casts of Radiolaria of the family Stichocorythidae (*Lithocampe*? sp.) were found in the upper part of the shale beds and in a core about 30 feet above the base of the section. This fossil is a marker of the lower part of the Torok Formation in the type section along the Chandler River south of Umiat, but it is not necessarily so elsewhere.

All arenaceous species of Foraminifera found in the pebble shale section of this test hole show a certain amount of distortion of the tests, but those species in the beds above 2,070 feet are less affected than those at lower depths. In the upper beds specimens of *Haplophragmoides topagorukensis* are common to abundant; many have dark sutures, and a variety of shapes have been formed by compression and distortion. Specimens of *Gaudryina tailleuri* are compressed in part or in their entirety, and many specimens are twisted and bent. The fine-textured tests of *Ammobaculites fragmentarius* are cylindrical or slightly flattened and twisted. Some of these tests have nearly uniform width, but others are narrowed in the area of the initial uniserial chambers. Sand grains adhere to the surfaces of most specimens of *Ammodiscus* and *Glomospira*. Specimens of *Gaudryina barrowensis* and "*Tritaxia*" *athabascensis* are generally flattened.

A few pelecypods recovered from cores in the lower part of the Cretaceous section within the *Gaudryina tailleuri* zone have been identified generically by Ralph Imlay and are reported by Collins (1961, p. 601) in her lithologic description of the test well.

LOWER JURASSIC ROCKS (TOARCIAN)

UNNAMED FORMATION (2,328–2,443 FT)

Below the lower Albian pebble shale beds, about 115 feet of light-olive-gray sandstone and siltstone of Jurassic age was penetrated from 2,328 to 2,443 feet in this test well. The upper part of this section yielded a few Foraminifera of which the most common species is *Haplophragmoides kingakensis* Tappan, a large form having few chambers and deeply incised sutures. This species and nine others from a core at 2,341–2,356 feet have been identified by Helen Loeblich (Tappan, 1955, p. 27) as identical to some of the species found in cores considered to be of Toarcian age in South Barrow test well 3. (Also see pl. 17.) The arenaceous specimens have milky-white quartz grains on the surfaces in the same manner as those specimens found in cores from 1,739–1,798 feet in South Barrow test well 3.

Ammonites of Toarcian age were identified by Imlay (1955, p. 73) from South Barrow test well 3 from beds as high as 1,772 feet, but small fragments of ammonites from a core at 2,391 feet in South Barrow test well 2 were identified by Imlay as *Tmetoceras* and were regarded by him to be similar to specimens from the lower part of the Kialagvik Formation (lowermost Bajocian) of southwestern Alaska (Imlay, 1955, p. 89). However, the ammonite occurrence at 2,391 feet is below the core containing Foraminifera identical to those of Toarcian age found in South Barrow test well 3. Therefore, I would question the Bajocian age assignment of the thin Jurassic beds in South Barrow test well 2, because no Middle Jurassic rocks were recognized in test well 3, where only a thick sequence of fossiliferous Lower Jurassic rocks were identified.

PALEOZOIC(?) ROCKS

ARGILLITE (2,446–2,505 FT, TOTAL DEPTH)

Bluish-black to black, siliceous, carbonaceous and pyritic argillite was penetrated below the Jurassic rocks in this well, and it constitutes "basement" rock as in South Barrow test well 1. According to Charles Milton, the rock was probably originally a marine sediment, possibly of volcanic origin, that contained a radiolarian(?) fauna (Collins, 1961, p. 602). However, the objections mentioned to the interpretation of the origin of the rock that is older than the argillite in test well 1 apply here also; it is extremely doubtful that any of the northern Alaska upper Paleozoic rocks were rich in radiolarian assemblages.

SOUTH BARROW TEST WELL 3

South Barrow test well 3 was drilled about 7 miles southeast of South Barrow test well 2 and penetrated less than 1,600 feet of Lower Cretaceous rocks under a thin mantle of the Gubik Formation of Pleistocene age. A total footage of 180 feet of cores was taken from the Cretaceous rocks, but starting at 1,645 feet, a section of 965 feet of Lower Jurassic rocks was drilled and extensively cored, and 189 feet of Triassic rocks were cored from 2,610 feet to the top of the black argillite at 2,799 feet. The top of the argillite is about 356 feet deeper than at South Barrow test well 2, but is about 586 feet higher than at test well 1. Although the argillite is much lower in this test hole than in test well 2, the Cretaceous beds are structurally higher because of the additional thick section of Jurassic and Triassic beds. That the Cretaceous beds are higher is also indicated by the position of the top of the pebble shale section, which in test well 3 is 645 feet higher than in test well

2 and 1,540 feet higher than in test well 1. The first Cretaceous beds penetrated are, therefore, stratigraphically lower in test well 3 than in test wells 1 and 2, and they are barren or sparingly fossiliferous.

MIDDLE ALBIAN ROCKS

LOWER PART OF VERNEUILINOIDES BOREALIS FAUNAL ZONE (65–1,285 FT)

The highly fossiliferous beds of the *Verneuilinoides borealis* faunal zone, the horizon of *Gaudryina nanushukensis*, and the glauconitic casts of *Dictyomitra* sp. present in test wells 1 and 2 are absent in test well 3. Absent too are the species "*Tritaxia*" *manitobensis* and *Gavelinella stictata*. Beds above 200 feet are barren. Very few specimens of only four species of Foraminifera of the *V. borealis* zone occurred in samples down to the core at 774–794 feet, in which long thin tests of *Textularia topagorukensis* Tappan were common. This species and a few specimens of *Haplophragmoides topagorukensis*, *Bathysiphon vitta*?, *Conorboides umiatensis*, and a few pyritic casts of *Radiolaria* of the family Stichocorythidae (*Dictyomitra*? sp.) were of rare occurrence in other samples down to the pebble shale beds. The radiolarian casts were found at 1,115 feet, 1,145 feet, and 1,261–1,285 feet.

The specimens of *Textularia topagorukensis* which were common in the core from 774–794 feet are within a subzone that occurs below the very fossiliferous beds of the upper part of the Torok Formation. This species occurred commonly only at this depth in test well 3. As the species was common in cores 400 feet apart (1,200–1,210 ft and 1,600–1,610 ft) in test well 1 and 536 feet apart (459–469 ft, 860–870 ft, and 995–1,003 ft) in test well 2, its singular common occurrence in test well 3 suggests that only the lower part of the faunal zone is represented. As this occurrence is 851 feet above the top of the pebble shale and as the lowest common occurrence of the species in test well 1 is 1,215 feet above the pebble shale, the species seemingly occupies a stratigraphically lower position in test well 3 than in test well 1. However, the difference is due to thinning of the intermediate shale section of the Torok Formation below the *T. topagorukensis* beds and above the top of the pebble shale between test wells 1 and 3.

LOWER ALBIAN ROCKS

GAUDRYINA TAILLEURI FAUNAL ZONE (1,285–1,645 FT)

The pebble shale beds in test well 3 are correlative with the section of the same lithology found in test wells 1 and 2, and the microfauna is similar but smaller. Most of the species were found in samples from the two cored intervals 1,388–1,416 ft and 1,613–1,639 ft. Only 12 or 13 species of arenaceous Foraminifera were found throughout, and of these *Haplophragmoides topagorukensis* was most common and frequent, whereas *Gaudryina tailleuri*, which elsewhere characterizes these beds, occurred only erratically and was not common. Broken specimens of *Ammobaculites fragmentarius* were scattered through samples from 1,345–1,639 feet but were common only in a core from 1,625–1,639 feet. *Trochammina eilete* occurred in samples from 1,435–1,639 feet and was common in three. *Gaudryinella irregularis* was common in a core from 1,388–1,396 feet and occurred sparingly in two other samples. Specimens of *Gaudryina barrowensis* were common in ditch samples from 1,595–1,625 feet. Of the 14 specimens of "*Tritaxia*" *athabascensis* found, all but one was in the lower cored interval 1,613–1,639 ft. Other species occurred rarely but only one to six specimens of a species were found in a sample. The preservation of the arenaceous Foraminifera is similar to those found in test wells 1 and 2. Calcareous Foraminifera are represented by five species of only one occurrence each.

LOWER JURASSIC (LOWER TOARCIAN TO UPPER PLIENSBACHIAN, SINEMURIAN TO HETTANGIAN) ROCKS

UNNAMED SHALE (1,645–2,610 FT)

A section of 965 feet of rocks which was extensively cored from 1,739 to 1,798 feet and 1,979 to 2,595 feet was identified as Early Jurassic age by Ralph Imlay after he had examined the numerous ammonites that were found in the cores. On the basis of his studies, Imlay determined the age of beds from at least 1,772 feet through 2,063 feet to be early Toarcian—as identified by finely ribbed specimens of five species of *Dactylioceras* in cores from 1,772 feet and 2,016–2,018 feet (Imlay, 1955, p. 81, 82)—and the age of beds from at least 2,069 feet through 2,198 feet to be late Pliensbachian—as identified by species of *Amaltheus* in cores from 2,069–2,099 feet, 2,111 feet, and 2,186–2,196 feet.

The cores also yielded a large number of well-preserved Foraminifera which Helen Loeblich identified as the first Lower Jurassic foraminiferal fauna found in the western hemisphere; she described 29 new species and recorded 55 other species from this well (Tappan, 1955), mostly from shaly clay beds cored between 1,979 and 2,334 feet. A less fossiliferous zone of shaly clay occurs between 2,468 and 2,589 feet, beneath 116 feet of barren siltstone and sandstone beds (2,334–2,450 ft). Several of the species, notably *Ammobaculities fontinensis* (Terquem), *Dentalina tenuistriata* Terquem, *Marginulina interrupta* Terquem, *Nodosaria apheilolocula* Tappan, and *Nodosaria regularis* Terquem, found only in the upper fossiliferous beds, are the same as species that occur throughout the Pliensbachian of France and Germany (Tappan, 1955, p. 27). In the section below the ammonities (that is, 2,198–2,610 ft), Mrs. Loeblich also noted that some species of Foraminifera suggest lower Liassic beds of Sinemurian and Hettangian age. These species include *Marginulina radiata* Terquem (2,478–2,496 ft) and *Glomospira perplexa* Franke (2,587–2,589 ft), which were not found in the upper more fossiliferous section. Agglutinated milky-white quartz grains on the surface of arenaceous Foraminifera found in the cores from 1,739–1,798 feet give these fossils a distinctive appearance in contrast to Foraminifera found in the Albian beds.

Calcareous species of Foraminifera predominate in the fauna and make up about 71 percent of the total species found. Most of these species occur in the upper fossiliferous beds, largely in the interval 2,028–2,179 feet; several species are limited to only one or two occurrences. In the lower fossiliferous beds, only 18 calcareous species were found, and they are limited to the interval 2,468–2,496 feet; however, arenaceous species were found in samples through 2,589 feet. Plate 17 indicates the occurrences and distribution of all the Foraminifera found in the Jurassic strata.

UPPER TRIASSIC ROCKS

SHUBLIK FORMATION (2,610–2,799 FT)

Between the base of the Jurassic strata and the top of the black argillite at 2,799 feet is a section of approximately 189 feet of limonite oolite layers and interbedded limestone, calcareous siltstone, and glauconite pellets. The rocks have been identified by Bernhard Kummel (written commun., 1950) as Norian age of the Upper Triassic (Shublik Formation) from the presence of specimens of *Monotis subcircularis* (Gabb) at 2,621 feet, 2,631 feet, and 2,635 feet, and of *Monotis* sp. at 2,771 feet. Washed microfossil sample cuts of this rock contained some Jurassic Foraminifera that were apparently introduced into cracks in the cores by the circulating drilling mud during drilling operations, but no Triassic Foraminifera were found.

PALEOZOIC(?) ROCKS

ARGILLITE (2,799–2,900 FT, TOTAL DEPTH)

Below the thin Triassic strata, a black argillite was penetrated. It resembles certain metamorphosed rocks of late Paleozoic age in the Brooks Range but may be Precambrian (Payne, 1951). In a few cores of this rock, spinelike and tubular pyritic objects were found, some resembling sponge spicules. These objects from argillite chips at 2,865 feet were studied by members of the Geological Survey. It is believed that they are organic but unidentifiable and that no age determination can be made from them.

SOUTH BARROW TEST WELL 4

South Barrow test well 4, drilled 447 feet N. 28° E. of South Barrow test well 2 to supplement the gas supply for the Barrow camp, penetrated a section of rocks similar to that found in the earlier gas well. Cores were obtained from only two intervals, 1,598–1,648 feet and 2,320–2,475 feet.

MIDDLE TO UPPER ALBIAN ROCKS

VERNEUILINOIDES BOREALIS FAUNAL ZONE (114–1,970 FT)

Species of Foraminifera indigenous to the *Verneuilinoides borealis* faunal zone of the upper part of the Torok Formation were found in ditch samples from 120–1,590 feet and 1,650–2,000 feet and in the cores from 1,598–1,648 feet. Most of the same species occurred throughout the ditch samples, but a few species found only in the lower interval of ditch samples are considered to be contamination from the initially penetrated higher beds.

The fauna found in this zone is similar in species and in type of preservation of specimens to the fauna found in South Barrow test well 2. It consists of approximately 25 species of Foraminifera and glauconitic casts of *Dictyomitra* sp. and has fragments of *Ditrupa cornu* Imlay occurring in 12 samples. Specimens are distributed similarly in the two wells, but fewer specimens were found in each sample from South Barrow test well 4 than in each sample from test well 2. The arenaceous species of Foraminifera found are virtually the same as those in test well 2, but not all the calcareous species are the same. *Haplophragmoides topagorukensis* Tappan occurs most frequently of all species, as it does in test well 2, but the number of specimens in each sample is usually smaller. Likewise, specimens of *Verneuilinoides borealis* Tappan are less numerous in test well 4 than in test well 2; they occurred in only about half as many samples as did *H. topagorukensis*.

The cored interval 1,598–1,648 feet yielded only a small fauna of a few specimens of *Haplophragmoides topagorukensis* and common specimens of *Textularia topagorukensis* Tappan and a few specimens of *Trochammina gatesensis* Stelck and Wall (at 1,608–1,618 ft). Foraminifera were found in ditch samples below the cored section, but most specimens probably came from upper beds as generally there are few specimens in the lower part of the *Verneuilinoides borealis* zone in the subsurface of the Arctic coastal plain region.

LOWER ALBIAN ROCKS

GAUDRYINA TAILLEURI FAUNAL ZONE (1,970–2,352 FT)

A pebble shale section 382 feet thick underlies the beds of the *Verneuilinoides borealis* zone and is about equivalent in thickness to the pebble shale section in

South Barrow test well 2. The microfauna of the two sections is similar and is probably of the uppermost part of the lower Albian, equivalent to some of the lower part of the Torok Formation in the southern foothills region. Specimens of *Gaudryina tailleuri* Tappan, which characterize the zone, occurred in most of the samples from 2,010 feet through the core from 2,340–2,350 feet and were common in part of the cores (2,320–2,340 ft.). Specimens of *Gaudryina barrowensis* Tappan were found in numerous samples and were common in the core from 2,320–2,329 feet. In several samples, there were specimens of "*Tritaxia*" *athabascensis* Mellon and Wall. The other species of Foraminifera in the zone are similar to those of the upper part of the Torok Formation; some of these specimens may have come from beds higher in the section because there are two kinds of preservation. Specimens from the cores are dark gray to brown and only slightly distorted, whereas, ditch specimens are light gray to buff colored and greatly compressed or distorted and are the same as those found in the younger beds. Two kinds of preservation can also be seen among specimens of *Haplophragmoides topagorukensis*. and the specimens were common in nearly every ditch and core sample in the pebble shale section. Specimens from the cores are generally only slightly compressed, have rounded peripheries, are light gray, and have dark gray sutures. This kind of specimen also occurred in the ditch samples along with compressed buff to tan specimens of *H. topagorukensis* that are seemingly identical to specimens from the upper beds; these specimens are most likely merely contamination from the younger part of the section. No species of *Trochammina* were found.

Scattered specimens of 12 species of calcareous Foraminifera were found in the pebble shale, but all occur also in younger beds. A few pyritic casts of Radiolaria of the family Stichocorythidae (*Lithocampe?* sp.) were found in scattered samples, particularly in the upper 100 feet of the pebble shale beds.

LOWER JURASSIC (LOWER TOARCIAN) ROCKS

UNNAMED FORMATION (2,352–2,471 FT)

The only Foraminifera found in the section between the pebble shale beds and the basement argillite are fragments of *Bathysiphon* sp. of undetermined age. Lithologic comparisons, however, indicate that the beds must be equivalent to the thin section of 115 feet of Jurassic strata found in test well 2. The section in that well is identified by microfossils of early Toarcian age, and therefore the same age should apply to the comparable section in South Barrow test well 4. Nothing indicates that any of the Jurassic section is younger.

PALEOZOIC(?) ROCKS

ARGILLITE (2,471–2,538 FT, TOTAL DEPTH)

Unfossiliferous black argillite of the same type found in the other Barrow test wells was penetrated for 67 feet to total depth at 2,538 feet. Contaminating microfossils from Cretaceous strata found in some of the core samples were introduced by drilling mud.

AVAK TEST WELL 1

Avak test well 1 was drilled approximately 4 miles east of South Barrow test well 2, on the north edge of a complexly faulted area. The well penetrated approximately 1,260 feet of Lower Cretaceous pebble shale, almost 950 feet of Lower Jurassic rocks, and 1,713 feet of pre-Mesozoic rocks consisting of argillite interbedded with siliceous dolomite and siliceous chert. Slight shows of oil were indicated, but the test was abandoned as a dry hole. The first sample, from 130–173 feet, was composed of sand and clay and contained Pleistocene and Cretaceous Foraminifera and a few *Inoceramus* prisms. Seismic shot holes in the vicinity indicate that the Pleistocene Gubik Formation in few places exceeds 100 feet; therefore, it is assumed that the thickness at the test site is approximately the same.

LOWER ALBIAN ROCKS

GAUDRYINA TAILLEURI FAUNAL ZONE (100± TO 1,360 FT)

The youngest Cretaceous rocks penetrated beneath the Gubik are largely pebble shale from which a small microfauna of 1 species of radiolarian and 22 species of Foraminifera was obtained. Although, for the most part, specimens are compressed, distorted, and difficult to identify, some species appear to be the same as species found in the pebble shale of the Barrow wells. From these fossils the section is equated in part to the lower part of the Torok Formation and therefore of early Albian age.

The most diagnostic fossil in the section is *Gaudryina tailleuri* Tappan, which ranges throughout the pebble shale. Specimens occurred sparingly in several of the upper samples and were common to abundant in many of the samples between 525 and 804 feet and in most of the samples from the two cored sections 1,004–1,092 feet and 1,219–1,348 feet. Actually there seem to be three kinds of *Gaudryina* in the pebble shale section. (See p. 127.) Sort, flared, or twisted specimens occur in the upper beds down through 645 feet. A second type, which ranges from about 572 feet through the core at 1,082–1,092 feet, has a narrow, elongate test with parallel sides. These tests may be compressed, twisted, and broken, but they seem to be the same as specimens found in the lower part of the Torok Formation. A third type, found in cores from 1,258–1,348 feet, has well-preserved, triserial tests, which are partly filled with pyrite. The tests of this *Gaudryina* are of the "*Verneuilinodes*" type, and inasmuch as they are similar to specimens previously described as *Verneuilinoides tailleuri* Tappan (Tappan, 1957, p. 208) from outcropping beds of the Fortress Mountain Formation, they represent the *Verneuilinoides* stage of the faunal zone. Specimens that show both triserial and biserial stages are the same as forms that were described as *Dorothia chandlerensis* (Tappan, 1957, p. 209) from outcropping beds in the lower part of the Torok Formation.

Since publication of the descriptions of *Verneuilinoides tailleuri* and *Dorothia chandlerensis*, however, studies made by Mrs. Loeblich of a suite of specimens from the subsurface pebble shale sections, particularly from the Avak well, suggested a gradational development from the triserial form to the more elongated triserial-biserial from typical of *Gaudryina*. Furthermore, no specimens found had the initial stage characteristic of the genus *Dorothia*, although distortion of the initial part of the test might suggest such a stage. Mrs. Loeblich thus concluded that the specimens previously described as *V. tailleuri* and *D. chandlerensis* are the same species and has accordingly reassigned the species to *Gaudryina tailleuri* (Tappan, 1962, p. 149).

Though not exclusively characteristic of the pebble shale beds, specimens of *Haplophragmoides topagorukensis* Tappan of both small and large size were common in many of the samples, and flattened tests of *Trochammina eilete* Tappan occurred in significant numbers in several samples. In addition, specimens of *Bathysiphon brosgei* Tappan, *Miliammina* cf. *M. subelliptica* Mellon and Wall, *Gaudryinella irregularis* Tappan, and *Ammobaculites fragmentarius* Cushman are relatively numerous. Most of these specimens are somewhat twisted; but the tests of *G. irregularis* are especially delicate, and nearly all are badly distorted. Many of the tests of *A. fragmentarius* range from small, narrow specimens to wide, robust forms that have an initial whorl of approximately the same width as the uniserial chambered part of the test.

Species of *Miliammina* in this section are of particular interest as specimens of the genus were rarely found in the lower part of the Torok Formation, and none have been observed in samples from the Fortress Mountain Formation. The distorted tests of the specimens found in the Avak well prohibit definite specific determination, but they seem to be more closely related to *M. subelliptica* Mellon and Wall described from the basal shales of the Clearwater Formation in Alberta, Canada than to one of the three species found in the *Verneuilinoides borealis* faunal zone of the younger Albian beds in Alaska.

Tests of *Trochammina gatesensis* Stelck and Wall were found in a core sample from 1,082–1,092 feet and were common in some core samples from 1,258–1,338 feet. Small pyramidal tests of *Gaudryina barrowensis* Tappan of the sort found in the pebble shale section of the Barrow wells were common in the samples from 1,004–1,013 and 1,278–1,298 feet and occurred in the cores from 1,313–1,338 feet. Specimens of "*Tritaxia*" *athabascensis* Mellon and Wall were found sparsely in a few samples, and questioned specimens of this species were common in a core sample from 572–592 feet. All are flattened. Some of the specimens in the lower samples are relatively large and tend to be biserial in the later part of the tests; thus they closely resemble the specimens described from the basal shales of the Clearwater Formation of Alberta, Canada. Other arenaceous species of Foraminifera are rare in occurrence and number of specimens found. The total assemblage of microfossils in the well samples is given on plate 17.

Only three calcareous species were found in all the samples, and of these, only *Conorboides umiatensis* (Tappan), could be identified specifically. Specimens of this species were scattered in the samples, and in a core sample from 1,061–1,077 feet somewhat distorted tests were common. Radiolaria are virtually unknown for this section except for two occurrences of single specimens of pyritic casts of *Dictyomitra* sp.

LOWER JURASSIC (LOWER TOARCIAN TO SINEMURIAN) ROCKS

UNNAMED SHALE (1,360–2,307 FT)

A section of approximately 1,000 feet of Jurassic rocks was penetrated beneath the Lower Cretaceous pebble shale. Although these beds are predominantly clay shale, a sandy section is present between 1,518 and 1,558 feet, and approximately 254 feet of argillaceous sandstone was penetrated between 1,636 and 1,890 feet. The basal 27 feet of beds is conglomerate.

A small microfauna equivalent to part of that identified from lower Toarcian and upper Pliensbachian rocks in South Barrow test well 3 (Tappan, 1955, p. 27) was found between 1,378 and 1,664 feet. A core sample from 1,378–1,397 feet yielded abundant specimens of flattened tests of *Trochammina sablei* Tappan and numerous broken small tests of *Ammobaculites alaskensis* Tappan, pyritic casts of *Eoguttulina liassica* (Strickland), and pyritized fragments of chambers of *Dentalina pseudocommunis* Franke. Also present were a few pyritized tests of small specimens of *Ammodis-*

cus? sp., numerous pyritic casts of three or four species and genera of Radiolaria.

Seventeen species of well-preserved Foraminifera were identified from a core at 1,558–1,569 feet. The following nine species were common: *Bathysiphon anomalocoelia* Tappan, *Involutina aspera* Terquem, *Ammobaculities sthenarus* (Tappan), *Marginulina prima* d'Orbigny, *Marginulina thuringica* (Franke), *Astacolus arietis* Tappan, *Lentinculina excavata* (Terquem), *Nodosaria phobytica* Tappan, and *Nodosaria prima* d'Orbigny. Arenaceous specimens in this sample are white and rough textured. Most of the calcareous specimens are an opaque white similar to that of tests of many of the microfossils in the Pliensbachian section of South Barrow test well 3. Several of the species are characteristic of beds of late Pliensbachian age in South Barrow test well 3 and are not recorded from beds higher in the Jurassic section of that well.

Much of the thick sand section and sandy beds between 1,518 and 1,890 feet is barren except for a few fragmentary Foraminifera in a sample from 1,655–1,664 feet and six or seven species of Foraminifera and an ammonite in a sample from 1,836–1,842 feet. The ammonite was identified by Imlay (1955, p. 73) as "*Arietites*" cf. "*A.*" *bucklandi* (Sowerby) of early Sinemurian age, but the Foraminifera are some of the same species as occur in the overlying beds, consisting of a few specimens of each of the following: *Involutina aspera* Terquem, *Haplophragmoides barrowensis* Tappan, *Lenticulina excavata* (Terquem), *Marginulina thuringica* (Franke), and fragments of *Ammobaculites alaskensis* Tappan and *Frondicularia lustrata* Tappan. Preservation as well as texture of tests, is similar to that of specimens found in higher samples.

A comparison of the Jurassic section of Avak test well 1 with the extensively cored section in South Barrow test well 3 reveals several differences, although the two sections are nearly comparable in thickness. In the South Barrow well the section yielded numerous ammonites, which were determined to be of early Toarcian and late Pliensbachian ages. An abundant microfauna also occurred there almost continuously through 355 feet of beds, and additional microfossils occurred in the lowest 130 feet of the Jurassic section. Some of the Foraminifera in the lower beds were identified as of Sinemurian age (Tappan, 1955, p. 27).

In the Avak well, only one ammonite was found, and microfossils occurred erratically in the section. In South Barrow test well 3, the Jurassic section includes approximately 418 feet of lower Toarcian rocks, at least 137 feet or possibly more of upper Pliensbachian rocks as indicated from the known range of the ammonite *Amaltheus* found therein and possibly as much as 410 feet of Sinemurian (and possibly Hettangian) rocks, the thickness depending on the amount of section assigned to the upper Pliensbachian. Rocks of these same ages may not all be present in the Avak well, nor are the thicknesses of rocks of correlative age units the same. Microfossils found in the upper beds of the Avak well are mostly of species which did not occur above the Pliensbachian rocks in South Barrow test well 3. Only in the top of the Jurassic section in the Avak well were there numerous microfossils of several species such as occurred both in the lower part of the lower Toarcian and in the upper Pliensbachian rocks in South Barrow test well 3, whereas in the latter well the upper beds from 1,740 feet through 1,779 feet are dominated by one species, *Involutina aspera* Terquem, and only a few specimens of three or four other species of Foraminifera.

In the Avak well sandy beds from 1,518 to 1,588 feet are nonfossiliferous, but a fossiliferous core at 1,558–1,569 feet yielded some Foraminifera that were recorded in South Barrow test well 3 only from rocks below the lower Toarcian section. These Foraminifera include common specimens of *Bathysiphon anomalocoelia* Tappan; *Ammobaculites sthenarus* (Tappan); *Astacolus arietis* Tappan; *Nodosaria phobytica* Tappan; *Nodorsaria prima* d'Orbigny; and a few specimens of *Astacolus calliopsis* Terquem, *Vaginulina curva* Franke, and *Frondicularia squamosa* Terquem and Berthelin. In the South Barrow test wells, about 200 feet of rocks in the lower Toarcian section are barren, and only the lowest 85 feet of the section is fossiliferous, but underlying this section is an extensive fossiliferous section of late Pliensbachian age.

Thus it seems that the Jurassic section in the Avak well might include not only the lower fossiliferous part of the lower Toarcian section of South Barrow test well 3, but also all the Pliensbachian occurring in that well, although the Avak section is less fossiliferous. Stratigraphically the top of the Jurassic section in the Avak well might be 300–350 feet lower than the top of the Jurassic section in South Barrow test well 3.

Although rocks of early Sinemurian age were identified by Ralph Imlay from an ammonite found in a core at 1,836 feet, the amount of section in the Avak well that might be of this age cannot be determined precisely. Almost 175 feet of rocks above the fossiliferous core are barren, as are some of the beds immediately below, and Foraminifera associated with the ammonite are the same as species that occur in the overlying rocks of late Pliensbachian and early Toarcian age. Sinemurian rocks, however, may be restricted to the type of sandstone in which all these fossils occurred as this rock was first penetrated at about 1,636 feet and continues to a depth of about 1,892 feet. The beds below 1,892 feet are largely claystone, clay, and shale to about 2,080 feet, and below 2,080 feet is a considerable amount of sand. If only the sandstone is of Sinemurian age, the section in the Avak well would be about equal in thickness to equivalent age beds that can be delimited more precisely in South Barrow test well 3.

Two species of Foraminifera from the section below 2,006 feet in the Avak well have been identified by Mrs. Loeblich as being restricted to rocks of possible Hettangian age in South Barrow test well 3. One of the species is *Dorothia? squamosa* (Terquem and Berthelin), common in a core from 2,006–2,021 feet in the Avak well and also in a lower sample. The other species is *Gaudryina kelleri* Tappan, found in conglomerate in cores from 2,280–2,283 feet and 2,286–2,292 feet. Because these species occurred in a section of claystone, clay, shale, and conglomerate that constitute a stratigraphic unit below 1,892 feet, the entire sequence from 1,892 to 2,307 feet may be of Hettangian age. This sequence is considerably thicker than the possible Hettangian section in South Barrow test well 3, but the increased thickness may be due to some duplication of beds by faulting as steep dips and slickensides were noted in the lower section of Jurassic rocks in the Avak well. The basal conglomerate, however, probably represents the true basal part of the Jurassic section.

PALEOZOIC(?) ROCKS

ARGILLITE (2,307–4,020 FT, TOTAL DEPTH)

Beneath the Jurassic rocks a sequence of 1,713 feet of black carbonaceous, siliceous argillite was penetrated. The argillite was interbedded with siliceous dolomite and dolomitic chert except for the uppermost 40 feet, which is a black clay shale that may be a weathered phase of the argillite. No fossils were found in any of the cores, but fragments of pyritized fillings of tubes or spines occurred in a core from 2,678–2,706 feet. Microfossils noted in ditch samples are all contamination from the overlying Jurassic and Cretaceous beds. Presumably the argillite is the same as the basement rocks penetrated in the Barrow area, rocks which Payne (Payne and others, 1951) considered to be Precambrian.

SIMPSON TEST WELL 1

Simpson test well 1 was drilled in 1947–48 near lat 71°57′ N., long 155°21′ W. At this site about 8 feet of Pleistocene sediments of the Gubik Formation mantles the area. Beneath the Gubik sediments the drill penetrated at least 5,520 feet of Lower Cretaceous rocks of Albian age; a section of Lower Jurassic rocks which is at least 635 feet thick and possibly as much as 800 feet; approximately 278 feet of Upper Triassic rocks; and below 6,534 feet to the bottom of the hole at 7,002 feet, a section of steeply dipping argillite of possible Paleozoic(?) age.

The Cretaceous rocks are predominately clay shale but include minor beds of slitstone; within the upper 1,000 feet of section are massive sandstone beds. In this report the upper 1,000 feet is considered to be part of the Tuktu and Grandstand Formations undifferentiated; the thick shale sequence below, which Robinson (1959b) differentiates as Topagoruk and Oumalik Formations, Upper Jurassic(?) and Lower Cretaceous(?) rocks are herein grouped together as the Torok Formation. Two microfaunal zones are present within the sequence of Cretaceous rocks. Microfossils also occur in the Jurassic and Triassic rocks, but no zones are distinguished.

PLEISTOCENE MICROFAUNA

Specimens of 10 calcareous species of Pleistocene Foraminifera (including *Elphidiella magnifica* Tappan, *Cribroelphidium arcticum* Tappan, and species of *Elphidium*, *Cassidulina*, *Pyrulina*, and *Cornuspira*) were found in ditch samples from 25–116 feet in this well, but 3 arenaceous species of Lower Cretaceous Foraminifera and *Inoceramus* prisms were scattered through the samples also. From the same ditch samples came six species of ostracodes, which Swain (1949) has tentatively identified as Pliocene or younger. As there were no samples from the first 25 feet of section, the thickness of the Pleistocene Gubik Formation is not known, but it is assumed to be only a thin mantle of less than 25 feet in the area of the well.

MIDDLE TO UPPER ALBIAN ROCKS

VERNEUILINOIDES BOREALIS FAUNAL ZONE (25–2,949 FT)

Microfossils of the *Verneuilinoides borealis* faunal zone of Albian age were found below the thin mantle of the Gubik Formation through nearly 3,000 feet of section. These fossils occur in rocks that are largely clay shale with minor sandstone and siltstone layers down to 753 feet, largely sandstone between 753 and 990 feet, and clay shale containing fewer siltstone beds in the section below 990 feet.

On the faunal chart (pl. 18) for Simpson test well 1, 22 arenaceous Foraminifera and 46 calcareous species are listed in the *Verneuilinoides borealis* faunal zone. A statistical evaluation of specimen count indicates that four arenaceous species make up approximately 61 percent of the total. *Haplophragmoides topagorukensis* Tappan alone makes up about 42 percent of the count and far outnumbers any other species in abundance. The next most abundant species is *Verneuilinoides* *borealis* Tappan, constituting approximately 9 percent. *Miliammina manitobensis* Wickenden accounts for about 6 percent of the total count and *Bathysiphon vitta* Nauss? for about 5 percent. Other arenaceous species are represented as follows: *Ammobaculites wenonahae* Tappan, about 2 percent; *Gaudryina canadensis* Cushman and *Glomospirella gaultina* (Berthelin), 1 percent each, and 15 other species, less than 1 percent each. One calcareous species, *Gavelinella stictata* (Tappan), accounts for about 8 percent of the faunal count, whereas most calcareous Foraminifera are relatively rare. Eight calcareous species constitute only 1–2 percent each of the faunal count, and 29 species are so rare that only from 1 to 10 specimens are listed.

Several calcareous species are known only from the few specimens identified by Mrs. Loeblich and were not recognized in the comparative collections which I have studied.

A few specimens *Verneuilinoides borealis*, *Haplophragmoides topagorukensis*, and *Miliammina manitobensis* were present in the first sample (25–35 ft). This small fauna continues to about 180 feet. From 130 through 1,370 feet coring was nearly continuous, and except for a barren sandy section from 763 to 900 feet, the beds carried about five-sixths of the total number of Foraminifera found in the *Verneuilinoides borealis* zone; more than half the species were in the upper 550 feet of section. Short tests of *V. borealis* and somewhat compressed tests of *H. topagorukensis* occur frequently, and in many samples these species were common to abundant. Specimens of *M. manitobensis* were rare to common in many samples, and in the lower part of the cored section some specimens are large and well preserved. *Inoceramus* prisms, a few echinoderm remains, ostracodes, charophytes, and spores were present as shown on plate 18.

Foraminifera wefe scarce from 753 through 1,000 feet, but below 1,000 feet through the cored beds at 1,370 feet, the fauna is about as prolific as in the upper beds.

Most of the arenaceous Foraminifera in these beds are white to buff; although some are smooth, most are granular and frequently have glassy quartz grains in the walls. This appearance contrasts with the dark-brown and smooth-textured surface of many specimens that come from the same fauna in the outcrop areas and from the wells drilled in the northern foothills section. Although nearly all arenaceous Foraminfera in this well are flattened, few are distorted. Many specimens of *Verneuilinoides borealis* are compressed slightly with the result that the tests are wedge shaped in outline. Most specimens of *Haplophragmoides topagorukensis* and *V. borealis* have a granular texture that obscures the sutures of the tests, but the specimens in a sample from 443–444 feet are all very fine textured and have deeply incised sutures.

Mere species and specimens of calcareous Foraminifera were found in the thick cored section of the Simpson test well than in any other well. Most of the calcareous specimens belong to the Lagenidae and the Discorbidae, but the latter are most common and numerous. Of the Discorbidae, *Gavelinella stictata* (Tappan) is the most abundant, making up about 31 percent of the calcareous species. Specimens are remarkably well preserved although the tests have not been filled or replaced by mineral matter. In some of the larger specimens of *G. stictata*, small breaks are common in the walls of the later chambers, but such damage was probably done during washing of the samples. In general, the calcareous specimens from the cored section of the upper beds in this well are prevailingly tan, but some are stained dark brown, similar to the color noted on specimens from wells in the northern foothills.

In the thick cored section, in addition to the Foraminifera, fragments of tapered calcareous worm tubes, *Ditrupa cornu* Imlay, were found in several samples from 231–1,330 feet, and fragments of *Balanocrinus* sp., identified by A. L. Bowsher, were found in samples from 293–308 feet. Valves of a microscopic pectinate pelecypod occurred at several depths between 91 and 633 feet. *Inoceramus* prisms were common to abundant in washed samples of many cores from 950 through 1,287 feet, and cores from this interval had numerous fragments and sections of *Inoceramus* shells embedded in them.

The association of *Ditrupa cornu* and *Balanocrinus* sp. with the assemblage of Foraminifera found in the upper beds in this well suggests a Tuktu faunal facies rather than the fauna of the poorly fossiliferous Grandstand Formation, but the section is considered to be Tuktu and Grandstand Formations, undifferentiated, to the bottom of the sandy section at 1,370 feet. Below this depth, the clay shale section down to the top of the Jurassic is herein considered to be part of the Torok Formation. There is no faunal break in Foraminifera between the sandy facies and the upper part of the clay shale beds, but not all of the same species are found in both facies. Some species are more abundant in the Torok Formation than in the upper sandy beds. A few species that were found in the clay shale beds of the upper part of the Torok Formation were not in the younger sandy facies, but these are so rare that they have no special significance.

Species that are more common in the upper part of the Torok Formation in this well than in the Tuktu faunal facies include *Lenticulina macrodisca* (Reuss), *Bathysiphon vitta* Nauss?, *Gaudryina nanushukensis* Tappan, *Glomospirella gaultina* (Berthelin), and *Eurycheilostoma robinsonae* Tappan. *G. nanushukensis* and *E. robinsonae* are almost always found more often in beds of the upper part of the Torok Formation than in younger beds of the *Verneuilinoides borealis* zone, and they have never been noted in outcrop samples of the Grandstand Formation.

Within the upper part of the Torok Formation, about midway within the *Verneuilinoides borealis* zone, is a zone of glauconite with glauconitic casts of a conical radiolarian, *Dictyomitra* sp. The highest occurrence of these casts is in a sample from 2,060–2,070 feet, and presumably they continue to 2,350 feet as glauconite is common in a core from 2,343–2,353 feet. The conical casts range in shape from narrow specimens on which the segments and vertical costae are sharply retained to short roughly conical specimens showing only a vague suggestion of segments and ornamentation. Glauconitic casts of *Dictyomitra* sp. found in ditch samples from 2,770 feet through 3,100 feet are probably contamination from above.

Tests of *Gaudryina subcretacea* Tappan were found in ditch samples from 2,440–3,120 feet; the only other occurrence of the species is in the Barrow area, where it occurs lower in the section.

A core at 2,939–2,949 feet seems to be the lowest good sample control for the basal part of the prolific fossiliferous section of the *Verneuilinoides borealis* faunal zone, and it may closely approximate the base of the upper part of the Torok Formation. The core carried four or five arenaceous species of Foraminifera including abundant fragile, elongate biserial tests of *Textularia topagorukensis* Tappan.

LOWER PART OF THE TOROK FORMATION

Most microfossils found in the samples between 2,949 and 5,297 feet probably did not occur in that part of the section. Those picked in 1947 from ditch samples are obviously contamination from the *Verneuilinoides borealis* zone, and most of the few Foraminifera found in the originally prepared core samples were in all probability introduced by drilling mud. Contamination is indicated by the light-colored specimens, which are the same as specimens occurring in higher beds of the *V. borealis* zone, and by the fact that no Foraminifera were found in carefully prepared check samples studied later. Only a core sample from 3,986–3,996 feet yielded Foraminifera. There are numerous tests of *Textularia topagorukensis* in a sample composed of 5 feet of clay shale recovered from 3,986–3,991 feet combined with 4 feet of mixed shale and drilling mud recovered from a lower core from 3,991–3,996 feet. As these tests are like those found in abundance in the sample from 2,939–2,949 feet, it would necessitate extreme selectivity for the drilling mud to have picked up only these delicate tests from nearly 4,000 feet of section. Inasmuch as the species was not found in any ditch samples immediately above or below 3,986–3,996 feet, the occurrence may suggest some duplication of beds by faulting, but faulting of the magnitude of 1,000 feet would certainly have been detected on the electric log. If *T. topagorukensis* ranged below the *V. borealis* zone, a fault of only a few hundred feet might be feasible. However, this species is unknown in the lower part of the Torok Formation; in South Barrow test wells 1 and 2, the species has a definite span of 1,000–1,200 feet within the upper part of the Torok Formation, and in Oumalik test well 1, more than 1,800 feet within the upper part of the Torok Formation.

Because some of the Foraminifera found in ditch samples from approximately 3,000 through 5,297 feet may be due to contamination from the prolific *Verneuilinoides borealis* faunal zone found in the upper part of the well, part of the section may be unfossiliferous except for the pyritic casts of nasseline Radiolaria that are found in several ditch samples between 3,730 and 4,960 feet. Radiolaria are seemingly of the Stichocorythidae (*Lithocampe*? sp., *Dictyomitra*? sp.) and occurred as follows: 1 specimen each in 5 samples from 3,730–3,760 feet, 3,790–3,800 feet, and 3,820–3,830 feet; 3 specimens in a sample from 3,950–3,960 feet; 5 specimens in a sample from 4,460–4,470; and a few specimens in samples between 4,550 and 4,960 feet.

Through how much of the stratigraphic sequence the Radiolaria extend is unknown, but their span probably is restricted to only a fraction of the footage suggested by their distribution in ditch samples. Pyritic casts of stichocorythidian forms similar to the specimens found in these beds occur in beds described as the Oumalik Formation in Oumalik test well 1 (Bergquist, 1956b, p. 66) and are a characteristic of the lower part of the Torok Formation and the Fortress Mountain Formation. Although a correlation with beds somewhere in the lower part of the Torok Formaion is assumed from the presence of Radiolaria, it would be inadvisable to base an age determination of a sequence of rocks solely on the pyritic casts as radiolarian casts are not found exclusively in the Lower Cretaceous beds of northern Alaska. The same kind of pyritic casts occur in beds of late Jurassic age in Topagoruk test well 1 and also in numerous samples of outcropping Jurassic rocks in northern Alaska. It seems to be impossible to distinguish these pyritic casts from those found in Lower Cretaceous beds.

LOWER ALBIAN ROCKS

GAUDRYINA TAILLEURI FAUNAL ZONE (5,150–5,464± FT)

The *Gaudryina tailleuri* faunal zone is known only from two cores (5,297–5,308 ft) in which were pyritic casts of *Dictyomitra* sp. and *Lithocampe*? sp., pyritized fishbone fragments, and five species of arenaceous Foraminifera in beds that are approximately equivalent to the pebble shale of the Barrow area. Of the Foraminifera, specimens of *Gaudryina tailleuri* (Tappan), *Trochammina eilete* Tappan?, and *Bathysiphon brosgei* Tappan were common, and specimens of *Saccammina lathrami* Tappan and *Haplophragmoides topagorukensis* Tappan were rare. No calcareous species were found.

The Foraminifera are small, dark-colored, flattened to distorted specimens that are difficult to identify. They contrast greatly with the larger, lighter colored specimens from the *Verneuilinoides borealis* faunal zone. In the ditch samples, very few specimens of these foraminifers were found, but the reported occurrence of a specimen of *Dorothia chandlerensis* Tappan (synonym of *Gaudryina tailleuri*) in a sample from 5,150–5,160 feet (Tappan, 1957, p. 209) is here regarded as the highest controlled position for this zone. It is possible, however, that the small dark arenaceous specimens of this fauna might have been sparingly present in ditch samples but overlooked; only the larger, more obvious light-colored specimens, which are actually contamination from the *V. borealis* faunal zone, were picked and mounted in 1947. The sample from 5,150–5,160 feet was not repicked. Sample cuts made in 1953 of the cores (5,279-5,308 ft) originally regarded as barren in 1947 yielded the specimens that are indicated above and that are tabulated on the faunal chart.

LOWER JURASSIC ROCKS

KINGAK FORMATION (5,464± TO 6,265 FT)

Microfossils of Jurassic age have been identified in four cores spanning 613 feet of the well section. The highest occurrence of a probable Jurassic fossil is in a core from 5,464–5,484 feet in which a solitary pyritic cast of *Eoguttulina metensis* Tappan? was found. A pyritic cast of a specimen which may be *Bathysiphon anomalocoelia* Tappan? was found in a ditch sample from 5,580–5,590 feet, and an ostracod from the same sample has been identified by F. M. Swain as *Monoceratina* sp. aff. *M. herburgensis* Sylvester-Bradley of Jurassic age (written commun., 1949). Most of the Jurassic Forminifera were found in the interval between 5,677 and 6,077 feet, but the base of the Jurassic section is herein taken as 6,265 feet in accord with the conclusion reached by Robinson (1959b); thus the thickness for the Jurassic section in this well is 800 feet.

Jurassic Foraminifera from the Simpson test well were described by Mrs. Loeblich (Tappan, 1955), who considered them to be equivalent to the Early Jurassic Lias fauna of Germany. Species were listed by cores, but restudy of additional samples from the cores indicates that more species can be added to Mrs. Loeblich's list.

A Pliensbachian age for at least part of the Jurassic strata is suggested by Imlay (1955, p. 82), who identified *Amaltheus* sp. undet. from a core at 5,680 feet. Pelecypods at 6,174 feet and 6,186 feet were identified by Imlay as *Oxytoma* sp.

Most of the Foraminifera are from cores at 5,677–5,692 feet and 5,866–5,874 feet where the following occur: *Bathysiphon anomalocoelia* Tappan, *Haplophragmoides barrowensis* Tappan, *Involutina silicea* Terquem, *Ammobaculites alaskensis* Tappan, *Trochammina canningensis* Tappan, *T. sablei* Tappan, *Nodosaria mitis* (Terquem and Berthelin), and *Vaginulina sherborni* (Franke). Of all these species, only *T. canningensis* was common, and small specimens of this species were numerous in the higher core. A specimen each of *Reophax suevica* Franke, *Lenticulina excavata* (Terquem), and *Astacolus pediacus* Tappan occurred in a core from 6,067–6,077 feet, and one specimen of *Marginulina utricula* Terquem and Berthelin was all that was found in a core from 6,173–6,183 feet. Most of the ditch samples carried Cretaceous fossils as contamination, and very few had Jurassic microfossils.

A foraminifer described as a Triassic species under the name of *Ammobaculites sthenarus* Tappan (Tappan, 1951c) from ditch samples within the Triassic section of the well, is instead of Jurassic age as I have found the species in six ditch samples within the Jurassic section of the Simpson test well. Specimen described as *A. sthenarus* seem to be only young robust forms of a species later described as *Ammobaculites barrowensis* Tappan (Tappan, 1955) from the Jurassic beds of South Barrow test well 3. However, the name *A. sthenarus* has priority and should be the specific name for the Jurassic form in both wells.

LATE TRIASSIC FAUNA OF THE SHUBLIK FORMATION

A small microfauna of Late Triassic age occurs in cores from 6,304 through 6,356 feet. Few Triassic fossils were found in ditch samples from this interval or from depths down to the top of the argillite at 6,546 feet. The cores below 6,356 feet were barren. Most of the fauna came from the top core at 6,304–6,314 feet and includes 12 species of Foraminifera, pyritic casts of a radiolarian (*Dictyomitra*? sp.), smooth-shelled ostracodes, shell fragments of *Monotis* sp., and numerous pyritic casts of a minute subcircular pelecypod which occurs with the same foraminiferal assemblage in numerous samples from exposures of the Shublik Formation of the Sadlerochit River area. The Foraminifera are part of the fauna described by Mrs. Loeblich (Tappan, 1951c) as the first Triassic foraminiferal assemblage from the North American Continent, and the Triassic beds in this well were placed by her in the Shublik Formation. Only a few species of Triassic Foraminifera were found in relative abundance in this well. Specimens of *Astacolus connudatus* Tappan were abundant, specimens of *Rectoglandulina simpsonensis* (Tappan) were common, and in a core from 6,346–6,349 feet specimens of *Gaudryina adoxa* Tappan were abundant. Other species (see pl. 18) were relatively rare.

Many of the Triassic Foraminifera are partially replaced by pyrite; specimens of some species are entirely pyritic. Such replaced forms include *Pyrulinoides plagia* Tappan, *Spirillina gurgitata* Tappan, *Discorbis pristina* Tappan, *Sagoplecta goniata* Tappan, *S. himatioides* Tappan, *S. incrassata* Tappan, and *Eoguttulina bulgella* Tappan, but very few specimens of each species occurred in the well samples.

Arenaceous Foraminifera are rare in the Triassic fauna; only three species were found and each has a limited occurrence. *Gaudryina adoxa* was common to abundant in one core sample; specimens of *Tolypammina glareosa* Tappan occurred in one core sample, and specimens of *Trochamminoides vertens* Tappan were found in three ditch samples. The species described as *Ammobaculites sthenarus* Tappan from ditch samples from Triassic beds has been omitted from the fauna because, as indicated previously, it actually came from the overlying Jurassic beds.

PALEOZOIC(?) ROCKS

ARGILLITE (6,546–7,002 FT, TOTAL DEPTH)

Basement rocks of hard greenish-gray argillite, locally with grayish-red banding, were penetrated at 6,546 feet and were drilled to a depth of 7,002 feet. No evidence of fossils was noted. The rock may be as old as Precambrian (Payne and others, 1951) or may be metamorphosed sediments of late Paleozoic age, originally similar to those of the Siksikpuk Formation.

NORTH SIMPSON TEST WELL 1

North Simpson test well 1 was located on the east side of an embayment east of Dease Inlet, approximately 11 miles northeast of Simpson test well 1. The well penetrated an extensive but poorly defined section of Upper Cretaceous sediments of Senonian and Turonian age and Lower Cretaceous beds which are possibly of middle Albian age.

The first sample taken at the well was labeled "0–110 ft." The sample was largely sand similar to that of the Gubik Formation but contained no microfossils, whereas four or five specimens of Pleistocene Foraminifera were found with Cretaceous Foraminifera in ditch samples from lower in the well. The rarity of Gubik microfossils in the North Simpson well is either a criterion of the poor quality of the samples or reflects a relatively thin mantle of Gubik sediments.

Samples from 130 through 2,990 feet yielded Late Cretaceous Foraminifera and Radiolaria, and below 2,990 feet a few Foraminifera of Early Cretaceous (possibly middle Albian) age were found. Ditch samples were mostly clay and carried so few fossils that stratigraphic contacts could not be determined in the well. On the faunal chart (pl. 18) no formation contacts are indicated for this well, and only approximate ranges of formations are shown. Lithologic descriptions of cuttings and cores from this well have been given by Robinson (1959b).

SCHRADER BLUFF FORMATION (SENONIAN)

The largest concentration of microfossils found in this well was in samples from 380 through 500 feet, where a small assemblage of Foraminifera and a few species of Radiolaria were found. Several of the calcareous species of Foraminifera in this interval and in samples through 1,500 feet of section are characteristic of rocks of Late Cretaceous (Senonian) age and of the Schrader Bluff Formation. Of these species, the most frequently occurring is *Praebulimina carseyae* (Plummer), a foraminifer that is common in beds of Austin and Taylor age in Texas. Specimens were found in samples spanning the interval from 380 to 900 feet and scattered in samples through 1,499 feet. Specimens of *Nonionella taylorensis* Hofker were found from 180 feet through a core at 490 feet and are significant because the species is a Senonian fossil in beds of Navarro and Taylor age in the Gulf Coastal Plain. In the Schrader Bluff Formation of northern Alaska, it occurs most frequently and commonly in the Sentinel Hill Member. Specimens of *Aeolostreptis vitrea* (Cushman and Parker), a species from the Selma of Mississippi and the Austin of Texas, was found through at least 500 feet of section. In Alaska the species appears to be restricted to the Sentinel Hill Member of the Schrader Bluff Formation. Also found in the upper samples are two Senonian species that were described from the Upper Cretaceous Lea Park Shale of Alberta, Canada. These species are *Neobulimina canadensis* Wickenden, which first appeared at 180 feet and ranged downward to at least 890 feet, and *Quinqueloculina sphaera* Nauss, which ranged from 360 feet through a core at 1,190–1,200 feet.

A few other Senonian Foraminifera were found but were rarer. These Foraminifera include *Gavelinella ammonoides* (Reuss), a Senonian species from Europe, *Gavelinella tumida* Brotzen, described from the Senonian of Sweden, and *Eoeponidella linki* Wickenden, a Senonian species from Canada. *G. ammonoides* occurs in the Schrader Bluff Formation and was found scattered in upper samples from this well; *G. tumida* is found in the Sentinel Hill and Barrow Trail Members of the Schrader Bluff Formation and was found in scattered samples below 380 feet; *E. linki* occurs in the Sentinel Hill Member of the Schrader Bluff Formation and was of rare occurrence in the upper few hundred feet in the North Simpson well.

Arenaceous Foraminifera found in samples from the upper part of the North Simpson well range throughout beds of the Colville Group. Most of the specimens were scattered in samples below 380 feet except *Haplophragmoides rota* Nauss, which occurred as high as 190 feet and was found in nearly every sample from 380–1,200 feet. Much less significant in numbers and frequency of occurrence are specimens of *Dorothia smokyensis* Wall, *Spiroplectammina webberi* Tappan, and *Trochammina whittingtoni* Tappan. A few specimens of *Verneuilinoides fischeri* Tappan were found below 500 feet, and specimens of *Trochammina ribstonensis* Wickenden were found below 800 feet.

More significant than the arenaceous Foraminifera are the specimens of Radiolaria which have about the same range as the Foraminifera. Eight species found in samples from 180–300 feet also occurred at lower depths, whereas in a core sample from 890–900 feet, seven species of Radiolaria occurred along with five species of Foraminifera. In all, 11 species of Radiolaria, representing 5 genera of the Spumellina and 2 of the Nassellina, were found in the upper 900 feet of well section, but 2 species make up 77 percent of the total specimens. These two species are *Spongodiscus* cf. *S.* (*Spongodiscus*) *renillaeformis* Campbell and Clark, which constitutes 47 percent of the fauna, and *Cenosphaera* (*Cenosphaera*) sp. A, which constitutes 30 percent; they are conspicuous in the radiolarian fauna of Fish Creek test well 1. (See p. 177–178.)

Specimens of *Archicorys*, whose highest occurrence was at 380–395 feet in the North Simpson well, make up 5 percent of the fauna; specimens of *Spongodiscus* (*Spongodiscus*) sp. A, make up slightly more than 4 percent of the same fauna. Seven other species make up the remaining 14 percent of the radiolarian fauna and are ranked in order of relative abundance as follows: *Spongurus* (*Spongurantha*) sp., *Spongodiscus* (*Spongodiscus*) sp. B, discoidal pyritic casts of *Cenodiscus*? sp. A, *Sethocyrtis* sp. A (highest occurrence, 580–590 feet), discoidal pyritic casts of *Cenodiscus*? sp. B, *Cenosphaera* (*Cenosphaera*) sp. B, and a solitary specimen of *Stylospongia* sp. A at 890–900 feet.

Although relatively few species of Radiolaria were found in the North Simpson well, the fauna apparently is part of the large Upper Cretaceous radiolarian fauna which occurs in beds of the basal part of the Sentinel Hill Member and upper part of the Barrow Trail Member of the Schrader Bluff Formation in Fish Creek test well 1 and in some beds of outcropping Schrader Bluff sediments.

Volcanic glass beads and shards are abundant in many washed microfossil samples of the Schrader Bluff section from 180–1,200 feet in this well. The relative abundance of shards is probably less than that found in the Fish Creek section (p. 175), but the glass beads are more prevalent.

Only a few fossils were found in the ditch samples from 1,200–2,090 feet, and most species range throughout the Colville Group. But among the few Foraminifera found in a core from 1,790–1,800 feet were two specimens of *Eoeponidella linki* Wickenden, which suggests that the beds at that depth are also in the Schrader Bluff Formation. *E. linki* was described by Wickenden (1948) from Upper Cretaceous beds of Senonian age in the Upper Lea Park and Grizzly Bear Formations of Saskatchewan, Canada. In northern Alaska, this species seems to be restricted to the Schrader Bluff Formation, and in surface sections has been found only in the two upper members. In the North Simpson well the species ranges upward from the core at 1,790–1,800 feet to 300 feet below the surface, and I believe its presence in the core indicates that at least 1,800 feet of section in this well is of Senonian age.

The few Radiolaria in the core from 1,790–1,800 feet include specimens of *Spongodiscus* and *Cenosphaera* and a pyritic cast of *Cenodiscus*? but offer little basis for distinguishing between beds of the Schrader Bluff Formation and the Seabee Formation, though they are usually more indicative of the former.

SEABEE FORMATION (TURONIAN)

The Seabee Formation was penetrated in this well, but the thickness of the formation cannot be accurately determined from paleontologic data. The top could be anywhere between 1,800 and 2,090 feet, and the base, between 2,710 and 2,900 feet. It is impossible to try to establish the top and bottom of this formation. The only diagnostic fossil of the Seabee Formation found in the entire well is a print of a Turonian ammonite, *Borissiakoceras* sp. in a core from 2,090–2,100 feet. The ammonite appears to be the same species of *Borissiakoceras* found in the Seabee Formation in some of the Simpson core tests approximately 10 miles to the southeast. In the same core (2,090–2,100 ft) was a tiny (1½ in.) skeleton of a fish which D. H. Dunkle of the U.S. National Museum identified as an immature specimen of what may be a member of the ray fin fishes, genus *Leptolepis*? (Dunkle, written commun., June 19, 1951). A few poorly preserved specimens of Upper Cretaceous Foraminifera and Radiolaria were recovered from the core containing the Turonian ammonite and fish skeleton and from samples down to a core (2,990–2,998 ft) in which Albian fossils occurred. None of these fossils are of help in distinguishing formations of the Upper Cretaceous rocks.

ALBIAN ROCKS

A few Early Cretaceous Foraminifera of the lower part of the *Verneuilinoides borealis* faunal zone were found in some of the cores in the lowest 800 feet of section penetrated, but ditch samples almost all carried contamination from the Colville beds. The large assemblage of Foraminifera that is characteristic of the Tuktu Formation and the upper part of the Torok Formation is absent, and only a few of the species characteristic of this part of the section were found. Instead, the recovered fauna is similar to that in the lower part of the *V. borealis* zone in Simpson test well 1, the Barrow wells, and in the Oumalik wells, a part which is characterized by *Textularia topagorukensis* Tappan. This form occurs erratically in the *V. borealis* zone in many of the North Simpson cores except the deepest one (3,760–3,774 ft).

In addition to *Textularia topagorukensis*, a few specimens of *Haplophragmoides topagorukensis* Tappan, *Verneuilinoides borealis* Tappan, *Miliammina awunensis* Tappan, and *Reophax minuta* Tappan and a few scattered calcareous species are found. *R. minuta* occurred in several samples from 3,170–3,350 feet and was common in samples from 3,320–3,340 feet. This species was described from beds of late Albian age in Texas and is known in beds of early Cenomanian age in the Gulf Coastal States. If correctly identified here, it occurs in older rocks in the northern Alaska Cretaceous. The association of this species with *T. topagorukensis* is somewhat unusual as I did not find it in any of the outcrop samples of the Albian rocks of northern Alaska and noted it only rarely in samples from the subsurface. Mrs. Loeblich, however, lists the species as occurring in Albian rocks both in the *V. borealis* zone and in the *Gaudryina tailleuri* zone (Tappan, 1960, p. 283).

If the section in this well which yielded the specimens of *Reophax minuta* and *Textularia topagorukensis* represents only the lower part of the *Verneuilinoides borealis* zone and is equivalent to beds bearing *T. topagorukensis* in the Barrow, Oumalik, and Simpson areas, a hiatus of several hundred feet of Albian rocks is present. This hiatus would include all the abundantly fossiliferous beds of the upper part of the *V. borealis* zone, the *Inoceramus*- and *Ditrupa*-bearing beds, and the glauconitic *Dictyomitra* zone of the Simpson-Topagoruk area.

A few fossils characteristic of the Nanushuk Group were found in ditch samples below 3,350 feet, but the samples yielded mostly Colville fossils as contamination. In the bottom-hole core (3,760–3,774 ft) were numerous fragments of both narrow and wide specimens of *Bathysiphon* (*B. brosgei* Tappan and *B. vitta* Nauss?), *Ammodiscus rotalarius* Loeblich and Tappan, *Trochammina* sp., and one or two calcareous Foraminifera, plus two pyritic casts of *Dictyomitra*? sp. The presence of the pyritic radiolarian casts alone are not interpreted as evidence of the lower part of the Torok Formation even though pyritic casts of stichocorythidian Radiolaria (*Dictyomitra*? sp. and *Lithocampe*? sp.) were found in the lower beds of the Torok Formation in the Oumalik wells and in the Simpson-Topagoruk area. These casts are rarely associated with Foraminifera. Furthermore, similar casts have been found in both Lower and Upper Cretaceous rocks, so that one or two casts can hardly be regarded as exclusive criteria for beds of early Albian age. The species of the small foraminiferal assemblage found in the bottom-hole core also occur in all the Albian rocks in northern Alaska. For these reasons, therefore, the bottom core is here considered as part of the *Verneuilinoides borealis* zone of the upper part of the Torok Formation, instead of the "Oumalik" Formation, in contrast to Robinson's (1959b, p. 561) interpretation of the lowest 184 feet of the well section.

SIMPSON CORE TESTS

Four oil seeps in the vicinity of Cape Simpson and one near Admiralty Bay were discovered by American explorers 75–80 years ago, but some of these must have been known to Eskimos long before that time, if for no other reason than that larger animals became mired there when the ground was not frozen. Seep 1 was such a death trap in the spring of 1949 when two caribou does and their fawns were mired while attempting to cross the area (fig. 45).

The seeps in the Cape Simpson area are alined approximately north-south, parallel to the coast of Smith Bay; the most northerly (seep 1) is about 3¼ miles

FIGURE 45.—Simpson Oil Seep 1, Cape Simpson, Alaska, showing mired caribou, June 1949.

northwest of Cape Simpson and is about one-third of a mile from the coast. Another seep (seep 2) is about 2 miles southwest of the Cape at a point approximately 1½ miles inland, and a small seep (seep 2A) is about three-fourths of a mile inland, approximately 3¼ miles south-southwest of the Cape. A fourth seep (seep 3) is about 5 miles south-southwest of the Cape and approximately 2 miles from the coast.

Numerous core tests were drilled to secure information on the stratigraphy and structure of the area of the seeps. In 1945 the Navy drilled 12 core tests on the west side of Simpson Peninsula preparatory to drilling the Simpson deep test. During 1949–51, 19 cores tests, two offset holes, and a seismograph velocity test were drilled near Cape Simpson to determine something of the origin of the seeps and the extent of the oil found there. The seismograph velocity test was drilled in the center of Lake Minga.

A total footage of 4,112 feet was drilled in the first 12 core tests, the holes ranging in depth from 116 to 580 feet. Four tests reached only 116–151 feet, three tests were 226–368 feet deep, and five tests were 460–580 feet deep. All drilling, coring, and logging of the tests was performed by Navy personnel. Apparently the cores were skeletonized, and much of the material discarded at the drill sites. Subsequently some core sections were processed for paleontologic studies, and the washed material was ultimately examined for microfossils by specialists. The only lithologic records of the sections penetrated are those prepared by Navy geologists and these data are included by Robinson (1964) in her study of the Simpson Seeps area.

CORE TESTS 1–12

Paleontologic data from core tests 1–12 are meager. Cores were apparently caked with drilling mud, and this material was processed and sent out for examination. Some of the material was submitted to the late Dr. Joseph Cushman in 1946; he provided some preliminary determinations. In 1947 washed material from the tests was examined by Mrs. Loeblich. The following year the late Helen Jean Plummer examined a few samples. Both Plummer (1948) and Loeblich (1948) reported their findings in November 1948. As only a few of the fossils found and examined by Mrs. Loeblich and Mrs. Plummer were later available for my studies and as none of those examined by Cushman were seen by me, most of the paleontologic data on core tests 1–12 are from the reports by Mrs. Plummer and by Mrs. Loeblich. The interpretations of the sections penetrated, however, are my conclusions based on current stratigraphic knowledge of the area.

As indicated by chert pebbles logged by the Navy geologists and by the presence of Pleistocene Foraminifera in samples, the area of those core tests is mantled by Pleistocene (Gubik Formation) deposits. The thickness of these deposits can only be inferred because of the condition of the cored material but probably is in the range of 25 to 100 feet if judged on the basis of the known thickness of the Gubik Formation in Simpson test well 1 and in the core tests in the Cape Simpson area. The few cores from core tests 1–10 indicate sediments that are largely argillaceous fine sand, silt, and clay shale with some carbonaceous material. The only fossils reported from core tests 2, 3, 4, and 6 are Foraminifera from the Gubik beds, but these Foraminifera apparently were introduced into the broken cores by drilling mud. A few Foraminifera that are now known to be from the *Verneuilinoides borealis* zone of Early Cretaceous (Albian) age came from material from core tests 5, 7, 8, and 10. Inasmuch as the sediments found in each of core tests 1–10 were of the same general type, Lower Cretaceous rocks were very likely penetrated in each hole.

In core tests 11 and 12, Upper Cretaceous beds were probably penetrated, and although they were not recognized as such in 1948, both Helen Plummer and Helen Loeblich noted that the fauna in core test 11 differed from that in core tests 1–10; both investigators suggested that a fault might cut the area. Both investigators also mentioned volcanic glass in core test 11; although I have not seen the material they noted, certain specimens on the few slides available referred to as "*Aschemonella*" by Mrs. Loeblich (1948) are volcanic glass beads which superficially bear resemblance to the foraminifer *Aschemonella.* Both Mrs. Plummer (1948) and Mrs. Loeblich (1948) called attention to the similarity of calcareous Foraminifera from core test 11 to specimens found in certain outcrop samples collected by Detterman in 1947 from rocks exposed along the Coleville River and Prince Creek southwest of Umiat. The Detterman samples to which core test 11 was compared are now known to be from the Barrow trail and Sentinel Hill Members of the Schrader Bluff Formation.

Core test 12 apparently yielded no fossils, and volcanic glass is not mentioned by either Mrs. Plummer or Mrs. Loeblich; but as carbonaceous material and brown mica were noted, the beds penetrated could also be of Cretaceous age. The brown mica may be the type of biotite that is characteristic of bentonitic beds in the Seabee and Schrader Bluff Formations.

Oil shows in four core tests together with the seismic data led to the drilling of the Simpson deep test 2 years later.

CORE TESTS 13–31

In core tests 13–31 and the Lake Minga velocity test, depths ranged from 115 to 2,505 feet, and a total footage of 24,026 feet was drilled. Although the holes were intended as core tests, only 5,076 feet of the footage was cored. About 45 percent of this coring was done in two holes. In core test 13, coring was continuous from 20 to 1,310 feet, and in core test 25, from 508 to 1,510 feet or total depth. In four other holes, coring was continuous as follows: from 107 to 446 feet in core test 27, from 71 to 469 feet in core test 29, from 102 to 693 feet, total depth, in core test 30, and from 115 to 355 feet, total depth, in core test 31.

Core test 26 flowed oil and was completed as a well for pumping tests. Core test 31 had the same potentiality, but the hole froze up. Oil also flowed or was recovered from core tests 27, 30, and 30A.

All the extensively cored sections provided good lithologic and paleontologic samples from a considerable thickness of rock and yielded most of the microfossils found, but in other tests where cores were taken at only infrequent intervals or where there was no coring, as in tests 19 and 20, many of the samples had relatively few microfossils. In fact, a large percentage of ditch samples was of no value and contained a high percentage of drilling mud because a shale shaker was not used on the rig. Thus, most of the ditch samples were "barren", even immediately above or below fossiliferous cores. In some of the holes, Pleistocene Foraminifera occurred as contamination in samples through several hundred feet of section below the Gubik beds. In spite of the shortcomings of the samples, however, information from the microfossils from the Cape Simpson test holes provided the first absolute proof of Cretaceous sediments beneath Pleistocene beds in the coastal plain area.

Core tests 13, 14, 14A, 25, and 28 yielded the best faunal record of all the tests, and therefore faunal charts are included only for these tests. Instead of faunal charts for each core test, table 16 summarizes all pertinent information for core tests of the Cape Simpson area. In this table, the suggested intervals for the Cretaceous formations penetrated are indicated where fossil and lithologic data are considered reliable; also shown for the Seabee Formation are intervals of a radiolarian zone, a pelagic microfauna, and the occurrences of a Turonian ammonite of the genus *Borissiakoceras*.

PALEONTOLOGIC DATA

TURONIAN ROCKS

Hedbergella-Heterohelix and Radiolaria zone of Seabee Formation

Beneath the mantling Pleistocene Gubik Formation, the rocks penetrated in each core test of the Simpson seeps area are largely clay shale but include minor thin beds of limestone and bentonite of the Seabee Formation (Turonian age). These rocks seem to rest nonconformably on Lower Cretaceous sediments. In five core tests, there were specimens of a small ammonite, *Borissiakoceras* cf. *B. ashurkoffae* Cobban and Gryc, and flattened, incomplete shells of *Inoceramus* sp. (possibly *Inoceramus* cf. *I. labiatus* Schlötheim associated with an extremely restricted pelagic microfauna. This pelagic microfauna consists of two species of Foraminifera, *Hedbergella loetterlei* (Nauss) and *Heterohelix globulosa* (Ehrenberg), which are found in Turonian rocks in Canada, the Western Interior, and the Gulf Coastal plain. Locally in the core tests, a few other Foraminifera occur, but these are long-ranging Colville species.

In 10 core tests, a few species of Radiolaria, most commonly two or three species each of *Cenosphaera*, *Spongodiscus*, and *Dictyomitra*, were found in relative abundance within a limited part of the section. The Radiolaria are indigneous to the Schrader Bluff Formation, but seemingly were found as an assemblage in association with *Borissiakoceras* in three of the core tests. The radiolarian beds were best represented in the interval 117–170 feet in core test 26, at 124–201 feet in core test 27, and 143–243 feet in core test 30. The Radiolaria were also found in core test 14 in ditch and core samples at 270–305 feet, in ditch samples at 330–385 feet, and in a core sample, in which there were great quantities of drilling mud, recovered at 465–475 feet.

Fish-bone fragments were found through a few hundred feet of section in the Seabee Formation in some core tests or were in scattered samples in others. In-

TABLE 16.—*Stratigraphic summary for Simpson core tests 13–31 and Minga velocity test*

[Depth or range of stratigraphic and paleontologic elements given in feet; T.D., total depth]

Simpson core test	Total depth (feet)	Number of feet of coring	Depth or depth range (feet)											Sample information
			Approximate base of Gubik Formation	Seabee Formation	*Borissiakoceras* sp. cf. *B. ashurkoffae* Cobban and Gryc	Fish bones	Radiolarian zone	Pelagic Foraminifera	Other Colville Foraminifera	Beds of Albian Age	*Ditrupa cornu* Imlay	*Verneuilinoides borealis* zone	Tuktu fauna	
13	1,438	1,190	83	83–661	655	105–190 569–673	592–655	640–641	--------	661–T.D.	852–1,050	661–1,158	852–1,158	Mostly barren in upper 600 ft; very fossiliferous Albian section.
14	1,270	238	85	85–475±	--------	240–305	[1] 270–475	--------	295–305	475–T.D.	865–?	661–?	1,015–?	Ditch samples; cores fossiliferous in Albian section.
14A	290	90	--------	(Cored, 200–290)	275	250–T.D.	[2] 258–T.D.	--------	--------	--------	--------	--------	--------	No samples above 200 ft.
15	900	7	75	75–?	--------	235–370	235–430?	266–268	295–430	Below 560	870–T.D.	870–T.D.	--------	Gubik contamination through 215 ft; largely barren below 430 ft.
16	800	35	80?	80?–544?	--------	250–544	270–440	410–420	290–430	--------	--------	--------	--------	Barren below 544 ft.
17	1,100	45	80?	?	--------	--------	--------	--------	--------	([3])	1,003–1,013	1,003–T.D.?	--------	Samples poor, mostly barren except for Gubik contamination through 560 ft; Chandler Formation(?) 710–1,000 ft.
18	1,460	40	90?	90?–?	407	--------	--------	--------	--------	--------	--------	--------	--------	Samples poor; Gubik contamination throughout; few nondescript Radiolaria and Foraminifera of Cretaceous(?) age.
19	1,061	0	80	80–T.D.?	--------	520–620 1,000–1,050	--------	--------	340–350	--------	--------	--------	--------	Samples poor; Gubik contamination throughout; *Inoceramus* prisms below 1,020 ft.
20	1,001	0	85	85–T.D.?	--------	290–?	?	--------	--------	--------	--------	--------	--------	Samples poor; Gubik contamination through 790 ft; few nondescript Radiolaria and Foraminifera.
21	1,500	251	90	90–1,270?	--------	130–208 300–309	--------	--------	--------	1,270–T.D.	1,290–?	1,270–?	--------	Most cores barren; Gubik contamination through 1,320 ft; a few specimens of *Haplophragmoides*.
22	903	79	80?	80?–T.D.?	--------	500–510	--------	--------	--------	--------	--------	--------	--------	Poor data; Gubik contamination through 680 ft; casts of "*Zonodiscus*" at 300–309 ft; No Foraminifera.
23	1,035	118	110	110–580?	--------	490–?	--------	--------	--------	580?–T.D.	860–1010	860–T.D.	1,000–T.D.	Most cores barren; Gubik contamination throughout; small fauna in core at 1,000–1,010 ft.
24	900	55	90±	90±–580±	--------	310–?	--------	--------	--------	580–T.D.	850–T.D.	--------	--------	Samples poor, largely barren; Gubik Foraminifera in core 100–110 ft; Gubik contamination through 560 ft.
25	1,510	1,007	110?	110?–832	--------	591–791	--------	--------	--------	832–T.D.	853–1446	832–T.D.	832–T.D.	No data on upper beds; Seabee Formation on Tuktu(?) Formation.
26	1,171	128	90	90–498?	148	137–170	[1] 117–170	--------	159–170	498?–T.D.	820–?	498–?	--------	No cores below 580 ft; ditch samples poor; Gubik contamination through 620 ft.
27	1,500	348	?	107–?	154–168	--------	[4] 124–201	168–190	124–446	?–T.D.	720–T.D.	720–T.D.	1,490–T.D.	Continuous cores 102–446 ft; no samples 450–540 ft; probably Grandstand and Chandler below 540 ft; Tuktu fauna may start higher than lowest core (1,490–1,500 ft).
28	2,505	111	?	120?–1,040	--------	410–?	--------	--------	--------	1,040–T.D.	1,120–2,344	1,040–T.D.	1,491–T.D.	Some clay shale may be equivalent to upper part of Torok Formation.
29	700	408	85	85–449	--------	102–173	427–438	--------	163–223 417–449	459–T.D.	679–T.D.	679–T.D.	679–T.D.	Continuous cores 71–469 ft; Radiolaria very restricted; barren beds may be in Chandler Formation.

See footnotes at end of table.

TABLE 16.—*Stratigraphic summary for Simpson core tests 13–31 and Minga velocity test*—Continued

Simpson core test	Total depth (feet)	Number of feet of coring	Depth or depth range (feet)											Sample information
			Approximate base of Gubik Formation	Seabee Formation	*Borissiakoceras* sp. cf. *B. ashurkoffae* Cobban and Gryc	Fish bones	Radiolarian zone	Pelagic Foraminifera	Other Colville Foraminifera	Beds of Albian Age	*Ditrupa cornu* Imlay	*Verneuilinoides borealis* zone	Tuktu fauna	
30	693	622	85?	85?–429±	-----	-----	[1]143–253	153–162	182–398	429–T.D.	-----	429–620	-----	Small Albian fauna 577–620 ft similar to that in East Topagoruk test well 1 at 400 ft.
30A	701	20	85	-----	-----	-----	-----	-----	-----	681–T.D.	680–T.D.	680–T.D.	691–T.D.	Cored 680–700 ft only; no samples above.
31	355	240	100±	100±–T.D.	-----	125–219	[2]186–296	-----	208–317	-----	-----	-----	-----	Cored continuously 115–355 ft, but *Borissiakoceras* sp. not found.
Minga	1,233	8	85?	85?–610	-----	280–?	-----	-----	-----	740–?	860–?	1,020–T.D.	1,020–T.D.	Only cored at bottom of hole; samples above 1,020 ft too poor for paleontologic diagnosis; Gubik contamination through 960 ft.

[1] Zone good.
[2] Zone fair.
[3] Present.
[4] Very good.

frequently a fish scale was found in a few cores; large scales of about an inch in diameter found in a core at 417 feet in core test 29 were identified by D. H. Dunkle of the U.S. National Museum as being from a chirocentrid fish of the genus *Portheus* (*Hypsodon*) or *Ichthyodectes*.

The thickness of the Seabee Formation in the Simpson Seeps area could be as much as 1,200-1,400 feet, if the data from core tests 18 and 21 are reliable. However, only four cores were taken in core test 18, and the lowest was at 816–826 feet. No fossils other than three or four specimens of Radiolaria (*Cenosphaera*? sp.) were found in samples from the lower beds, and the poor quality of the ditch samples is indicated by Gubik contamination through 1,360 feet of section. A better indication of the thickness of the Seabee Formation is suggested in core test 21, where a core taken at 1,200–1,209 feet was still in clay shale that is probably part of the same formation as the higher beds, whereas Albian fossils were found in samples from 1,270–1,280 feet and 1,290–1,300 feet. The thickest cored section of the Seabee Formation was in core test 13; almost 600 feet of Seabee was continuously cored, and the formation rests on Lower Cretaceous beds at 661 feet.

All the Upper Cretaceous beds penetrated in the Simpson Seeps core tests have been assigned to the Seabee Formation because of the presence of the early Turonian ammonite *Borissiakoceras* and the planktonic Foraminifera *Hedbergella loetterlei* (Nauss) and *Heterohelix globulosa* (Ehrenberg). However, the presence of Schrader Bluff beds is suggested because the Radiolaria that occur above the ammonite and that seemingly are associated with it in core tests 14A and 27 are the same species found elsewhere in the lower part of the Sentinel Hill Member and the upper part of the Barrow Trail Member of the Schrader Bluff Formation. In addition, a few specimens of *Quinqueloculina* cf. *Q. sphaera* Nauss found above the Radiolaria in some of the core tests suggest the presence of Schrader Bluff beds because this foraminifer seems to be more characteristic of the Schrader Bluff Formation than of the Seabee Formation. It is thus entirely possible that part of the sequence could be in the Schrader Bluff Formation, but that the evidence is obscured because of a possible unconformity in the Upper Cretaceous rocks. An unconformity together with faulting could have brought middle Schrader Bluff radiolarian beds into contact with strata bearing the planktonic Foraminifera and Turonian ammonite; faulting could also explain the absence of the ammonite beds in some of the core tests. Only a minor displacement would be needed to produce the faunal relationship noted above, if there were an unconformity between the Shale Wall Member of the Seabee Formation and the radiolarian beds of the Schrader Bluff Formation. Furthermore, if in this area structures were forming between the close of early Turonian time and the beginning of Campanian time, few or no sediments would have been deposited, and the radiolarian beds of the middle part of the Schrader Bluff Formation would rest on beds of the Shale Wall Member of the Seabee Formation. Slight faulting could have brought the beds into their present close relationship.

MIDDLE TO UPPER ALBIAN ROCKS

Verneuilinoides borealis faunal zone

Sparingly fossiliferous beds of Albian age underlie the Seabee Formation, and these range in thickness from a few feet to 950 feet in core test 27. These beds represent the only part of the section that is nearly analogous to the Grandstand Formation of the foothills region, as they carry a restricted microfauna consisting chiefly of *Verneuilinoides borealis* Tappan, *Miliammina awunensis* Tappan, and *Saccammina lathrami* Tappan of the *Verneuilinoides borealis* faunal zone.

Tubes of *Ditrupa cornu* Imlay occur within this poorly fossiliferous section in the Simpson core tests; however, in the Foothills region these worm tubes are confined almost entirely to beds lower in the section and are associated with a prolific *Verneuilinoides borealis* fauna characteristic of the Tuktu Formation. The appearance of the tubes above that zone in the Simpson area suggests that they extend higher in the Albian section in the coastal plain than in the Foothills region. There is not, however, any consistent top to the *Ditrupa* occurrences in the Simpson area, and very likely chance was an important factor in their being retained in the drilling mud-impregnated ditch samples of the Simpson core tests.

Microfossils of the *Verneuilinoides borealis* zone were found in clay shale beds in 15 of the Cape Simpson core tests. Most of these fossils can be readily recognized although the greater number of arenaceous specimens are crushed and somewhat distorted. In nine of the core tests, very fossiliferous beds of the lower part of the *V. borealis* faunal zone contain a microfauna that is equivalent to the assemblage characteristic of the Tuktu Formation and the upper part of the Torok Formation, but in only three or four of these core tests, where several hundred feet of the fossiliferous section of Albian age was penetrated, were the specimens numerous and the assemblage large.

The thickest Albian section was penetrated in core test 28, where approximately 1,485 feet of Tuktu and Grandstand Formations undifferentiated underlie approximately 1,020 feet of beds that may be the Seabee Formation. In core test 28, however, the Albian section yielded a relatively small microfauna, largely from 10 cores taken at approximately 100-foot intervals below the 1,281-foot depth. Only 16 core samples and 23 ditch samples from the entire 1,500-foot section between 1,000 feet and the bottom of the hole at 2,505 feet were available for microfossil study, but of that interval there were no ditch samples from 1,450–2,090 feet and only six core samples.

In core test 28 the restricted *Verneuilinoides borealis* fauna characteristic of the Grandstand Formation was found about 400 feet above a more extensive *V. borealis* fauna which is correlative with the Tuktu faunal facies; in core test 13, a limited fauna is approximately 190 feet above a prolific *V. borealis* fauna, but in core test 23 the interval between the two faunas is only about 140 feet. The lowest beds penetrated may be in the Torok Formation.

In core test 25, an abundant microfauna of Albian age appears immediately beneath beds that may belong to the Seabee Formation; this microfauna was found throughout nearly 700 feet of a continuously cored section. The fauna includes 37 species of Foraminifera and 2 species of Radiolaria and could represent the lower part of the Tuktu faunal facies of the *Verneuilinoides borealis* zone or the upper part of the Torok Formation. It is much too well developed to be within the Grandstand Formation. Ten Foraminifera were common to abundant in one or more samples and occurred relatively frequently in others; in order of abundance they are *Verneuilinoides borealis* Tappan, *Haplophragmoides topagorukensis* Tappan, *Miliammina manitobensis* Wickenden, *Miliammina awunensis* Tappan, *Textularia topagorukensis* Tappan, *Ammodisscus rotalarius* Loeblich and Tappan, *Glomospirella gaultina* (Berthelin), "*Tritaxia*" *manitobensis* Wickenden, *Globorotalites alaskensis* Tappan, and *Pallaimorphina ruckerae* Tappan. Seven other species occurred in 6–12 samples, but in each occurrence the number of specimens was rare. Twenty more species of Foraminifera and 2 species of Radiolaria were found only rarely.

In a continuously cored section in core test 13, about 190 feet of poorly fossiliferous to barren Lower Cretaceous beds occur immediately below the Seabee Formation. This cored section is followed by about 300 feet of section (852–1,158 feet) in which an abundant *Verneuilinoides borealis* microfauna was found. The extent of the microfauna is unknown, however, as the lowest 52 feet of the continuously cored section is barren, and very few microfossils were found in the ditch samples from 1,210 feet to the bottom of the hole at 1,438 feet. In core test 14 the abundant microfauna is known only from three cores (1,015–1,023 ft, 1,039–1,045 ft, and 1,072–1,075 ft) as ditch samples to total depth at 1,265 feet were barren or yielded only an infrequent foraminifer. In other core tests the section bearing the abundant *V. borealis* fauna was penetrated to a depth of only a few feet.

POSSIBLE STRUCTURE OF THE SIMPSON SEEPS AREA

Speculation as to the origin of the Simpson seeps has led interested geologists to consider as causal factors possible depositional features such as offshore sand bar deposits; structural features including faults; and erosional features such as submarine canyons. Seismic evidence has generally ruled out the possibility of shallow faults of any magnitude in the area. Perhaps the best suggestion has been that of submarine canyons as T. G. Payne originally proposed (Payne, unpublished data). The possibility of Late Cretaceous submarine canyons in the Simpson area was reviewed by F. M. Robinson (written commun., 1954). She concluded that rapid submarine erosion produced canyons and residual highs of sands in the Lower Cretaceous sediments that were rapidly filled and buried by subsequent deposition of younger Cretaceous rocks almost contemporaneous with erosion. Oil later accumulated in the stratigraphic traps produced by the ridges of sand, and minor faulting probably provided avenues through which oil could migrate to the land surface.

A study of the Lower Cretaceous paleontologic data suggests that some consideration of a structural interpretation for the origin of the seeps should not be overlooked. The prolific *Verneuilinoides borealis* fauna of the Tuktu and Torok facies occurs in the Simpson Seeps area and was found on "highs"; contours can be drawn to show the top of this prolific fauna. If the contours are coordinated with the prevailing dips in the upper 2,000 feet of reflections from seismograph lines crossing this area, a possible structural pattern that can be drawn suggests that the Lower Cretaceous beds were involved in a series of shallow minor folds in part eroded prior to Colville time. Post-Cretaceous faulting in this area could have provided the necessary avenues of escape for the oil that accumulated in minor folds of the upper Albian rocks. The seeps themselves probably formed relatively late, their growth in part stimulated by the permafrost action that has gone on since Pleistocene time.

TOPAGORUK TEST WELL 1

This test well was drilled on a seismic structure, on the west side of the Topagoruk River, about 9 miles air line south of its mouth. It was the second deepest well (10,503 feet) in the Reserve and penetrated about 36 feet of Pleistocene sediments, approximately 6,540 feet of Lower Cretaceous rocks, 2,040 feet of Jurassic rocks, 740 feet of Triassic rocks, and more than 1,100 feet of middle to late Paleozoic rocks. The stratigraphy and lithology have been discussed by Collins (1958b). Collins regarded the Cretaceous rocks through 1,350 feet as the Grandstand Formation, from 1,350 to 3,900 feet as the Topagoruk Formation, and from 3,900 to 6,600 feet as the Oumalik Formation. In this report the section from 50 to 1,350 feet is considered as Tuktu and Grandstand Formations undifferentiated, and the section from 1,350 to 6,600 feet as the Torok Formation. Cretaceous rocks in the upper 1,350 feet of the well are largely marine sandstone with a large amount of marine clay shale and a few thin beds of coal. Sandstones range from a few feet to 50 feet in thickness. The sequence below 1,350 feet to the top of the Upper Jurassic rocks is composed largely of clay shale with thin beds and laminae of siltstone. In the upper part are a few beds of sandstone less than 10 feet thick.

A preliminary summary of the microfossils in this test hole was published (Bergquist, 1958c, p. 311–313), but subsequent detailed studies of the Cretaceous microfossils has necessitated certain nomenclatural changes as follows: *Ammobaculites* n. sp., now *A. wenonahae* Tappan; *Spiroloculina ophionea* Loeblich and Tappan, now reidentified as *Psamminopelta subcircularis* Tappan; *Spiroplectammina koveri* Tappan, now a synonym of *Textularia topagorukensis* Tappan; *Globulina lacrima* Reuss, now separated as the subspecies *G. canadensis* Mellon and Wall; *Ditrupa* sp., now *Ditrupa cornu* Imlay. All microfossils recovered from the Cretaceous rocks, plus those from the Jurassic and Triassic beds, are tabulated on the faunal chart (pl. 19).

MIDDLE TO UPPER ALBIAN ROCKS

VERNEUILINOIDES BOREALIS FAUNAL ZONE (200–3,600 FT)

The only microfaunal zone recognized in this test well is the *Vernuenilinoides borealis* zone, which extends through the sequence of sandstone and clay shale in the upper 1,350 feet of the well and through part of the thick clay shale sequence of the Torok Formation. The first few fossils of this zone were found in a sample from 200–220 feet, and fossils continued at least through the core at 3,550–3,560 feet.

Relatively few species were found in the ditch samples, but numerous species of Foraminifera were found in some of the cores. This fact suggests that the quality of the ditch material was poor. For example, four species of Foraminifera were found in relative abundance in a core at 911–919 feet, but only a few specimens of some of these species were found in ditch samples from above and below the same core. Furthermore, the Tuktu faunal facies, which is fairly well developed in Simpson test well 1, 17 miles N. 17° E., seems to be only meagerly present in the Topagoruk well in the core at 911–919 feet where *Ammobaculites wenonahae* Tappan and *Psamminopelta subcircularis* Tappan were common. The former of these two species was not found in outcrop samples of the Grandstand Formation, and the latter was noted only rarely. Almost certainly, however, these two fossils and the Tuktu faunal facies in general have much greater extent than the core indicated, as it would be strange indeed if the coring occurred in the only good fossiliferous strata in several hundred feet of section.

One interpretation of the limited zone is that the Tuktu faunal facies is interbedded with a predominantly less marine Grandstand faunal facies because a core from a position approximately 300 feet higher and a core from about 200 feet lower were both nonfossiliferous.

In evaluating the fauna for statistics on the *Verneuilinoides borealis* zone in this test hole, only the samples to the depth of 2,950 feet have been considered, as it is almost certain that specimens in ditch samples below that depth are contamination from higher beds. A total of 45 species of Foraminifera are tabulated for this interval on plate 19. Of these, 25 species are calcareous, but they constitute only 14 percent of the fauna tabulated, as only 1 species, *Gavelinella stictata* (Tappan), is conspicuous in the fauna. It constitutes 6 percent of the count, whereas 16 calcareous species are represented by only 1–5 specimens each.

Twenty identified species of arenaceous Foraminifera constitute 86 percent of the *Verneuilinoides borealis* fauna in this test well. Heading the list is *Haplophragmoides topagorukensis* Tappan constituting 37 percent, and *V. borealis* Tappan making up 18 percent. Specimens of *Bathysiphon vitta* Nauss? account for 14 percent, and *Ammobaculites wenonahae* Tappan is represented by 3 percent of the count; 17 other arenaceous species together account for 12 percent of the total, but 7 of these species are represented by only 1–7 specimens each.

Most of the specimens found in beds through the upper part of the faunal zone have a fine arenaceous texture, are light tan to buff, and are flattened but not crushed. Although most of the *Verneuilinoides borealis* specimens are compressed, the chambers are fairly distinct and show their similarity to the few specimens that have retained inflated, subtriangular tests. Lower in the test hole, compressed specimens of *V. borealis* are short, triangular in outline, and have a coarse texture that almost obscures the chambers. Specimens of *Ammobaculities wenonahae* and *Gaudryina canadensis* Cushman are brown, have a granular texture, and are flattened so that the chambers are not very distinct. Compressed specimens of *Textularia topagorukensis* Tappan are white, narrow, elongate, and very delicate. Scattered through the samples are tubes of *Ditrupa cornu* Imlay; in some of these tubes the middle layer is partially replaced by pyrite, whereas the inner and outer layers are still calcareous.

In the upper part of the Torok Formation, compressed, light-colored specimens of *Haplophragmoides topagorukensis* are conspicuous. The core at 1,490–1,501 feet yielded 22 species of Foraminifera, one of the largest assemblages from any sample in the *Verneuilinoides borealis* faunal zone. Specimens of *H. topagorukensis* and *Gavelinella stictata* make up about 32 percent of this assemblage; *Bathysiphon vitta* Nauss?, *B. brosgei* Tappan, *Vaginulinopsis mülleri* (Reuss), the short cone-shaped calcareous tests of *Eurycheilostoma robinsonae* Tappan, and the high cone-shaped *E. grandstandensis* Tappan make up approximately 40 percent. Other species are represented by one to five specimens each. The preservation and appearance of the specimens from the core at 1,490–1,501 feet are similar to those of specimens in the upper part of the well. Arenaceous species are compressed; specimens of *H. topagorukensis* are distorted; and the chambers on the specimens of *V. borealis* are indistinct. Many of the calcareous specimens are partly crushed.

In ditch samples from 1,690–1,790 feet, a few tests of *Gaudryina nanushukensis* Tappan were found. Specimens are large, rather stout, and are easily identified by the broad triangular cross section and the light-gray surface mottled by sooty manganese spots along the sides and sutures.

Several glauconitic casts of *Dictyomitra* sp. were picked from a ditch sample from 2,530–2,540 feet, and specimens were common in a sample from 2,620–2,630 feet. The casts are dark green and are elongate conical; many show transverse septal strictures, and a very few have impressions of the longitudinal ribs characteristic of *D. multicostata* Zittel. Two vaguely conical specimens occurred as high as 2,120–2,130 feet, and there were rare occurrences of casts in samples down to the depth of 3,000 feet. Through the succeeding 1,000 feet of beds, the casts were common in some ditch samples but were not found in any cores. Apparently the specimens were replaced in a zone of glauconite that can be traced in the upper part of the Torok Formation in wells and shot holes drilled in the Simpson Peninsula, Topagoruk, and Barrow areas. In the Topagoruk test well, the zone is probably within the interval 2,530–2,640 feet, where the casts were abundant, but in samples from 3,000–3,150 feet, the casts were also very common. Either there is a second zone, or the casts were introduced from the higher beds by ditch contamination.

Apparently contamination of ditch samples from the higher beds of the Cretaceous was prevalent in much of the lower part of the Cretaceous section as many of the species of the *Verneuilinoides borealis* faunal zone occurred continuously in ditch material throughout the Torok Formation. If only the data from the cores are considered, the fauna is rather small in the lowest 500–1,000 feet of the *V. borealis* zone. In the core at 2,940–2,950 feet *Bathysiphon vitta* Nauss? and *Haplophragmoides topagorukensis* Tappan were common. An imprint of an ammonite at 3,249 feet was identified by Ralph Imlay as *Cleoniceras sablei* Imlay. At 3,550–3,650 feet light-colored flattened, tapering tests of *Textularia topagorukensis* Tappan were common.

LOWER PART OF TOROK FORMATION (3,600–6,600 FT)

There are scarcely any paleontologic data to evaluate the beds between 3,600 and 6,600 feet, which are the lower part of the Torok Formation. Most of the microfossils found in ditch samples are species from the *Verneuilinoides borealis* fauna. Thirty-six of the forty cores from this part of the formation were barren, and the 4 "fossiliferous" cores gave scant data. A core at 4,100–4,110 feet was barren except for a few *Inoceramus* prisms. From a core at 4,345–4,348 feet, only a questionable specimen of *Haplophragmoides topagorukensis* was found. Two distorted specimens of *H. topagorukensis* were found in core 17 (4,632–4,635 ft), and two specimens came from a core at 6,480–6,490 feet.

There were, however, a few pyritic casts of Radiolaria of the forms found in the type section of the "Oumalik" Formation in Oumalik test well 1 and in the lower part of the outcropping Torok Formation. The pyritic casts are stichocorythidian specimens found in ditch samples starting at 4,610–4,620 feet and continuing through 5,180–5,190 feet. Most of the casts are spindle shaped (*Lithocampe?* sp.); a few are conical and have a flattened top (*Dictyomitra?* sp.). Some of the latter are short and stubby; others are elongate. Some casts are pitted from original pores; others are granular. On some, transverse strictures are faintly indicated between joints, but surface ornamentation is not retained. The casts of *Lithocampe?* sp. are the more numerous of the casts of the two genera.

JURASSIC ROCKS

A section of fossiliferous Upper Jurassic sediment was penetrated from 6,600 to 7,820 feet. Beneath these sediments, the beds from 7,820 to 8,640 feet are considered to be of Middle Jurassic age. Lower Jurassic rocks apparently are absent.

UPPER JURASSIC (OXFORDIAN OR LOWER KIMMERIDIGIAN) ROCKS

The sequence from 6,600 to 7,820 feet is largely clay shale but has a basal unit of glauconitic sandstone. No Foraminifera were found in ditch samples from the upper 140 feet of the section, but tiny pyrite concretions were found in all samples from 6,630 feet through a fossiliferous core at 7,042–7,062 feet. In the 300 feet of "pebble shale" (6,600–6,910 ft) in the uppermost part of the section, a sparse microfauna was found in two cores (6,742–6,753 ft and 6,849–5,859 ft). Specimens are crushed, which make identification difficult, but the few species present appear to be closely related to the prolific microfauna found 300 feet lower. Specimens of *Gaudryina topagorukensis* Tappan? were common, and a vitreous-looking low spired small species of *Trochammina* that has several chambers in the last whorl was abundant. The specimens appear to be the same as the specimens of a species found with the prolific fauna at a lower depth.

The determination of the Upper Jurassic beds as Oxfordian or early Kimmeridgian age was made by Mrs. Loeblich (Tappan, 1955), who also described several new species from this well. In a sample of "pebble shale" in a core at 7,042–7,062 feet, about 24 species of Foraminifera were identified. These are tabulated on plate 19. Associated with the Foraminifera were fragments of mollusk shells, including a specimen of *Buchia* cf. *B. rugosa* (Fischer) at 7,060 feet and a species of ostracode. According to Imlay, who identified the mollusk, *B. rugosa* has a range from middle Kimmeridgian to early Portlandian age.

Of the Foraminifera found in the core sample at 7,042–7,062 feet, calcareous specimens are prevailingly grayish tan, and the tests are filled with calcite. Some are broken, but none are distorted. Specimens of arenaceous Foraminifera are generally dark colored; some are pyritic. Where replaced by pyrite, the original shape is retained, but otherwise many of the trochoid and planispirally coiled forms are crushed and distorted. Nonpyritized specimens of the bulbous *Trochammina canningensis* Tappan are severly flattened and distorted. The high-spired *Trochammina topagorukensis* Tappan is preserved mostly as conical pyrite-filled tests, having sutures flush with the surface. Specimens of *Ammobaculites alaskensis* Tappan show a considerable range in size and shape from long narrow specimens to short wide ones; the fine-grained surfaces of many have a few larger grains of quartz that give a seemingly coarse texture to the surface.

Below the fossiliferous core mentioned above, Foraminifera were of erratic occurrence and abundance, and few species were found in the ditch samples. In some caved material, sloughed from the sides of the hole somewhere between the top of the Jurassic beds and the 7,500-foot depth, dark-colored specimens of *Ammobaculites alaskensis* Tappan and *Gaudryina leffingwelli* Tappan were very abundant. Various stages in the growth of tests of the latter are seen in the collections; specimens vary from short triserial forms to large mature individuals having an elongate parallel-sided biserial stage following the triserial stage.

Upper Jurassic species of Foraminifera appeared consistently in the ditch samples from about 7,400 feet to a barren core at 7,803–7,816 feet; and in the interval 7,857–8,100 feet, *Haplophragmoides canui* Cushman was common in many samples.

MIDDLE(?) JURASSIC ROCKS

Approximately 800 feet of beds (7,820–8,640 ft) between the glauconitic sandstone at the base of the Upper Jurassic rock sequence and the top of the Triassic rocks at 8,640 feet has been considered Middle Jurassic age (Collins, 1958b, p. 270). The sequence consists largely of clay shale but has nearly 100 feet of siltstone at the top and about 60 feet of siltstone at 8,215–8,275 feet. Fragmentary molds of ammonites found within a core at 8,111–8,113 feet were studied by Imlay (1955, p. 82, 89), who identified two specimens as *Pseudolioceras*? sp. and one specimen as *Tmetoceras* sp. Imlay considered the last specimen mentioned to resemble the inner whorl of specimens of *Tmetoceras* from the lowermost exposed beds of the Kialagvik Formation in the Alaskan Peninsula (Imlay, 1955, p. 89). As these ammonites normally occur near the base of the Middle Jurassic, Collins (1958b, p. 270) suggested that some of the strata above the Triassic beds may be of Early Jurassic age. There were no Foraminifera in the core with the ammonites, and the lower Toarcian and upper Pleinsbachian foraminiferal fauna which was so prolific in South Barrow test well 3 and in Simpson test well 1 was completely absent. The Foraminifera found in ditch samples in the lower part of the Jurassic section are contamination from Upper Jurassic beds.

TRIASSIC ROCKS

SHUBLIK FORMATION (8,640–9,380 FT)

The top of the Shublik Formation is questionably placed at 8,640 feet in the midst of a clay shale sequence—on the basis of one specimen of *Astacolus connudatus* Tappan, a thin planispiral narrow keeled calcareous Shublik species. In the succeeding ditch samples from 8,670–8,690 feet, two fragments of a Shublik costate *Nodosaria* (*N. shublikensis* Tappan) were found. Other ditch samples down to a core at 8,917–8,921 feet were either barren or had only contaminating Upper Jurassic Foraminifera. In the core sample from 8,917–8,921 feet were incomplete pyritic internal molds of an elongate biserial calcareous species, *Pyrulinoides plagia* Tappan; several pyrite-filled specimens of the tiny *Bolivina lathetica* Tappan; and a fragment of the compressed and ribbed *Frondicularia acmaea* Tappan. Pyrite casts of indeterminate Foraminifera species, tiny smooth-valved ostracodes, and pyritic internal molds of a tiny rounded to ovate unidentified pelecypod complete the microfauna of this core. Incomplete casts of the valves of two Triassic mollusks (*Halobia* sp. and *Monotis* sp.) were found in the same core.

Among the few Foraminifera in succeeding ditch samples were three or four additional Triassic species and some Upper Jurassic (contamination) specimens. From 9,202 to 9,380 feet, some Upper Jurassic species were common to abundant. Dark-colored specimens of the most frequently occurring Triassic species, *Astacolus connudatus*, were found scattered through ditch samples between 9,100 and 9,200 feet and were more numereous in several ditch samples below 9,200 feet. Specimens of *Trochamminoides vertens* Tappan, a small planispiral arenaceous species characteristic of the Shublik Formation, occurred in samples from 9,220–9,416 feet. Specimens of two species of ostracodes, fragments of closely ribbed minute echinoid spines, pyritic internal molds of a tiny rounded to ovate, unidentified pelecypod, and a high-spired unornamented gastropod were found in ditch samples throughout most of the formation and continued in many ditch samples from the underlying Paleozoic beds. All these microfossils are additional aids in identifying the Shublik Formation; they were found in many samples of the Shublik from the Sadlerochit River region and in similar beds in Simpson test well 1 and South Barrow test well 3. Minute echinoid spines occur only in the upper 120 feet of the Shublik Formation in the Sadlerochit River area, but the ostracodes and pelecypod and gastropod molds range throughout the formation; Foraminifera are fewest in the upper beds.

PERMIAN ROCKS (9,380–9,770 FT)

A gray sandstone that was cored continuously from 9,416 to 9,596 feet probably was penetrated at 9,380 feet, where the first cuttings of a similar sandstone appeared. Ditch samples from the interval above the cored sandstone carried only Jurassic and Triassic microfossils as contamination. The cored sandstone did not contain microfossils, but in the upper 80 feet (9,416–9,496 ft), there were narrow, elongate, light- and dark-gray opalized shells of *Lingula* sp., a long-ranging brachiopod. At 9,438 feet were poorly preserved leaflike objects that D. H. Dunkle, U.S. National Museum, identified as Permian coelacanth fish teeth; they determined the age of this section.

RED BEDS (9,770–10,040 FT)

The 270-foot section of predominantly red siltstone, claystone, and sandstone was nonfossiliferous and can only be assumed to be part of the late Paleozoic. Contamination from Jurassic and Triassic beds introduced Mesozoic mircofossils into the ditch samples.

MIDDLE OR LOWER DEVONIAN ROCKS (10,040–10,503 FT, TOTAL DEPTH)

There were not any microfossils in the cores from this interval; the few specimens in ditch samples were contamination from the Mesozoic beds. Carbonized plant fragments in clay shale from a core at 10,441 feet were identified by J. M. Schopf as species restricted to Middle or possibly Lower Devonian beds. His identifications include spiney stems of *Psilophyton* n. sp. and small branches of *Zosterophyllum?* n. sp., *Aphyllopteris* sp. and *Hostimella?* sp. According to Schopf, *Psilophyton* is sufficient to identify the beds as Middle or Lower Devonian.

EAST TOPAGORUK TEST WELL 1

This shallow test of Cretaceous rocks was drilled to a depth of 3,589 feet on a small structure about 12½ miles S. 75° E. of Topagoruk test well 1. Approximately 75 feet of Pleistocene sand and gravel of the Gubik Formation mantles Lower Cretaceous rocks in the area of this test hole. The Cretaceous section consists of sandstone and interbedded shale to about the 1,750-foot depth and clay shale with some interbedded sandstone from that depth to the bottom of the hole. Lithologic descriptions of the entire section were presented by Collins (1958b), who has divided the Cretaceous beds into the Grandstand and Topagoruk Formations on the basis of sandstone and clay shale content. In this report the Grandstand Formation is considered as Tuktu and Grandstand Formations undifferentiated and the clay shale sequence (Topagoruk Formation of Collins) is referred to the Torok Formation. A preliminary summary of the microfossils found in the Cretaceous section has been published (Bergquist, 1958c, p. 313–314), but some changes have since been made in a few generic and specific determinations. A complete tabulation and distribution of all microfossils identified are shown on plate 19. It should be noted that no Foraminifera were found in the sample of Gubik sand (40–90 ft), but some Gubik Foraminifera were found in the sample cuttings of Cretaceous rocks.

MIDDLE TO UPPER ALBIAN ROCKS

VERNEUILINOIDES BOREALIS FAUNAL ZONE (90 FT TO TOTAL DEPTH)

Only the *Verneuilinoides borealis* faunal zone was recognized in the Cretaceous section. The highest indication of this zone is in the sample from 110 feet, but the microfossils through 210 feet are mostly very fragile, compressed forms. Components of the zone can be compared with those of the same zone in Topagoruk test well 1 on the basis of abundant assemblages or the first occurrence of several of the microfossils. Such comparison suggests that the shallow Cretaceous beds in East Topagoruk test well 1 are 300–400 feet structurally lower than in Topagoruk test well 1 (fig. 46).

The *Verneuilinoides borealis* zone appears as a sparse fauna of less than a dozen species of Foraminifera in samples from the upper 500 feet of the section and, with two or three exceptions, was absent from most of the ditch samples between 570 and 1,560 feet. In part, this absence may be due to exceptionally poor samples above 1,140 feet, as many samples are badly contaminated with sand and gravel of the Gubik Formation; also, the section from 1,140 to 1,700 feet is predominantly sandstone. The paucity of microfossils in this long interval contrasts with the highly fossiliferous section of about the same stratigraphic position in Simpson test well 1 and in the wells of the Umiat field, and seemingly nothing equivalent to the Tuktu faunal facies is present in this well. It may be that the sandstone occupies the interval of the faunal facies identified in Topagoruk test well 1. In the predominantly clay shale beds (Torok Formation), however, the *V. borealis* fauna expands rapidly to a total of 51 species of Foraminifera and 4 species of Radiolaria. Of these, six species of Foraminifera are dominant, particularly in the continuously cored section between 2,012 and 2,184 feet.

The faunal count for all samples studied from the test hole indicates that 20 arenaceous Foraminifera account for approximately 82 percent of the entire fauna and 31 calcareous species for about 18 percent. Percentage for each group is as follows: *Haplophragmoides topagorukensis* Tappan, 40 percent, far outnumbers all other species; *Bathysiphon vitta* Nauss?, 10 percent, is next; *Verneuilinoides borealis* Tappan, 9 percent; *Gavelinella stictata* (Tappan), 5 percent; *Eurycheilostoma grandstandensis* Tappan, nearly 4 percent; *Gaudryina nanushukensis* Tappan, 3 percent; *Ammodiscus rotalarius* Loeblich and Tappan, 3 percent; and *Ammobaculites wenonahae* Tappan, 3 percent.

Most of the Foraminifera in ditch samples collected from 130–400 feet in the test hole have certain features in common: the tests are white to light tan, fine textured, fragile, and generally are flattened by compression; some have been misshapen. Pyritic fillings retain the original shape for a few.

Compressed tests of *Verneuilinoides borealis* Tappan were common in three samples, but the original structure of the inflated chambers is preserved in only a very few specimens. The white elongate oval tests of *Miliammina awuenensis* Tappan, flattened to ovate petallike

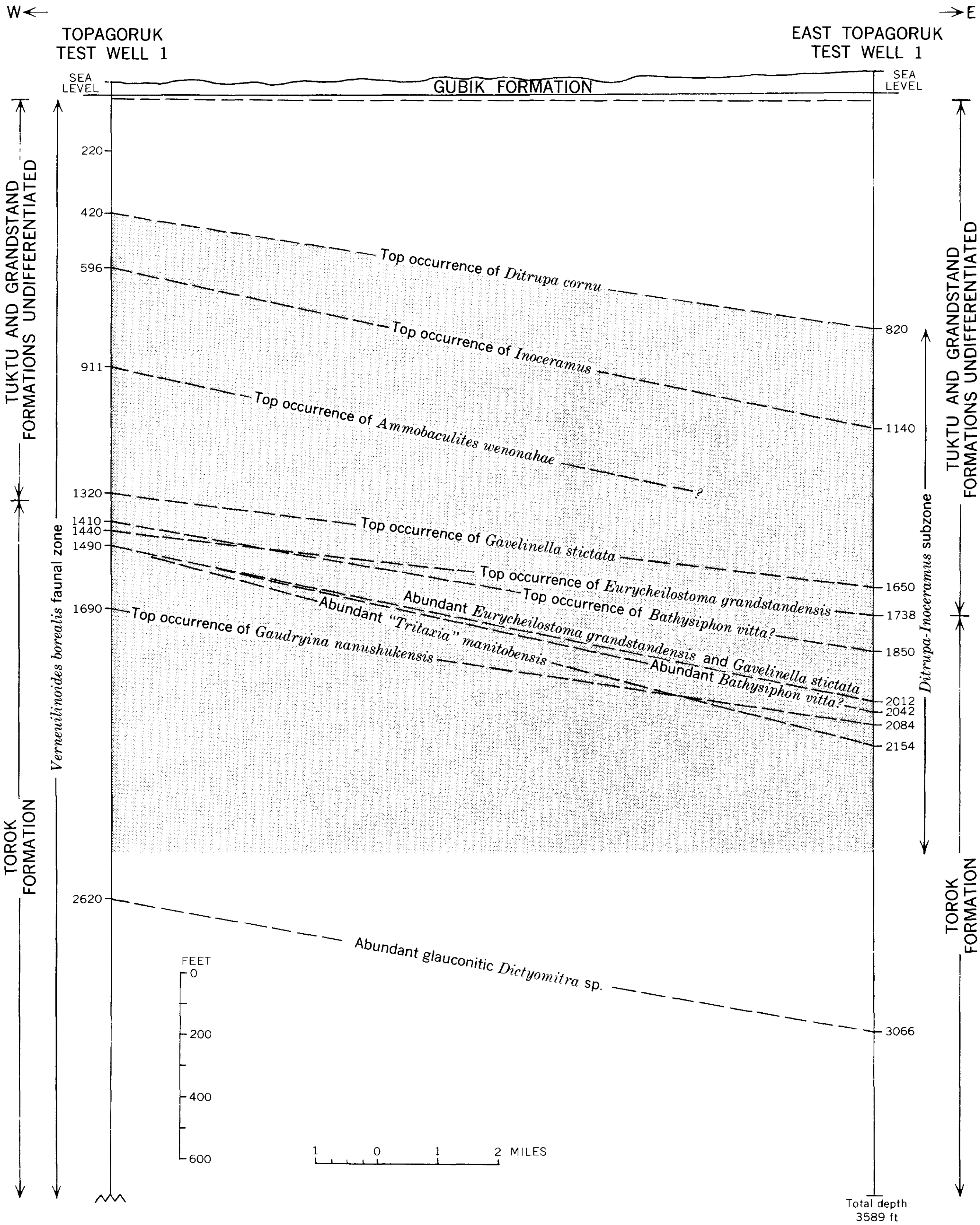


FIGURE 46.—Microfossil horizons within the *Verneuilinoides borealis* faunal zone, Topagoruk area, northern Alaska.

shapes, were common in one sample. The next most frequently occurring species is *Gaudryina canadensis* Cushman, whose long, narrow, flattened or only slightly inflated tests were found sparingly in five samples. A few other species of the *V. borealis* faunal zone and fragments of pyritic casts of radiolarian tests augment the small fauna.

Microfossils were even fewer below 400 feet. One core and most of the ditch samples were barren. Two specimens of *Pallaimorphina ruckerae* Tappan, a minute globular calcareous species, and two specimens of *Marginulina planiscula* (Reuss), a smooth-walled species of variable size and shape, occurred in a core at 540–547 feet. *Verneuilinoides borealis* and *Haplophragmoides topagorukensis* Tappan were common to abundant in two cores (1,100–1,110 ft and 1,731–1,748 ft) in association with a few calcareous Foraminifera, but tests of both arenaceous species are so granular that the outlines of the chambers are greatly obscured. Two crushed tests of the arenaceous "*Tritaxia*" *manitobensis* Wickenden were found in a sample from the core at 1,100–1,110 feet.

Fragmentary tubes of *Ditrupa cornu* Imlay were in a few ditch samples beginning at 820–830 feet and were associated with *Inoceramus* prisms below 1,070 feet. A ½-inch coquina bed of *Ditrupa* and *Inoceramus* shell material occurred in a core at 1,735 feet.

Foraminifera were few in ditch samples from the upper 250 feet of the Torok Formation, but throughout the continuously cored section 2,012–2,184 ft was one of the largest concentrations of Foraminifera found within the Torok Formation in any of the northern Alaska wells. It includes more than 30 species (see pl. 19) of the *Verneuilinoides borealis* faunal zone, and several species were abundant or common in one or more cores from the interval. Most numerous are the vitreous, fine-textured, compressed, and constricted tubes of *Bathysiphon vitta* Nauss?; twisted tests of *Haplophragmoides topagorukensis* Tappan; short triserial tests of *V. borealis* Tappan, whose chambers are only vaguely discernible through a granular texture; and flattened, distorted, and closely coiled tubular tests of *Ammodiscus rotalarius* Loeblich and Tappan. Almost as numerous are such distinctive species as *Gaudryina nanushukensis* Tappan (cores at 2,113–2,144 ft), "*Tritaxia*" *manitobensis* Wickenden and *Miliammina manitobensis* Wickenden (both at 2,164–2,174 ft), *Eurycheilostoma grandstandensis* Tappan, and *Gavelinella stictata* (Tappan); the broken tests of *Ammobaculites wenonahae* Tappan were common at 2,094–2,103 feet. Other Foraminifera are rarer in numbers and occurrences. Fragments of *Ditrupa cornu* tubes and *Inoceramus* shells were found in several of the cores.

The large triserial *Gaudryina nanushukensis* Tappan is one of the most distinctive Early Cretaceous species in northern Alaska. Uncompressed specimens are triangular in cross section; tests are fine textured and are light gray, mottled by black streaks and spots of sooty manganese, principally along sutures. The black mottling is a peculiar selective feature seen almost exclusively on only this species of the northern Alaskan Mesozoic Foraminifera. The lowest occurrence of *G. nanushukensis* in this well is at 3,053–3,056 feet.

"*Tritaxia*" *manitobensis* Wickenden is also very easily distinguished even though it invariably seems to be flattened; the chambers are overlapped, and this produces a scalloped or rounded marginal effect. The white tests are finely textured, and generally each has a straight tubular neck terminating in a rounded aperture.

Tests of *Miliammina manitobensis* Wickenden are relatively large and have been less affected by compression than have most arenaceous species. Tests of *Ammobaculites wenonahae* Tappan are light tan and fine textured; many are broken, and the uniserial parts were recovered more commonly than the whorls.

Eurycheilostoma grandstandensis Tappan is readily recognized by its smooth conical light-brown spire, capped by three light-gray chambers that flare outwardly but slope abruptly inward into a medial depression. Many specimens of most of the other calcareous species are filled wholly or in part with pyrite or are broken.

Fragmentary tubes of *Ditrupa cornu* Imlay and *Inoceramus* prisms occurred in several of the cores through 2,154 feet; they are indicative of the *Ditrupa-Inoceramus* faunal subzone that starts at 820 feet in this test well and extends through nearly 1,350 feet of the section.

Dark-green glauconitic casts of a radiolarian (*Dictyomitra* sp.) occur in and below the lowest part of the *Ditrupa-Inoceramus* subzone. The casts are broadly conical and have transverse septal structures that indicate joint intervals, but no traces of the external ornamentation are preserved. Two specimens were found in a core sample from 2,144–2,154 feet, and specimens were abundant in a core from 3,066–3,076 feet. Apparently the glauconitic casts are part of a zone of glauconite noted in the Torok Formation in Topagoruk test well 1 and in South Barrow test wells 1, 2, and 4. In the Topagoruk area, however, more than one zone of glauconite is suggested within a general zone which occupies approximately the beds in the middle interval of the upper part of the Torok Formation.

Foraminifera from the *Verneuilinoides borealis* faunal zone were present in samples from the base of a nonfossiliferous sandstone at 2,221–2,251 feet to the bottom of the hole, but they did not occur in the abundance found in the upper beds. There were fewer species in these lower beds, but *Haplophragmoides topagorukensis* Tappan was common to abundant in most of the ditch samples. *Bathysiphon vitta* Nauss? and *H. topagorukensis* were both abundant in a core from 2,485–2,505 feet, and *Gavelinella stictata* (Tappan) was common. One or two specimens each of eight other species were associated with them.

Specimens of *Valvulineria loetterlei* (Tappan), a small trochoid calcareous species, were abundant in a core at 3,000–3,013 feet. In the succeeding core (3,013–3,023 ft), *Bathysiphon vitta*? was common, and *Haplophragmoides topagorukensis* was abundant. The latter was very abundant in a core at 2,053–3,056 feet and was common at 3,407–3,426 feet. Long, narrow brown specimens of *Gaudryina canadensis* Cushman were common at 3,056–3,066 feet. The core at the bottom of the hole was barren.

A general darker color tone prevails in the arenaceous Foraminifera found in the beds below 3,000 feet in this test hole. Instead of the light-tan color characteristic of most of the specimens in the very fossiliferous part of the well, light to dark brown is the predominant color of the specimens found in the lower beds, and the texture is prevailing finer. For example, specimens of *Verneuilinoides borealis* Tappan which, in the core at 3, 407–3,426 feet, have a smooth texture, are dark brown and have distinctly visible chambers even though the tests are compressed; this is in contrast to the light-tan color and the granulated texture that obscures sutures of specimens of the same species in the very fossiliferous upper section of the test hole. No significance is attached to this physical change, however, as in the northern foothills region most of the arenaceous specimens are dark brown and have a smooth texture throughout the entire *V. borealis* faunal zone in both the outcrop and subsurface samples.

FISH CREEK TEST WELL 1

Fish Creek test well 1 is in the Arctic coastal plain about 20 miles west of the mouth of the Colville River. The well was drilled in 1949 near an oil seep; it penetrated a thin mantle of sediments of the Gubik Formation and a thick sequence of gently dipping Cretaceous rocks. The operators drilled to a depth of 7,020 feet, and then tested an oil zone of siltstone and interbedded clay shale and fine sandstone at 2,920–3,050 feet. Dark heavy oil was pumped from this zone at the average rate of 9–12 barrels per day for nearly 3 weeks, and then the well was shut down and abandoned.

The oil produced from this well came from Lower Cretaceous beds that are probably equivalent to the Chandler Formation, but these beds lack some of the characteristics of the formation. Overlying the oil sand is a shale section of Upper Cretaceous beds of the Seabee and Schrader Bluff Formations, and below the oil zone (from 3,030 feet to total depth) the section is predominantly sandy shale and shale equivalent to the Tuktu and Torok Formations.

GUBIK FORMATION (15–65 FT?)

Data are limited for the uppermost part of the section penetrated in this well inasmuch as no samples were taken above 46 feet and only a single sample was taken from the interval 65–120 feet. The sample is consolidated clay, and because it marks an abrupt change from the sand of the Gubik Formation reported from 46–65 feet, the base of the Gubik Formation is inferred to be directly above the sampled depth (Robinson and Collins, 1959, p. 502). Shell fragments of pelecypods and tests of a few calcareous Foraminifera similar to specimens occurring elsewhere in the Gubik Formation were found in the clay sample. Similar specimens were found as contamination in ditch samples at several intervals through the upper few hundred feet of the well, and these specimens indicate the presence of fossiliferous beds in the thin mantle of Pleistocene sediments in the Fish Creek area.

UPPER SENONIAN ROCKS

SCHRADER BLUFF FORMATION (65–2,100 FT)

The Schrader Bluff Formation consists of several hundred feet of clay shale with interbedded siltstone. Thin beds of bentonite occur below 825 feet, and scattered carbonaceous flakes, coal fragments, and volcanic glass shards interspersed in the sediments are concentrated locally. The coal fragments, carbonaceous material, and shards increase in amount in ditch samples between 270 and 320 feet. The shards are especially characteristic of the upper beds and occurred in ditch samples from 120–1,120 feet and in the first three cores. In the first core (225–234 ft), about 50 percent of the washed residue consists of colorless volcanic glass shards with a few dark-colored shards. The remainder of the material consists of quartz; pyritic casts of cylindrical plant stem and possible seed pods or spores; and tapered, cylindrical pyritic casts marked by regular constrictions. Washed residue from the second core (425–435 ft) consists of about 75 percent fluted, elongate glass shards (fig. 47) which are largely colorless; the remainder of the material is composed of quartz, some carbonaceous particles, mica flakes, white clay mineral aggregates, and pyrite granules. Two specimens of

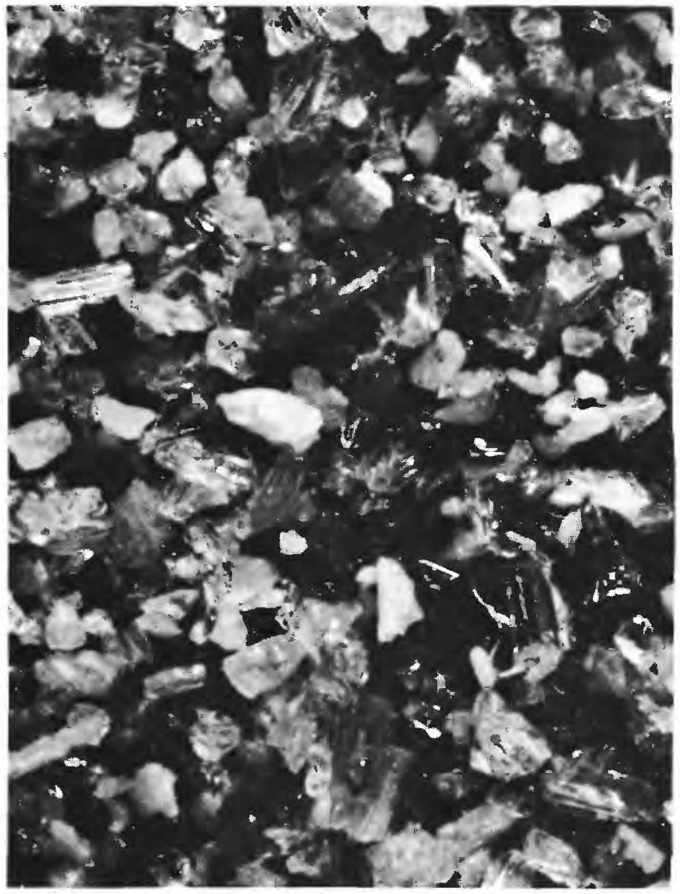


FIGURE 47.—Fluted and angular volcanic glass shards and subrounded quartz grains from Schrader Bluff Formation, Fish Creek test well 1, core 425–435 feet. × 30.

Praebulimina carseyae (Plummer), a foraminifer of Senonian age (Austin and Taylor), came from the core sample. Distribution of the microfauna is shown on plate 20.

Possibly the beds which are seemingly unfossiliferous to a depth of 400 or 425 feet are in part equivalent to the Kogosukruk Tongue of the Prince Creek Formation, but from 425 feet to the third core at 625–635 feet, the sediments are sparingly fossiliferous and are definitely in the Sentinel Hill Member of the Schrader Bluff Formation. However, the presence of volcanic shards throughout the section to 635 feet suggests a gradual upward change from marine sediments to beds that could be of nonmarine origin. A lowland to marginal marine environment is assumed for the beds above 635 feet, and a deeper-water environment for those below.

The Sentinel Hill Member comprises the section at least through the core at 627–635 feet, but there is not much fossil evidence to distinguish the members of the Schrader Bluff Formation. *Aeolostreptis vitrea* (Cushman and Parker) found at 590–600 feet is a Senonian fossil characteristic of the Sentinel Hill Member. Two speciments of *Eoeponidella strombodes* Tappan were found in ditch samples from 520–530 feet and 550–560 feet. Formerly *E. strombodes* was considered (Tappan, 1951a, p. 6) as a marker for beds 800–1,000 feet above the base of the Sentinel Hill Member, but the species is now known to occur at several horizons in the lower part of the member, and the occurrence in the Fish Creek well could be anywhere in the lower part. A few species of Radiolaria occurred in the lower beds and include *Archicorys* sp., common at 590–600 feet; *Sethocyrtis* sp. B, abundant in a core from 625–635 feet; and a few specimens each of five other species. Scattered volcanic glass shards and fish bones are interspersed in the lower beds.

Below 635 feet and through the core from 2,061–2,071 feet, most of the section could be assigned to the Barrow Trail and Rogers Creek Members of the Schrader Bluff Formation. Like the overlying beds of the Sentinel Hill Member, this section is also largely clay shale interbedded with siltstone. It contains scattered carbonaceous material and below 825 feet thin beds of bentonite. The lower limit of the Schrader Bluff Formation cannot be determined precisely from fossils, but the presence of Foraminifera of Senonian age in a core from 2,061–2,071 feet extends the base of the formation considerably below the depth of 1,635 feet, the depth determined by Robinson and Collins (1959, p. 502).

Radiolaria

Radiolaria form a conspicuous zone in clay shale beds that may be the lower part of the Sentinel Hill Member and the upper part of the Barrow Trail Member of the Schrader Bluff Formation, and Radiolaria become increasingly abundant and numerous in the samples between 680 feet and 1,035 feet. Below the latter depth they are fewer, but there is a fair distribution in ditch samples through 1,310 feet. In the lowest beds occurrences seem sparse and erratic. The greatest concentration apparently is in cores from 825–835 feet and 1,025–1,035 feet, but this concentration may be merely due to the fact that the washed samples from these cores were more thoroughly checked than were the ditch samples, which were given only cursory examination. None of the samples were treated with the express purpose of recovering Radiolaria, and only the standard process used in the Geological Survey laboratory in Fairbanks for recovery of Foraminifera were applied to them. The assemblage obtained from the Fish Creek well, however, is the largest yet found in any of the Alaskan sedimentary rocks and is one of the few occurrences known in North American Cretaceous rocks. Few Radiolaria have been described from Cretaceous rocks in North America other than a small fauna from Upper Cretaceous rocks in northwestern Manitoba (Rust, 1892) and a large fauna from one small piece of limestone in shale of probable late Campanian to Maestrichtian age near Tesla, California (Campbell and Clark, 1944).

None of the Radiolaria from Alaska have been described, but in 1949 a collection obtained from the Fish Creek well was tentatively classified into 19 genera and 40 lettered species by Helen Loeblich (1949, p. 8–15) as part of the general exploration studies conducted on the Arctic Slope. Present studies however, suggest that most of the fauna can be included under 16 genera and 23 species, as the slight variation of some specimens and the number of the specimens on hand seem to form insufficient basis for specific determination. The genera and species identified are listed or briefly described on the following pages, and their occurrences and relative abundance are shown on plate 20. Their identification conforms to the classification published by Campbell (1954). Because Cretaceous Radiolaria are not too well known, statements and brief descriptions from Campbell's classification are included herein where they apply to the Fish Creek fauna, but the reader should consult Campbell's work for detailed discussion of the morphology and systematic descriptions of genera.

Campbell (1954, p. D11) indicated that Radiolaria are a subclass of marine protozoans of the class Actinopoda and that nearly all have opaline-silica tests of geometric design. Campbell classified the Radiolaria into the Order Porulosida Haeckel, 1887, and the Order Osculosida Haeckel, 1887, and he subdivides each of these orders into two suborders. Under the Porulosida he has placed the Suborders Acantharina and Spumellina, and under the Osculosida the Suborders Nassellina and Ogaeidaruba. All the Radiolaria found thus far in the Schrader Bluff Formation of the Fish Creek well belong to the Spumellina and Nassellina.

Radiolaria of the Order Porulosida have pores distributed everywhere on the surface of the globular central capsule. Those of the Suborder Spumellina Ehrenberg, 1875, have the simplest forms "in which the central capsule is usually enclosed by a peripherally generated siliceous shell and a globular form that distinguishes many free-floating organism * * *. Often the spumelline shell is formed as a hollow lattice or fenestrate (open meshwork) sphere having similar or dissimilar pores" (Campbell, 1954, p. D42). The surface of these shells may be smooth or rough, and pores may be flush or within elevated hexagonal or polygonal framework. Spines may be distributed evenly on the surface, or there may be only two on opposite poles; the two on the poles may be similar or dissimilar. "Long principal spines, one to six in number, occur on some types of Spumellina, tending to be arranged in opposite pairs disposed along mutually perpendicular axes of a cube" (Campbell, 1954, p., D42). Other spumelline forms have a lattice shell of elliptical outline and spongy texture. These forms may be spined and similar to spherical forms. There are also flattened or discoidal Spumellina which have a flat circular porous plate and concentric rings around the central chamber. From the center, spines radiate and subdivide the rings into radial chambers and may in some forms radiate from the margin of the shell.

Spumelline forms are subdivided by Campbell into two divisions. Large shells compose of fused spicules make up the Division Collodari Haeckel, 1882, and latticed or spongy shells make up the Division Sphaerellari Haeckel, 1882. None of the Fish Creek Radiolaria appear to belong to the Collodari, but at least 11 genera and 16 or 17 species belong to the Sphaerellari and would be classified under 3 superfamilies, the Liosphaericae, Ellipsidiicae, and Cenodiscicae.

Members of the superfamily Liosphaericae Haeckel, 1882, have "spherical latticed or spongy shells or concentrically multiple * * *." (Campbell, 1954, p. D48). Shells without radial spines on the surface constitute the family Liosphaeridae Haeckel, 1882. In the Fish Creek radiolarian assemblage, two species of the Liosphaeridae were identified as *Cenosphaera* sp. A and *Cenosphaera* sp. B (fig. 48), each of which has a single latticed sphere, simple shell pores, and no spines. Of these, *Cenosphaera* (*Cenosphaera*) sp. A has circular, subregular pores without hexagonal frames, and *Cenosphaera* (*Cenosphaera*) sp. B has hexagonal to circular pores with hexagonal frames.

Also under the Liosphaericae is the family Stylosphaeridae Haeckel, 1882, whose members have a lattice shell with two polar spines (rarely more), opposite each other in one axis of the shell. At least one genus of this family occurs in the Fish Creek fauna. This is *Xiphosphaera* (*Xiphosphaera*) sp. (fig. 48), which has a single lattice shell with regular pores and two polar spines of equal size and form.

Members of superfamily Ellipsidiicae Haeckel, 1887, have "elliptical or cylindrical, fenestrated or spongy shell; commonly articulated by annular transverse strictures * * *" (Campbell, 1954, p. D68). The few Fish Creek Radiolaria identified as a part of this group all belong to the family Sponguridae Haeckel, 1862, characterized by having "spongy elliptical or cylindrical shell without equatorial strictures" (Campbell, 1954, p. D73). Two genera in the Fish

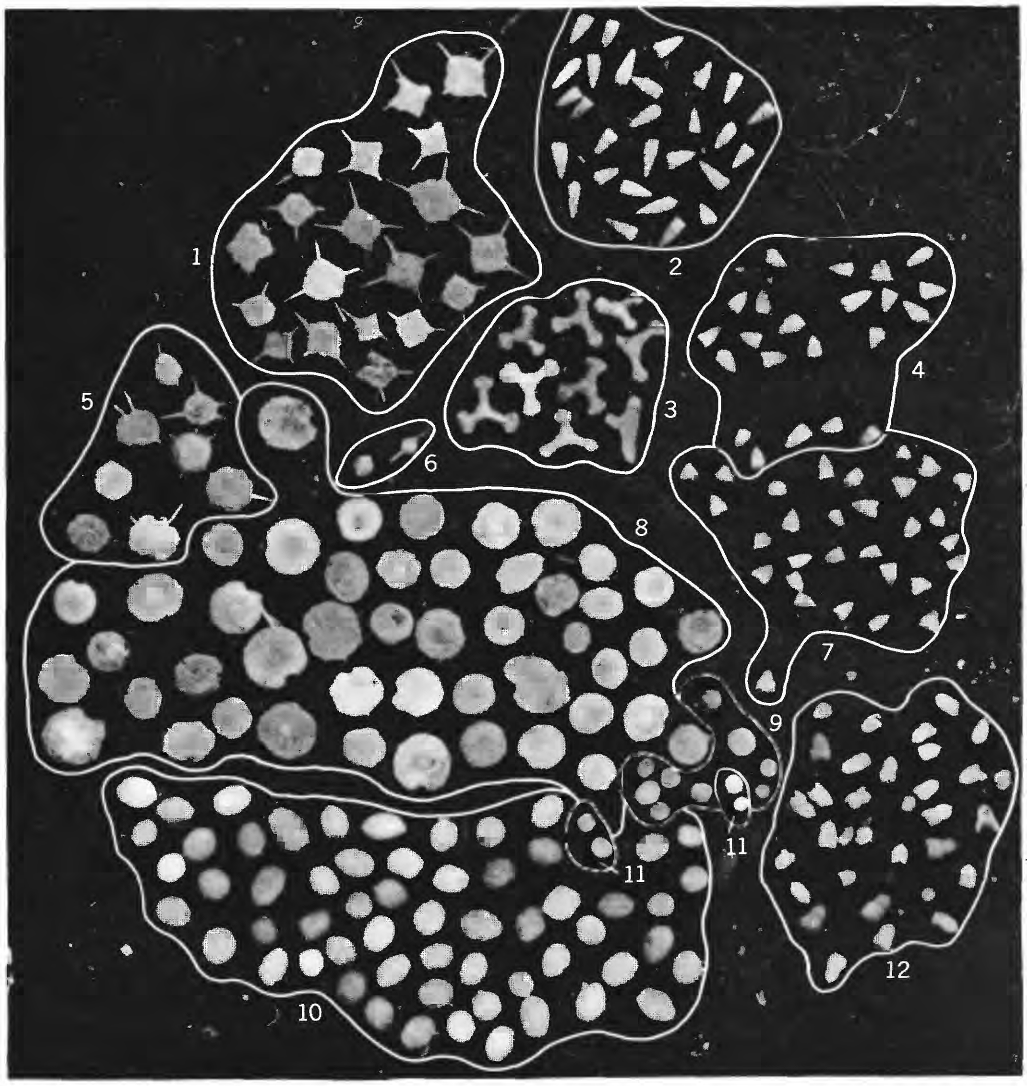


FIGURE 48.—Radiolaria from Barrow Trail Member, Schrader Bluff Formation, Fish Creek test well 1, core at 1,025–1,035 feet. × 20. Area identifications as follows: (1) *Spongostaurus* sp.; (2) *Dictyomitra multicostata* Zittel; (3) *Rhopalodictyum* (*Triachinosphaera*) sp.; (4) *Dictyomitra* (*Dictyomitrissa*) sp. G; (5) *Stylospongia* (*Stylotrochiscus*) sp.; (6) *Xiphosphaera* sp.; (7) *Theocorys* sp.; (8) *Spongodiscus* cf. *S. renillaeformis* Campbell and Clark; (9) *Spongodiscus* sp.; (10) *Spongurus* (*Spongurantha*) sp. A and *Cenosphaera* sp. B; (11) *Cenosphaera* sp. B; (12) *Sethocyrtis* sp. A.

Creek fauna which are classified in this family are *Spongoprunum* sp., which has an ovate solid shell with two opposite polar spines, and *Spongurus*, a genus without polar spines. The Fish Creek specimens of *Spongurus* (fig. 48) have ovate to subcylindrical shells without radial spines; they therefore belong to the subgenus *Spongurantha* and for the present are all included under one species.

Shells that have a lenticular or discoidal flat disk or biconvex lens belong to the superfamily Cenodiscicae Haeckel, 1887. In the Fish Creek samples, 7 genera and 9 or 10 species were identified in this group. All these would be classified under subsuperfamily Euchitonilae Haeckel, 1887, a group lacking a lenticular latticed shell. Several of these belong to the family Spongodiscidae Haeckel, 1882, whose members have a "simple central chamber surrounded by a spongy framework; without porous sieve plate * * *" (Campbell, 1954, p. D93). Under the subfamily Spongodiscina Haeckel, 1882, a group characterized by a simple circular disk without radial spines or arms, is the genus *Spongodiscus*, which has a spongy disk without concentric rings or spirals. In the Fish Creek assemblage, three species were identified. *Spongodiscus* (*Spongodiscus*) sp. cf. *S.* (*S.*) *renillaeformis* Campbell and Clark has a spongy disk, a chevron-shaped notch on the outer irregular rim, and sometimes tiny spines on the marginal edge (fig. 48). *Spongodiscus* (*Spongodiscus*) sp. A has flat sides and edge, and *Spongodiscus* (*Spongodiscus*) sp. B is biconvex and has a sharp edge.

The genera *Spongolonche*, *Spongostaurus*, *Spongotripus*, and *Stylospongia* identified in the Fish Creek material belong to the subfamily Spongotrochinae Haeckel, 1882, of the Spongodiscidae. Each is characterized by a spongy disk and radial spines, and each genus is represented by at least one species in the Fish Creek material. *Spongolonche* sp. has a spongy elliptical disk with two opposite equatorial radial spines. *Spongotripus* (*Spongotripus*) sp. cf. *S.* (*S.*) *morenoensis* Campbell and Church has three solid radial spines of equal size and distance emanating from a roughly triangular disk. The identified specimens of *Spongostaurus* have four crossed solid radial spines at corners of a quadrate rectangular to diamond-shaped or roughly circular disk (fig. 48). Circular or irregular disks that have a spongy framework and numerous radial spines on the equatorial margin identify *Stylospongia* (*Stylotrochiscus*) sp. (fig. 48).

Rhopalodictyum and *Spongasteriscus* are two genera found in the Fish Creek material which are classified under the subfamily Spongobrachinae Haeckel, 1882, of the Spongodiscidae. Members of this group all have a spongy disk and spongy radial arms. *Rhopalodictyum* has a spongy disk from which three spongy arms emanate. Specimens identified all belong to the subgenus *Triactinosphaera* which has three arms of dissimilar size or distance. More than one species of *Rhopalodictyum* could possibly be in the Fish Creek material, but all are grouped together here (fig. 48). Specimens range from those that have wide arms enlarged at the ends to forms that have narrow arms slightly inflated at the ends to some that have narrow arms not enlarged or inflated at the ends. *Spongasteriscus* has four spongy arms crossed in two equatorial diameters on a circular or quadrangular disk. It is represented in the Fish Creek well by a species belonging to the subgenus *Spongasteriscinus* Haeckel, 1887, a form in which the cross formed by the four arms is regular and rectangular and in which the arms are equal sized and equidistant. The few specimens found were all in one core (1,025–1,035 ft).

Radiolaria of the Order Osculosida Haeckel, 1887, have "pores restricted to one pole or to tubular openings in the central capsule" (Campbell, 1954, p. D100). In the Suborder Nassellina Ehrenberg, 1875, the central capsule of the shell is perforated at only one pole, and the skeleton is a tripod, ring, or lattice shell composed of opaline silica; opposite poles of the shell are dissimilar (Campbell, 1954, p. D100). Five genera and eight species of the Fish Creek Radiolaria which have complete lattice shells are identified as nasselline forms belonging to the Division Cyrtellari Haeckel, 1882, and to subsuperfamilies Archipiliilae, Sethopiliilae, Theopiliilae, and Triacartilae of superfamily Archipiliicae. The first three mentioned subsuperfamilies were established by Haeckel in 1882; the last, by Campbell in 1954. Subsuperfamily Archipiliilae includes simple shelled forms lacking joints or strictures. Members without radial apophyses (spinelike projections) make up the family Archicorythidae Haeckel, 1887. A genus of this family identified in the Fish Creek material is *Archicorys* sp., a form having a cup-shaped latticework shell with a spine or horn at the apex and an open but somewhat constricted mouth in the basal part. The species is one of the smallest found in the Fish Creek well and was common in several samples. It is readily identified from its small size, cuplike shape, and apical horn.

Two-jointed nasselline shells, divided by a transverse collar stricture into an apical joint (cephalis) and a basal joint (thorax), form the subsuperfamily Sethopiliilae (Campbell, 1954, p. D122). Some members have radial apophyses, but members of the family Lophophaenidae Haeckel, 1882, lack them. To this family belongs the genus *Sethocyrtis*, which has a cylindrical or ovate thorax with a simple constricted mouth and a cephalis with an apical horn. Two species of *Sethocyrtis*—species A (fig. 48) and B—were identified in the Fish Creek material. They are similar, but *Sethocyrtis* sp. B has a very tiny cephalis resting like a cap on the thorax of the shell.

Three-jointed nasselline shells that have two transverse constrictions are divided into a cephalis, thorax, and abdomen (third joint) and are classified under subsuperfamily Theopiliilae (Campbell, 1954, p. D129). Some members have basal apophyses, others do not. A form without basal apophyses classified in the family Theocorythidae Haeckel, 1882, is the genus *Theocorys*; it has a swollen abdomen, more or less constricted mouth, and an apical horn on the cephalis. Subgenus *Theocorys* has pores of nearly equal size and similar form on both thorax and abdomen. One species, *Theocorys* (*Theocorys*) sp. (fig. 48) was identified in the Fish Creek collection.

Members of the subsuperfamily Triacartilae have an annulated shell divided by three or more strictures into cephalis, thorax, abdomen, and postabdominal segments. Two genera of this family are identified in the Fish Creek well material. These genera belong to the family Stichocorythidae Haeckel, 1882, a group that does not have radial apophyses. *Dictyomitra*, a genus described by Zittel in 1878, has a conical shell but no apical horn. The subgenus *Dictyomitrissa* Haeckel, 1887, has a smooth shell and joints of different lengths. Subgenus *Dictyomitra* Haeckel, 1887, has a glassy surface, longitudinal ribs and furrows, and joints of different lengths. *Dictyomitra* identified in the Fish Creek material include *D.* (*Dictyomitra*) *multicostata* Zittel (fig. 48), easily recognized by its narrow, elongate conical shall having numerous longitudinal ribs and furrows; *D.* (*Dictyomitrissa*) sp. F (Loeblich, 1949, pl. 3), a large conical-shelled form having a knobby surface; and *D.* (*Dictyomitrissa*) sp. G (fig. 48), which has a smaller conical shell, large pores, and a small ball tip at the end of the cone.

Also included under the family Stichocorythidae is the genus *Lithocampe* Ehrenberg, 1838, which has an ovate or spindle-shaped shell, transverse strictures, constricted mouth, and a cephalis without an apical horn. One species was identified, and it was of rare occurrence in the Fish Creek material. This is *Lithocampe* (*Lithocampium*) sp., whose shell joints are of different lengths.

Relative abundance.—Species counts of radiolarians obtained from core and ditch samples prepared in 1949 for general microfossil studies indicate that approximately 53 percent of the Radiolaria belong to the following five species: *Dictyomitra multicostata* Zittel, approximately 16 percent; *Spongodiscus* sp. cf. *S. renillaeformis* Campbell and Clark, approximately 12 percent; *Sethocyrtis* sp. A, approximately 10 percent; *Cenosphaera* sp. A, approximately 8 percent; and *Spongostaurus* sp., approximately 7 percent. The inclusion of three other species—*Sethocyrtis* sp., approximately 6 percent, *Archicorys* sp., approximately 5 percent, and *Spongurus* sp., approximately 5 percent—raises the percentage to about 60 percent for eight species. *Archicorys* sp. is best represented in the interval between 590 and 700 feet where other species occurred only infrequently. Most specimens and the largest number of species recovered, however, came from cores at 825–835 feet and 1,025–1,035 feet. In the core from 825–835 feet, specimens of *Cenosphaera* sp. A, *Cenosphaera* sp. B, *Xiphosphaera* sp., *Spongodiscus* sp. cf. *S. renillaeformis*, *Spongodiscus* sp. A, *Spongostaurus* sp., *Rhopalodictyum* sp., *Sethocyrtis* sp., *Spongasteriscus* sp., and *Dictyomitra multicostata* Zittel were common to abundant. Approximately 23 percent of the fauna and almost every species except *Archicorys* sp. and *Cenosphaera* sp. A occurred in the core from 1,025–1,035 feet; in this core specimens of *Spongurus* sp., *Sethocyrtis* sp., *Theocorys* sp., *Dictyomitra multicostata*, and *Dictyomitra* sp. "G" were common to abundant.

Preservation.—Generally the radiolarian specimens are white to buff, and many of the Spongodiscidae have unusually large shells of conspicuous white spongy texture. Nasselline forms are of genera lacking spines or elongate apophyses and are compact enough that fairly good preservation has resulted. Also usually well preserved are the spumelline genera without spines—that is, *Cenosphaera*, *Spongurus*, and *Spongodiscus*. Spined genera—such as *Spongolonche*, *Spongotripus*, *Spongostaurus*, and *Xiphostylus*—have been subject to various degrees of breakage in the processing of the samples, and few specimens have been obtained with complete spines attached.

Comparison with Californian and Canadian faunas.—A comparison of the Upper Cretaceous radiolarian fauna from Alaska with the fauna described by Campbell and Clark (1944) from Upper Cretaceous beds near Tesla, California, east of San Francisco Bay, indicates that the California fauna may be more than three times as large. Furthermore, the California fauna is composed of approximately 40 percent spumelline species and 60 percent nasselline species as opposed to approximately 68 percent spumeline species and 32 percent nasselline species in the Alaskan fauna. The spumelline species in the California fauna are largely the ring-bearing *Saturnalis* type and the members of the Spongodiscidae; nasseline forms include *Dictyomitra* and several allied genera. The ring-bearing *Saturnalis* type of Radiolaria have not been observed in the Alaskan material, but among the Spongodiscidae there is similarity to the California forms, particularly in *Spongodiscus* sp. cf. *S. renillaeformis* Campbell and Clark. *Dictyomitra multicostata* Zittel, the most abundant species in the Alaskan material, was reported by Campbell and Clark (1944, p. 39) as exceeding all other Radiolaria in abundance. This species has also been found in Upper Cretaceous beds of northwestern Manitoba, where Rust (1892, p. 109) reported it as one of the two most frequently occurring radiolarian species in the Pierre Formation. Most of the other species reported from Canada appear to be unlike Alaskan species, the fauna consisting of only 3 species (20 percent) of the Spumellina and 13 species (80 percent) of the Nassellina. Most species of the Nassellina are joint-shelled forms belonging to the genera *Dictyomitra* and *Tricolocapsa*.

Ecology.—The Radiolaria found in the Fish Creek well are confined largely to the upper half of the Schrader Bluff beds, in the interval between 590 and 1,100 feet. These organisms probably flourished at the time of deposition of the containing beds because volcanic material was added to the accumulating sediments. If finely divided silicic volcanic ash remains for a period of time in sea water, the particles are partly dissolved, and the water may become rich in silica (Rubey, 1929, p. 168). Volcanic material in the form of glass shards and thin layers of bentonite is present intermittently through much of the Schrader Bluff Formation, and the shards and bentonite indicate that sufficient material was present in the Late Cretaceous boreal seas of the Alaskan area to provide an ample supply of silica for organisms. Thin layers of bentonite containing altered glass shards occur at 825–835 feet and 1,025–1,035 feet, where the radiolarian fauna was abundant, and unaltered volcanic glass shards were concentrated in the uppermost foot of the radiolarian-bearing core at 627–635 feet. Large, fresh-looking, sharply edged volcanic glass shards were found in abundance in the cores from 225–235 feet and 425–435 feet (fig. 47), but in these beds Radiolaria were not found nor did they occur anywhere in the uppermost few hundred feet of the well section. The large size and fresh appearance of these glass shards suggest that the upper beds may reflect a time of more rapid accumulation of volcanic material near shore or on land, perhaps not too far distant from the volcanic source. In fact, the shards may have been rapidly buried over a large area after a withdrawal of the sea, and the withdrawal would account for the absence of Radiolaria in the highest beds.

Despite the rather limited vertical range of the Radiolaria in the Fish Creek well, these organisms were seemingly the predominant life at the time of Schrader Bluff deposition in that area, as all other invertebrates seem to be rare or lacking. In certain outcrop areas of the Schrader Bluff region, however, a fairly representative collection of megafossils including *Scaphites*, *Inoceramus*, *Protocardia*, and other pelecypods has come from the Barrow Trail Member, but in the Fish Creek well the only evidence of larger invertebrates are aggregates of *Inoceramus* shell fragments and a piece of a tiny translucent pelecypod shell (*Anomia*? sp.) embedded in the core from 627–635 feet, a tiny nuculid-type pelecypod at 645 feet, a crinoid cirril segment from the core at 627–635 feet, and similar segments in ditch samples from 900–920 feet and in the core at 2,061–2,071 feet. Associated with the Radiolaria, however, are a few species of Foraminifera which include one arenaceous species and one calcareous species, each found in relative abundance in the core from 825–835 feet. No Foraminifera were found in the prolific Radiolaria-bearing core from 1,025–1,035 feet, but there were numerous fish-bone fragments. Fish bones also occurred in the core from 627–635 feet.

The ecological environment of the Fish Creek radiolarian fauna cannot be interpreted from the presence of the Radiolaria alone, but certain clues are provided from a comparison of the fauna with other known faunas. The Upper Cretaceous radiolarian fauna from California is considered by Campbell and Clark (1944, p. 4) to have probably lived in a cool-water environment, a conclusion based on the presence of a number of large radiolarian species of coarse texture, many jointed and basally fenestrated Nassellina, and the lack of tests with delicate apophyses. In contrast, the upper Eocene radiolarian fauna of California, which Clark and Campbell (1942, p. 18) earlier described, is believed to be composed of surface tropical forms deposited in fairly deep waters. Conclusions for the latter environment are based on the presence of radiolarian species known to live near the surface in warm waters, the presence of diatoms and pelagic Foraminifera, and the lack of bottom-dwelling invertebrates (Clark and Campbell, 1942, p. 8).

The absence of bottom-dwelling invertebrates—corals, brachiopods, bryozoans, echinoderms (except as their presence is indicated by a few crinoid cirril segments), and gastropods—and the relative scarcity of Foraminifera in the Fish Creek area do not necessarily preclude a deep-water environment for the Radiolaria. None of the Radiolaria found in the Fish Creek well are deep-water forms as all belong to the Spumellina and the Nassellina, which for the most part occur near the surface of open waters today (Campbell, 1954, p. D16). Many of the Alaskan species are spongy-shelled forms of relatively large size, which is also a characteristic of free-floating surface dwellers (Campbell, 1954, p. D16). These species could have lived in open waters and might have been carried into shallow waters or even to the strandline, a situation which has been inferred for some occurrences of Radiolaria in Teritiary rocks of Trinidad (Campbell, 1954, p D17). Postulation of at least a cool-water environment for Late Createceous Radiolaria of northern Alaska can be made from the presence of the numerous large spongy species of the Spongodiscidae and Sponguridae and the abundance of the joint-shelled *Dictyomitra multicostata* and other members of the Nassellina.

Geologic age.—The beds in which the Fish Creek Radiolaria occur are of middle Senonian age (possibly Santonian and early Campanian as determined from the known stratigraphic sequence of the beds in Fish Creek test well 1 and from the few associated Foraminifera found in the section. Because the Alaskan fauna occurs in clay shale beds which can be closely defined as to stratigraphic location and geologic age, a detailed study of the Radiolaria could provide an important contribution to the micropaleontology of North America.

Foraminifera

Relatively few Foraminifera were found in the Schrader Bluff beds in the Fish Creek well, but two or three species seemingly are restricted to rocks of Senonian age, although there are as many that range throughout all late Cretaceous time. Of the few

Foraminifera associated with the Radiolaria, pyritized and oxidized specimens indentified as *Textularia* cf. *T. rollaensis* Stelck and Wall were most numerous in the core from 825–835 feet, and this species occurred in a few ditch samples through the succeeding 100 feet of section. Although *T. rollaensis* was described from western Alberta, Canada, from beds in the lower part of the "central" Kaskapau Formation that are believed to be of late Cenomanian age, the species appears to occur in Alaska only in rocks that range from Turonian through Senonian. Recently this species has been reported by Wall (1960) from the Bad Heart Sandstone (Coniacian and Santonian age and the Puskwaskau Shale of Santonian age at Smoky River, Alberta. Specimens of *Dorothia smokyensis* Wall occurred in the core from 825–835 feet and in a few ditch samples starting 20–40 feet above the core, and specimens of this species occurred intermittently a few hundred feet below the core. Most specimens are crushed or distorted, but a few tests are sufficiently well preserved to indicate that they belong to the species described by Wall (1960, p. 23) from the Puskwaskau Shale of early Senonian age from Smoky River, Alberta. *Trochammina whittingtoni* Tappan, an Alaskan species that ranges throughout the Colville Group, also occurs in several samples from the Schrader Bluff section in the Fish Creek well.

A few Foraminifera were found, however, which appear to be entirely restricted to rocks of Senonian age. These Foraminifera include abundant specimens of *Praebulimina cushmani* (Sandidge) found in the core from 825–835 feet, mostly as aggregates cemented by nodular pyrite or by iron oxide, which has spread its red stain over the tests. This species, which is confined to beds of the Schrader Bluff Formation in Alaska, is prominent in beds of Austin to Navarro age in Texas. A specimen of *Anomalinoides pinguis* (Jennings), found in the same sample and in a core from 2,061–2,071 feet, is another species restricted in Texas to the Taylor and Navarro Formations of Campanian to Maestrichtian age. *Nonionella taylorensis* Hofker, which was found in a core sample from 825–835 feet, is also a gulf coast fossil of Navarro and Taylor age, and *Gavelinella ammonoides* (Reuss), found in ditch samples from 1,065–1,095 feet, is a species from European rocks of Senonian age.

In the Fish Creek well, the ditch samples below 1,570 feet and most of the cores from the Schrader Bluff beds were barren of all fossils. Foraminifera were absent in the core from 1,025–1,035 feet, where the large radiolarian assemblage was found, but a few were found in scattered ditch samples below 835 feet. These species include *Saccammina lathrami* Tappan, *Haplophragmoides rota* Nauss, *Verneuilinoides fischeri* Tappan?, and *Quinqueloculina sphaera* Nauss, all ranging throughout the Colville Group. A few poorly preserved specimens of *H. rota* Nauss? and *Trochammina whittingtoni* Tappan? and the radiolarian *Cenosphaera* (*Cenosphaera*) sp. B were found in the core from 1,625–1,635 feet. There, too, volcanic glass shards occurred. A core from 2,061–2,071 feet carried a small fauna which includes species of Foraminifera largely of Senonian age—*Anomalinoides pinguis* (Jennings), *Praebulimina cushmani* (Sandidge), *Vaginulina schraderensis* Tappan, and *Quinqueloculina sphaera* Nauss; these species suggest that the entire section through that core belongs in the Schrader Bluff Formation, as *Q. sphaera* is the only species of the group known to occur also in the Seabee beds (pl. 23, Umiat test well 11). If part of the section above the last-mentioned core is considered to be Seabee as suggested by Robinson and Collins (1959, p. 506), Schrader Bluff beds must be repeated by faulting, but there is no evidence for this.

TURONIAN ROCKS

SEABEE FORMATION (2,100–2,900 FT)

Beds assigned to the Seabee Formation are predominantly clay shale, but a few thin beds of limestone occur in the upper part; the highest limestone layer (2,100 ft) is considered in this report to be the top of the formation. The microfauna collected from these beds is rather meager and consists of a few species of Foraminifera and a few Radiolaria, but only one species of Radiolaria might be indigenous to the formation. This species occurs as biconvex discoidal pyritic casts characterized by a central depression on one side. The species could be a member of either the Cenodiscidae or the Phacodiscidae, but specimens are herein questionably referred to *Zonodiscus*? sp. This species is considered a criterion of the Seabee Formation and appeared first in cores at 2,200–2,210 feet but was scattered in many ditch samples. In the highest core (2,270–2,280 ft), *Textularia* cf. *T. rollaensis* Stelck and Wall was common, and specimens of *Saccammina lathrami* Tappan were very abundant. In a core from 2,493–2,503 feet, *Trochammina whittingtoni* Tappan was common; embedded in a piece of the same core was a coiled specimen of a calcareous foraminifer that has a side broken away, revealing the interior of the chambers. The specimen may possibly be *Hedbergella loetterlei* (Nauss), which in Alaska was found only in the shale of the Seabee Formation in the Simpson Seeps area. However, the specimen is large for the species, and the identity is uncertain.

Small broken fish bones and small fragments of *Inoceramus* shells were embedded in the core from 2,493–

2,503 feet, and near the edge of one piece of core was a part of a crushed ammonite, cut across the specimen so that only the body chamber and a very small part of the earlier whorls remain. The shell is highly iridescent and has numerous growth lines on the nearly smooth surface. Although nothing is seen of the sutures, the complete specimen must have been about the size, thickness, and general appearance of *Borissiakoceras ashurkoffae* Cobban and Gryc, an ammonite characteristic of the shale member of the Seabee Formation.

In a core from 2,700–2,710 feet, the washed residue has pyrite granules, carbonaceous particles, and green bentonitic clay particles amid abundant thin plates of brown, green, and gray mica that range in shape from thin tabular hexagonal crystals to extremely crinkled irregular crystals. Scattered fish bone fragments and flattened and distorted specimens of *Gaudryina irenensis* Stelck and Wall and *Haplophragmoides rota* Nauss were found. At first glance, the fauna resembles that found in beds of the Ninuluk Formation, but the fauna apparently is still part of the Seabee Formation because in the ditch samples that followed *H. rota* increased and specimens of *Haplophragmoides bonanzense* Stelck and Wall, *Trochammina diagonis* Carsey, and *Trochammina albertensis* Wickenden appeared for the first time. Some Radiolaria and spheres of collophane? occurred in this section, the latter appearing first at 2,140 feet. The species of Foraminifera occurring together suggest lower beds of the Seabee formation because in certain outcrop areas these species are present as a distinctive assemblage in the lower part of the Seabee.

Age.—The early Turonian age recognized for the Seabee Formation in general (Imlay and Reeside, 1954, p. 242) would apply to the section in the Fish Creek well. Of several microfossils on which the age determination of the Seabee Formation is based, only *Borissiakoceras* was found in the section; but in the interval of ditch samples from 2,700–2,900 feet, the beds are assigned to the formation entirely because of a characteristic foraminiferal assemblage.

MIDDLE TO UPPER ALBIAN ROCKS

The section below the beds of Turonian age is predominantly clay shale except for the uppermost 300 feet where some siltstone and sandstone are also present. Formations generally can be defined only on the basis of fossils in this section of the well. The uppermost 100 feet or more is nearly barren, whereas the beds from 3,030 feet to about 3,800 feet have a Tuktu faunal facies similar to the Tuktu and Grandstand beds of Umiat. These beds rest on strata that are equivalent to the Torok Formation. Beds older than the lower part of the Torok Formation were not penetrated.

VERNEUILINOIDES BOREALIS FAUNAL ZONE (2,915–4,500 FT)

A section composed largely of interbedded clay shale, siltstone, and sandstone was cored continuously from 2,915 through 3,060 feet and seems to be part of the Nanushuk Group. For the most part, the section was barren except for a few specimens of 3 species of Foraminifera within the uppermost 35 feet and a small fauna of 11 species in the lowest 200 feet. The occurrence of the three species in the uppermost 35 feet of the cored section marks the highest fossils that might be part of the *Verneuilinoides borealis* zone and includes a few poorly preserved specimens of *Gaudryina canadensis* Cushman? in the highest core and flattened specimens of *Trochammina mcmurrayensis* Mellon and Wall and *Hyperamminoides barksdalei* Tappan a few feet lower. The succeeding 80 feet of sediments was barren, but these and the fossiliferous beds to the depth of about 3,800 feet are considered virtually an age equivalent of the section of undifferentiated Tuktu and Grandstand Formations in the Umiat field.

Below the barren beds, a larger fauna which is definitely a part of the *Verneuilinoides borealis* zone started with the core at 3,030–3,040 feet and continued in successively lower cores. Of the 11 species recorded from cores taken from 3,030–3,060 feet, 9 species are arenaceous, of which the most characteristic are the few specimens of *Ammobaculites wenonahae* Tappan and *Verneuilinoides borealis* Tappan and the numerous specimens of *Haplophragmoides topagorukensis* Tappan. Specimens of *H. topagorukensis* continued to be common to abundant in succeeding cores, and the fauna as a whole continued in about the same relative abundance of species and individuals to nearly 4,000 feet. Below that depth in the cores between 4,140 and 4,708 feet, fossils declined in abundance, and at lower depths many cores were barren or Foraminifera were limited to one or two species. In the lowest 600 feet of section, all cores were barren.

Trochammina umiatensis Tappan, which is a horizon marker within the upper part of the *Verneuilinoides borealis* faunal zone in the Umiat field, is present in several ditch samples in the Fish Creek well, beginning with a sample at 3,200–3,210 feet, and in core samples from 3,356–3,366 feet and 3,776–3,786 feet. Together with *Ammobaculites wenonahae* Tappan, *Psamminopelta bowsheri* Tappan, and *Ditrupa cornu* Imlay—*Trochammina umiatensis* is characteristic of beds of a Tuktu faunal facies. Its range of approximately 600 feet in the Fish Creek well is much greater than that noted in the Umiat field and suggests a duplication of beds by faulting. Woolson (Woolson and others, 1962, p. 19) on the basis of seismic data suggested that a small normal fault of approximately 200 feet of downthrow to the east would intersect the well in the oil-producing sands and come to the surface near the oil seep. The unusual range of *Trochammina umiatensis* in this well suggests duplication of beds and substantiates the postulated fault, but the fault probably would cut the Tuktu-equivalent beds below the oil sands in the well and would duplicate the *T. umiatensis* section.

Other Foraminifera from the Albian section of the Fish Creek well include some of the usual species that are more common to the *Verneuilinoides borealis* zone. Most of the Foraminifera are arenaceous forms. Never more than four or five calcareous species are found, and only a few individuals of each species are present. In general, the fauna is much smaller than the fauna in equivalent beds in Simpson test well 1, but the distribution of the fauna suggests that the Albian beds in the Fish Creek well are greatly thinned as compared to equivalent sections penetrated in Simpson test well 1 of the coastal plain and in the Umiat field of the foothills.

In general, in the lower part of the *Verneuilinoides borealis* zone, the number of foraminiferal species is fewer, but *Textularia topagorukensis* Tappan may be characteristic of it in certain subsurface sections and of the upper part of the Torok Formation in outcrop areas. Its occurrence in the Fish Creek well aids in correlating that part of the section with Albian beds equivalent to the upper part of the Torok Formation in Simpson test well 1. A few specimens of *T. topagorukensis* were found in a core from 4,140–4,150 feet and were common in two lower cores (4,340–4,350 ft and 4,544–4,554 ft). This occurrence places the top of the subzone at about 1,225 feet below the top of the *V. borealis* zone, whereas in Simpson test well 1 this interval is aproximately twice as large. The reduced interval between the two wells is a further suggestion of the thinning of the upper beds of the Albian section eastward from Cape Simpson to the Fish Creek area (pl. 15).

In cores below 4,500 feet, Foraminifera are very poorly preserved, and tests are flattened and distorted. Sutures of arenaceous forms are indistinct, which makes identifications difficult. However, beds through 4,708 feet are certainly within the *Verneuilinoides borealis* faunal zone because 11 species of the zone were recognized in the core from 4,698–4,708 feet.

Comparison of Albian microfauna.—Besides having a smaller fauna, the *Verneuilinoides borealis* zone of the Fish Creek well has other differences when compared with the zone in Simpson test well 1. *Eurycheilostoma grandstandensis* Tappan and *E. robinsonae* Tappan are conspicuous species in the section in the Simpson well but are absent in the Fish Creek well; and *Gavelinella stictata* (Tappan), although a prolific foraminifer in the Albian beds in Simpson test well 1, is only meagerly represented in Fish Creek well. The calcareous Foraminifera in general are relatively rare in the Fish Creek well, and in that respect the zone resembles the zone as it was penetrated in deep tests of the Umiat field. Similarity between the upper beds at Fish Creek and those at Umiat field is indicated by the diagnostic marker *Trochammina umiatensis* Tappan, which indicates that the Tuktu faunal facies of Umiat is present in the Fish Creek well. *T. umiatensis* was not found in the Simpson well. Present in both the Simpson well and the Umiat field but absent in Fish Creek test well 1 is the foraminifer *Gaudryina nanushukensis* Tappan. At Umiat, this fossil ranges through a considerable part of the section below the top of the zone, and in the Simpson well it occurs at numerous depths in the Torok Formation below 1,700 feet.

ALBIAN BEDS WITHOUT FAUNAL ZONES

Only a few microfossils were found in cores between 4,708 and 6,432 feet. The species include *Ditrupa cornu* Imlay and the foraminifers *Trochammina mcmurrayensis* Mellon and Wall, *Gavelinella stictata* (Tappan), and *Globorotalites alaskensis* Tappan. All are Albian species and usually have been found only in the *Verneuilinoides borealis* zone. Their infrequent occurrence through more than 1,700 feet of section in this well cannot be adequately explained other than by considering the containing beds to be part of the upper part of the Torok Formation. Beds below 6,432 feet are barren and are probably within the middle or lower part of the Torok Formation or could be approximately equivalent to a part of the section penetrated in Oumalik test well 1. Beds as old as the pebble shale of the lower part of the Torok and Fortress Mountain section of the Avak-Barrow area were not penetrated. Microfossils found in most ditch samples from the lower part of the well are almost entirely contamination from higher beds, as most specimens are from upper beds of the *V. borealis* zone and from the Colville Group.

SENTINEL HILL CORE TEST 1

The Sentinel Hill core test was drilled in 1947 on the west side of the Colville River at a site 24 miles northeast of Umiat and 12 miles due north of Gubik test well 1. A résumé of the purpose of the test, the pertinent data obtained, and the lithologic descriptions of the rocks penetrated in this core test have been published (Robinson and Collins, 1959, p. 486–500). The beds penetrated are all within the upper part of the Schrader Bluff Formation. No fossils were found in the upper 475 feet of section, which is largely in the Kogosukruk Tongue of the Prince Creek Formation. Concentration of microfossils is largely in the intervals: 475 feet through 769 feet, 819–839 feet, and 1,100–1,180 feet (total depth). These intervals are within units of the Sentinel Hill Member of the Schrader Bluff Formation, but they are not differentiated on the faunal chart of this core test. (See pl. 20.) Specimens of *Eoeponidella strombodes* Tappan, a species which is regarded as a subzone of the *Neobulimina canadensis* faunal zone, were found in samples from 599–839 feet.

KAOLAK TEST WELL 1

Kaolak test well 1 was located in the western part of northern Alaska, about 130 miles southwest of Barrow. It was drilled along a tributary of the Kaolak River, on an east-trending anticline discovered by seismic work. The test penetrated a section of more than 6,900 feet of sediments that are almost devoid of fossils. At this location, approximately 100 feet of Recent and Pleistocene silt, clay shale, sand, and gravel overlie Lower Cretaceous rocks. Fine- to medium-grained sandstone, which is in part argillaceous and silty, some clay shale, abundant clay ironstone, a few thin beds of coal, and minor limestone make up the upper 1,100 feet of the Cretaceous beds (Collins, 1958c, p. 354). In the section between 1,183 and 3,270 feet, clay shale, siltstone, and argillaceous sandstone with minor amounts of clay ironstone were penetrated; but coal is prominent, and in a core at the top of the interval 16½ feet were penetrated. Below 3,270 feet the section was predominantly clay shale.

Collins (1958c, p. 355) tentatively assigned the section from 113 to 4,600 feet to the Chandler Formation and the section below that to the Topagoruk Formation. However, I consider the entire section as beds of the Corwin and Kukpowruk Formations undifferentiated (Bergquist, 1958e, p. 374), but possibly part of the clay shale sequence in the lower part of the well might be considered as the upper part of the Torok Formation. It is doubtful that a contact could be drawn precisely.

STRATIGRAHIC PALEONTOLOGY

The highest foraminifers found in this well came from a sample at 420–430 feet; the largest number of specimens were found in a core from 6,367–6,387 feet. Only 100 tests and fragmentary specimens of Foraminifera came from the entire well section, and these represent less than a dozen species, of which one is calcareous. (See pl. 21.)

Verneuilinoides borealis *faunal zone (4,625 ft to total depth)*.—None of the Foraminifera found above 4,600 feet are characteristic of any formation, but the appearance of *Verneuilinoides borealis* Tappan at 4,625–4,635 feet indicates the presence of the *V. borealis* faunal zone of Albian age. The zone is poorly developed in the well, however, and only in one core (6,367–6,387 feet) is there any faunal assemblage at all. In that core were five species, the specimens of which accounted for nearly half of those found in the well. *V. borealis* itself constitutes about 28 percent of the specimen count of the entire zone in this well; *Haplophragmoides topagorukensis* Tappan and *Miliammina awunensis* Tappan each account for about 20 percent; and "*Tritaxia*" *manitobensis* and *Siphotextularia? rayi*, which I consider to be one species, make up about 12 percent of the fauna. Seven other species account for the other 20 percent of the fauna; one is calcareous, and only two specimens are present.

MEADE TEST WELL 1

Meade test well 1 was drilled on a seismically located anticline near the southern edge of the Arctic coastal plain, about 100 miles south of Barrow, Alaska, and about 7 miles west of the Meade River. Nonmarine clay shale with interbedded coal, sandstone, and siltstone, and shallow marine standstone and clay shale of Early Cretaceous (Albian) age were penetrated beneath a thin mantle of Pleistocene deposits. The Cretaceous section of rocks has been described by Collins (1958c), who subdivided it as follows: 25–1,235 feet, Killik Tongue of the Chandler Formation; 1,235–4,200 feet, Grandstand Formation; and 4,200–5,305 feet (total depth), Topagoruk Formation. The rock sequence, and the fossils, however, are more like the Corwin and Kukpowruk units of Albian age in the western part of northern Alaska than like units of the Killik-Anaktuvuk Rivers area, 130–175 miles to the southeast. In this report, therefore, the upper 4,200 feet of section is regarded as undifferentiated beds of the Corwin and Kukpowruk(?) Formations, and the shale sequence below is regarded as part of the Torok Formation.

The Pleistocene deposits in this test well are only a few feet thick, but fragments of mollusk shells and tests of Foraminifera belonging to the Elphidiidae and Miliolidae were found in ditch samples through 70 feet. The species are forms that occur in the Gubik Formation. They are not shown on the faunal chart of this well. (See pl. 21.)

ALBIAN ROCKS

CORWIN AND KUKPOWRUK FORMATIONS UNDIFFERENTIATED (25–4,200 FT)

The upper 2,000 feet of section in the Meade well is largely nonmarine and contains an occasional charophyte oogonium, but around 1,000 feet and in the interval 1,400–2,000 feet, a few Foraminifera of the *Verneuilinoides borealis* faunal zone occurred in nearly every ditch sample. Relatively few fossils were found in the cores from the same interval, however, and the Foraminifera in the ditch samples are probably in part the result of cavings from a very few fossiliferous sections. These Foraminifera are associated with abundant carbonaceous material, which suggests that the marine rocks are only thin beds intertongued with lagoonal deposits. For these reasons, I consider the upper 2,000 feet of section to be the equivalent of the lower part of the Corwin Formation of western Alaska and the entire section from 25 to 4,200 feet to be an undifferentiated sequence of beds of the Corwin and Kukpowruk Formations.

In the interval of nearly 3,000 feet of section (1,235–4,200 ft) assigned to the Grandstand Formation by Collins, the logged sandstone and siltstone of any significance constitute only about 11 percent. This percentage would be somewhat higher if all the thin layers interbedded with clay shale were considered, but it hardly compares with the extensive sandstone of the Grandstand section of the type area. Furthermore, the fossils found in the interval 2,000–4,200 feet are part of a restricted fauna that contains certain species which either are unknown in outcropping rocks of the Grandstand Formation or are very rarely known but which are characteristic of the upper part of the Torok Formation and the Tuktu and Kukpowruk Formations. These species include *Ammobaculites wenonahae* Tappan, "*Tritaxia*" *manitobensis* Wickenden, *Eurycheilostoma robinsonae* Tappan, *Gavelinella stictata* (Tappan) and *Ditrupa cornu* Imlay. In the Meade well, this restricted fauna and the rock sequence from which it came correlate better with the Kukpowruk Formation than with the Tuktu Formation, whereas a correlation with the Grandstand Formation is less appropriate. The preservation of the microfossils, especially the tests of *Verneuilinoides borealis* and "*Tritaxia*" *manitobensis* is also much more like that of specimens of the Kukpowruk Formation than like that of specimens from beds of the same age found in the wells east of the Meade test well. In addition, the absence from the Meade well section and from the Kukpowruk Formation of *Gaudryina nanushukensis* Tappan, which is very diagnostic of the Tuktu Formation and the upper part of the Torok Formation, is another indication of similarity to the Kukpowruk section in western Alaska.

UPPER PART OF TOROK FORMATION (4,200 FT TO TOTAL DEPTH)

The section penetrated from 4,200 feet to total depth at 5,305 feet is largely clay shale, which I would assign to the upper part of the Torok Formation. Four cores were taken in this interval, but no fossils were found in the bottom hole core or in a core from 4,770–4,780 feet. A core at 5,048–5,058 feet carried an abundance of *Haplophragmoides topagorukensis* Tappan and a few specimens of *Ammobaculites wenonahae* Tappan and *Textularia topagorukensis* Tappan. Although ditch samples carried more microfossils, they were probably derived from beds higher in the section.

VERNEUILINOIDES BOREALIS FAUNAL ZONE (1,010–5,280? FT)

The *Verneuilinoides borealis* fauna is meager in the Meade well, consisting mostly of a few arenaceous Foraminifera that are relatively poorly preserved owing to the collapsed, crushed, and distorted condition of the tests. In general, the *V. borealis* fauna from this well is much like that in the Kukpowruk Formation, as the preservation is similar and the species are nearly the same; but a comparison of the fauna with that found in the Umiat wells or in Topagoruk test well 1 and the Arctic coastal wells shows that the fauna is smaller and that specimens of the same species are much more poorly preserved.

Coarsely textured specimens of *Verneuilinoides borealis* Tappan in a sample at 1,010 feet mark the top of the *V. borealis* fauna in this well. Tests of this species and a few of *Haplophragmoides topagorukensis* occurred sparingly through 200 feet of section, but between 1,380 and 1,500 feet the fauna expanded to a dozen species. Eight more species appeared at scattered intervals through the succeeding 1,400 feet of section. The fauna is of lesser extent in the shale beds of the upper part of the Torok Formation than it is in the undifferentiated section of the Corwin and Kukpowruk Formations above.

Approximate percentages of the principal species found in the *Verneuilinoides borealis* fauna are as follows: *V. borealis*, 39 percent; *Miliammina awunensis* Tappan, 20 percent; *Haplophragmoides topagorukensis* Tappan, 12 percent; "*Tritaxia*" *manitobensis* Wickenden, 4 percent; *Psamminopelta bowsheri* Tappan and *Miliammina manitobensis* Wickenden, each 3.6 percent; *Gaudryina canadensis* Cushman and *Trochammina gatesensis* Stelck and Wall, each 2.8 percent; *Gaudryinella irregularis* Tappan, 2.5 percent; *Gavelinella stictata* (Tappan), 2.1 percent; *Trochammina mcmurrayensis* Stelck and Wall, 1.7 percent; *Saccammina lathrami* Tappan, 1.6 percent; *Ammobaculites wenonahae* Tappan, 1.2 percent; all others, 2.8 percent. Specimens of five calcareous species of Foraminifera together total only 3.6 percent of the fauna.

In a résumé of the paleontology of the Meade test well (Bergquist, 1958e, p. 374), specimens of *Trochammina* were identified as *T. rainwateri* Cushman and Applin, a form described from the Woodbine of Cenomanian age in Texas. From my later studies, however, I think there are, instead, two other species of *Trochammina*, namely *T. mcmurrayensis* Stelck and Wall and *T. gatesensis* Stelck and Wall; these species were described from beds of middle Albian age in Alberta, Canada.

Specimens identified as "*Tritaxia*" *manitobensis* Wickenden also include numerous specimens which could be designated as *Siphotextularia*? *rayi* Tappan. As discussed on pages 137–139 of this report, specimens of "*Siphotextularia*? *rayi*" are always associated with the compressed specimens of "*Tritaxia*" *manitobensis* or are restricted to the same part of the section. Specimens from the Meade well show various stages of preservation, from the kind of test which Mrs. Loeblich described as *Siphotextularia*? *rayi*, to those generally referred to in this study as "*Tritaxia*" *manitobensis*. Mrs. Loeblich's assignment of the latter species to the genus *Uvigerinamina* is not recognized in this study.

OUMALIK CORE TESTS AND TEST WELLS

The Oumalik anticline is about 20 miles in length, has a general strike of N. 70° W., and lies near the northern boundary of the Arctic foothills province between long 155°12′ W. and 156°15′ W. On this structure several core tests and two test wells were drilled during the period 1947–51. Lithologic descriptions and a discussion of the stratigraphy of these tests have been published (Robinson, 1956) as has a preliminary report on the paleontology of the two test wells and four of the core tests (Bergquist, 1956b). Some of the microfossil names previously used, however, have been changed, or reidentifications have been made; the newer names are given on the faunal charts of the test wells and core tests 2, 11, and 12 (pl. 19). Significant nomenclatural changes are as follows: *Ditrupa* sp., now *D. cornu* Imlay; *Pelosina complanata* Franke, now *Saccammina lathrami* Tappan; *Ammobaculites tyrrelli* Nauss, now *A. wenonahae* Tappan; *A. humei* Nauss, now *A. fragmentarius* Cushman; *Gaudryina hectori* Nauss, now *G. canadensis* Cushman, and *Trochammina rutherfordi* Stelck and Wall, now listed as *T. mcmurrayensis* Stelck and Wall or *Trochammina* sp.

OUMALIK TEST WELL 1

This test hole, located on the apex of the anticline near long 156° W., was drilled to 11,872 feet. Seemingly only Lower Cretaceous rocks were penetrated throughout the test except for a few feet of Pleistocene sediments. These rocks are mostly of Albian age; but in the lower part of the hole (10,880 to total depth), strata of early Valanginian age were identified by Imlay (1961, p. 49–50), and the hole may actually have bottomed in rocks of Berriasian age. The section in the upper 2,800 feet of the test hole is composed of about 45 percent sandstone and siltstone, 50 percent clay shale, and 5 percent coal or carbonaceous material; below 2,825 feet to total depth, the section is predominantly clay shale. In earlier reports the rocks in the upper part were referred to the Grandstand Formation, but here they are considered as Tuktu and Grandstand Formations undifferentiated. Further, the thick clay-shale sequence, the upper part of which has been called the Topagoruk Formation and the lower 6,000 feet of which has been described as the type section for the Oumalik Formation (Robinson, Rucker, and Bergquist, 1956, p. 225), is herein considered to be the Torok Formation because there appears to be little justification for separating the sequence into two lithologic units.

All the cores and most of the ditch samples from this test were studied for microfossils; and, although the greater part of the ditch samples carried some fossils (many as contamination from higher beds), fossils were found in only about 66 percent of the cores. Detailed tabulation of the microfauna indicates that only the *Verneuilinoides borealis* microfaunal zone can be recognized, as the rocks below 5,670 feet are sparingly fossiliferous and give little evidence of other faunal zones.

MIDDLE TO UPPER ALBIAN ROCKS

Verneuilinoides borealis faunal zone (30–5,370 ft)

Microfossils of the *Verneuilinoides borealis* faunal zone were found sparingly in most of the samples in the upper few hundred feet of this well; but with increasing depth, the number of species gradually increases. Of 63 cores taken in the interval herein assigned to the *V. borealis* faunal zone, 28 were barren of fossils, and 4 were not recovered. In the upper part of the *V. borealis* zone, in the second core (617–628 ft), no microfossils were found, but there were carbonized plant remains which were identified by R. W. Brown as *Elatides* sp. and *Ginkgo digitata* (Brongniart) Heer; the latter is known from Lower Cretaceous beds (R. W. Brown, written commun., 1955). Microfossils found in the section above the core indicate an Albian age for the section.

A larger number of microfossils were found in the lower part of the section of Tuktu and Grandstand Formations undifferentiated than the highest beds yielded, and these microfossils continued in some degree of abundance in the upper part of the Torok Formation. In its entirety the *Verneuilinoides borealis* fauna in this test hole is composed of 37 species of Foraminifera; but 6 arenaceous species account for approximately 79 percent of the assemblage, and 2 species alone make up 55.7 percent. *V. borealis* Tappan accounts for 28.7 percent of the fauna and is most conspicuous in the Tuktu and Grandstand beds, whereas *Haplophrag-*

moides topagorukensis Tappan becomes the dominant form in the upper part of the Torok Formation and accounts for 27 percent of the fauna of the entire zone. The other four species found in greatest abundance are: *Textularia topagorukensis* Tappan, 6.5 percent, *Bathysiphon vitta* Nauss?, 5.9 percent, *Gaudryinella irregularis* Tappan, 5.6 percent, and *Miliammina awunensis* Tappan, 5.5 percent. Eight other numerically important species in the fauna are: "*Tritaxia*" *manitobensis* Wickenden, 2.7 percent; *Saccammina lathrami* Tappan, 2.3 percent; *Ammobaculites fragmentarius* Cushman, 1.8 percent; *Gavelinella stictata* (Tappan), 1.6 percent; *Haplophragmoides* cf. *H. kirki* Wickenden, 1.5 percent; *Bathysiphon brosgei* Tappan and *Miliammina manitobensis* Wickenden, each 1.2 percent; and *Ammobaculites wenonahae* Tappan, 1.1 percent. The remaining 23 species of the *V. borealis* fauna of this well comprise 15 arenaceous and 8 calcareous forms, but together these 23 species constitute only 6.9 percent of the entire fauna. Calcareous species actually represent only a minor part of the *V. borealis* fauna in this test; and as a group with *G. stictata* included, they constitute only 2.7 percent of the total fauna.

Compared with the *Verneuilinoides borealis* fauna in other wells, the relative percentages of several characteristic species are distinctly different. Only about 54 percent of the number of species of the prolific fauna found in Simpson test well 1 was found in Oumalik test well 1, and the number of specimens found was only about 30 percent of that recovered from the Simpson well. Ratios of *Haplophragmoides topagorukensis* Tappan and *V. borealis* Tappan are about equal in the Oumalik well, as compared to 42 percent for *H. topagorukensis* and 9 percent for *V. borealis* in the Simpson test well. The percentage of *Textularia topagorukensis* Tappan is larger in Oumalik test well 1 than in Simpson test well 1; whereas, *Ammobaculites fragmentarius* Cushman, *A. wenonahae* Tappan, and *Gavelinella stictata* (Tappan) are minor constituents of the fauna in the Oumalik test well but are of considerable importance in the fauna from the Simpson well.

Many of the specimens of *Verneuilinoides borealis* recovered from the Oumalik well samples are large; and although they are compressed, the triserial arrangement of the chambers is clearly defined. A few tests that were pyritized have retained their original inflated chambers and the cylindrical shape of the later part of the tests.

About 35 percent of all specimens of Foraminifera recovered from cores from the Tuktu and Grandstand beds came from the core at 723–733 feet, where large compressed brown specimens of *Verneuilinoides borealis* and tiny flattened specimens of *Gaudryinella irregularis* Tappan were common. Specimens of *G. irregularis* are elongate, narrow, and tapered or rounded at the initial end but flattening has obscured the arrangement of chambers on the initial part of some specimens, these flattened specimens now resemble *Textularia topagorukensis*. The few pyritic specimens, however, have chambers arranged loosely biserially or uniserially in the later part of the test, as is typical of the genus *Gaudryinella*.

In a core from 2,841–2,851 feet in the upper part of the Torok Formation, the light-brown planispiral tests of *Haplophragmoides topagorukensis* Tappan resemble worn sand grains, as nearly all are distorted either from lateral compression or marginal flattening. Light-gray tests of "*Tritaxia*" *manitobensis* Wickenden from the same beds are compressed, and many have an ovate outline with the distinguishing extended neck protruding at one end and the flattened initial chambers overlapped at the other. Specimens of *Textularia topagorukensis* Tappan are light brown, narrow, and elongate; they are compressed but only slightly distorted, and only a few specimens are entirely flattened.

Haplophragmoides topagorukensis was common in cores at 3,222–3,232 feet and at 3,710–3,713 feet. Associated species in the latter core sample were common *Textularia topagorukensis* and a few complete specimens and numerous segments of the uniserial part of tests of *Ammobaculites fragmentarius* Cushman. Specimens of the latter are light tan, relatively smooth, and all are compressed. At 4,420–4,440 feet, flattened tests of *H. topagorukensis*, discoidal to subovate flattened tests of *Hyperamminoides barksdalei* Tappan, and flattened ovate tests of *Miliammina awunensis* Tappan were common; slender, delicate, flattened tests of *T. topagorukensis* were abundant in the same core.

LOWER(?) ALBIAN ROCKS

Below the *Verneuilinoides borealis* faunal zone is a sequence of more than 5,500 feet of clay shale and sandy shale which is only sparingly fossiliferous; this sequence apparently is also of Albian age. Of the 26 cores cut in this part of the section, 5 were not recovered, and 13 were completely barren of microfossils. Ditch samples, however, carried as drilling contamination numerous microfossils of the *V. borealis* fauna from the upper part of the Torok Formation and the overlying beds of the Nanushuk Group. Because of this contamination, only the cores and six ditch samples for this part of the section are listed on the faunal chart (pl. 19). Specimens of *Gaudryina canadensis* Cushman, which were formerly identified as *Dorothia chandlerensis* Tappan, occurred in three ditch samples (Bergquist, 1956b). In two samples, the highest occurrence of *Lithocampe*?

sp. and *Glomospira corona* Cushman and Jarvis (8,050–8,060 ft and 8,860–8,870 ft) was tabulated, and one sample (5,990–6,000 ft) yielded a large specimen of *Haplophragmoides*, which could be *H. gigas* Cushman.

The above-mentioned sequence, plus beds beginning at the depth of 4,860 feet, was described as the type section of the Oumalik Formation (Robinson, Rucker, and Bergquist, 1956), and this formational name was used in subsequent reports (Robinson, 1956, and Bergquist, 1956b). In these reports the foraminifer *Dorothia chandlerensis* was cited as a characteristic fossil of the Oumalik Formation; its highest occurrence was considered to mark the top of the formation because contact with the "Topagoruk" Formation was regarded as gradational. However, the highest specimen formerly referred to *D. chandlerensis* appears to be a specimen of *Gaudryina canadensis* Cushman, a species which occurs sparingly in the *Verneuilinoides borealis* beds of this well.

In lower ditch samples (8,130–8,140 ft, 8,310–8,320 ft, and 9,310–9,320 ft), three specimens formerly identified as *Dorothia chandlerensis* are now listed under *Gaudryina canadensis* in the chart of this well (pl. 19). However, because the tests are compressed and exact identification is difficult, the specimens might possibly be the species *G. tailleuri* (Tappan)—formerly *D. chandlerensis* and *Verneuilinoides tailleuri* Tappan; on each the initial portion is relatively short, and the biserial stage forms most of the test. Furthermore, in about the same part of the section below 8,000 feet, pyritic casts of stichocorythidian Radiolaria (*Lithocampe?* sp. and *Dictyomitra?* sp.) were found, and these casts lend some support to the possibility that the *Gaudryina tailleuri* faunal zone occurs in the general interval 8,130–9,320 feet. If the zone is present, however, it is not as extensively developed as in the Avak-Barrow area, where a relatively large fauna was found in an extensively cored section.

The pyritic casts of Radiolaria in the section mentioned above are fairly distinctive. Those identified as *Lithocampe?* sp. were found in ditch samples from 8,060 feet and 10,210–10,220, feet and in cores from 10,233–10,240 feet and at 10,699–10,882 feet. These casts are spindle shaped and have tranverse strictures but no ornamentation. Eight pyritic casts identified as *Dictyomitra?* sp. came from a core sample at 10,233–10,240 feet. The casts are short and conical, some are compressed, and most have surfaces covered by impressions of pentagonal pits alined in rows normal to the axis or parallel to the faint transverse strictures visible on a few specimens. Similar casts occur in the lower part of the Torok Formation.

Because an incorrectly identified fossil was used to mark the top of the clay-shale sequence described as the type section of the Oumalik Formation and because this formation was considered to be gradational into the "Topagoruk" Formation (Robinson, Rucker, and Bergquist, 1956, p. 226), there seems to be no valid basis for separating this sequence from the overlying clay-shale beds. Furthermore, as indicated elsewhere in this report, separation of the entire thick clay-shale sequence beneath the Nanushuk Group into two formations is of questionable validity anywhere in the subsurface sections penetrated in northern Alaska, and it seems preferable to assign this entire section to the Torok Formation.

NEOCOMIAN ROCKS

In the lower 1,000 feet of the Oumalik well, the test penetrated a sequence of clay shale interbedded with siltstone and a very fine sandstone. Well-rounded quartz grains and green clay pellets are common in the shale and distinguish it from the overlying beds of the lower part of the Torok Formation. A pre-Albian age is indicated for at least the upper part of the sequence, as molluscan casts from the basal part of a core at 10,922–11,007 feet were identified by R. W. Imlay as *Buchia sublaevis* (Keyserling) of Early Cretaceous (early Valanginian) age. In earlier reports on this well, however, the section was referred to Upper Jurassic(?) and Lower Cretaceous(?) (Robinson, 1956, p. 10, and Bergquist, 1956b, p. 66) because the recovered Foraminifera resemble Late Jurassic species. The most frequently occurring of these Foraminifera is a large species of *Haplophragmoides* which is scattered through more than 750 feet of the section. The tests are dark brown, closely coiled, and subglobular and have broadly rounded margins and numerous chambers; they resemble tests of *H. canui* Cushman of the Upper Jurassic. They also are much like tests of a form that was found in large numbers in a rather prolific arenaceous foraminiferal assemblage in a suite of more than 30 samples collected from beds of the Okpikruak Formation along the Kemik Creek. The early Valanginian age of these rocks was ascertained by R. W. Imlay, who identified *Buchia sublaevis* in them.

Unfortunately, none of the other Foraminifera from the lower beds in the Oumalik test well can be compared to specimens from the outcropping Okpikruak Formation of the Kemik Creek area. In this report, therefore, the Foraminifera known to be indigenous to the rocks in which they are found in the lower part of the well are either listed only by generic name on the faunal chart (pl. 19) or are questionably referred to species. Thus two of them are referenced to Late Jurassic species (*Gaudryina topagorukensis* Tappan and *Globulina topagorukensis* Tappan), as the specimens seem to be more closely related to those forms than to known Cretaceous species. No fossils were found, however, which give positive evidence that rocks older than Cretaceous age were penetrated in the well, and it is thus assumed that all the rocks below those containing *Buchia sublaevis* are of Early Cretaceous age. Possibly that part of the section could be of Berriasian age, as *B. sublaevis* usually occurs only in the lower few hundred feet of rocks of Valanginian age in northern Alaska (Imlay, 1961, p. 50).

Pyritic casts of stichocorythidian Radiolaria (*Lithocampe*? sp. and *Dictyomitra*? sp.) were found in ditch samples from the lower beds, but these could be contamination from higher beds in the well. A pyritic cast of a radiolarian unlike any other in subsurface or outcrop samples in northern Alaska was found in a sample from 11,480–11,490 feet. The specimen, which has four equidistant subtriangular arms of equal length extending from an inflated central area, probably belongs to the Spongodiscidae (*Spongoastericus*? sp.).

EAST OUMALIK TEST WELL 1

East Oumalik test well 1, which was drilled about 12 miles S. 17° E. of Oumalik test well 1, penetrated a thin mantle of Recent or Pleistocene sediments and nearly 6,000 feet of Lower Cretaceous rocks. From 30 to 3,050 feet, the test penetrated about 700 feet of nonmarine clay shale and coal with thin interbeds of sandstone and siltstone and a section of more than 2,300 feet in which there is massive marine sandstone and clay shale. In this report, this entire section is regarded as Tuktu, Grandstand and Chandler Formations undifferentiated. Beneath these formations the predominantly marine clay shale beds pentrated to the bottom of the hole at 6,035 feet are herein collectively considered as the Torok Formation.

Microfossils of middle to late Albian age and some of possible early? Albian age were recovered, but only one faunal zone was recognized. Description of cores and cuttings from this well have been published (Robinson, 1956, p. 51–60), as well as a preliminary report on the microfossils (Bergquist, 1956b, p. 66–67). Changes made in certain fossil determinations since 1956 include the following: *Pelosina complanata* Franke, now *Saccammina lathrami* Tappan; *Ammobaculites humei* Nauss, now *A. fragmentarius* Cushman; *Ammobaculites tyrrelli* Nauss, now *A. wenonahae* Tappan; *Gaudryina hectori* Nauss, now *G. canadensis* Cushman; *Ditrupa* sp., now *Ditrupa cornu* Imlay.

MIDDLE TO UPPER ALBIAN ROCKS

Verneuilinoides borealis faunal zone (156–5,085? ft)

This faunal zone includes most of the section penetrated in the well, and microfossils found in it were briefly discussed above. The two names, Topagoruk and Oumalik Formations, are not used in this report and Grandstand is used here in an expanded sense. A complete tabulation of fossils recovered from the well samples is shown in the faunal chart (pl. 19). In the uppermost part of the well, the fossils in the core at 156–166 feet and in the ditch samples beginning at 350 feet suggest interbedding of the Grandstand and Chandler Formations and indicate Lower Cretaceous sedimentary rocks which are not younger than late Albian. A gradual increase in species occurs below 730 feet, and the greatest concentration of species and specimens in the upper part of the Torok Formation is at about 3,150–3,840 feet. The *Verneuilinoides borealis* zone, however, extends through at least 1,250 feet more of the section, but in most of the samples the abundant specimens recovered are probably due to drilling contamination.

A comparison of the *Verneuilinoides borealis* fauna of East Oumalik test well 1 with that found in Oumalik test well 1 indicates that the highest occurrence of a species is always several hundred feet lower in the East Oumalik well than in Oumalik test well 1. For example, the highest occurrence of such species as *Gaudryinella irregularis* Tappan, *Gaudryina nanushukensis* Tappan, and *Gavelinella stictata* (Tappan) is in the order named, 570 feet, 799 feet, and 945 feet lower in the East Oumalik well than in Oumalik test well 1.

As specimens of several arenaceous species are mostly brownish gray, and as they have a granular texture, the chambers are difficult to discern. Compressed and distorted tests are common, particularly in forms such as *Trochammina* sp. cf. *T. gatesensis* Stelck and Wall.

Tubes of *Ditrupa cornu* Imlay and shell fragments and prisms of Inocerami which occur in two cores within the interval 1,692–2,645 feet are found in ditch samples to the depth of 4,690 feet, and they probably are part of a subzone of the *Verneuilinoides borealis* zone as noted in the Barrow-Simpson-Topagoruk areas. The extent of the subzone in this well cannot be determined, but it may not be much more than 1,000 feet, as the material found in ditch samples could have come from the higher beds.

LOWER(?) ALBIAN ROCKS (5,085?–6,080? FT OR TOTAL DEPTH)

A few microfossils from the lower part of this well suggest correlation with part of the *Gaudryina tailleuri* zone of the lower part of the Torok Formation. However, no specimens of *G. tailleuri* were found, and the fossils recovered are only a few pyritic casts of stichocorythidian Radiolaria of the type which occur in the lower part of the Torok Formation in Oumalik test well 1.

A faunal count of all specimens listed on the faunal chart, exclusive of the Radiolaria and one Foraminifera from the lower(?) Albian rocks, gives the following data. Of 36 species found, 15 are calcareous and 21 are arenaceous. The calcareous species combine to make up only 3.5 percent of the faunal count. Twelve species, including one calcareous form, make up 94.5 percent of the fauna, whereas 24 species together amount to only 5.5 percent. *Verneuilinoides borealis* Tappan is the most abundant species and accounts for 53.4 percent of the count; it far outranks all other species. Next in order is *Miliammina awunensis* Tappan, which accounts for 10.4 percent; and this species is followed by *Haplophragmoides topagorukensis* Tappan, which constitutes 9.3 percent. Percentages of other species of the top 12 are as follows: *Trochammina* cf. *T. gatesensis* Stelck and Wall, 4.7 percent; *Ammobaculites fragmentarius* Tappan, 4.2 percent; *Gaudryinella irregularis* Tappan, 4.1 percent; *Textularia topagorukensis* Tappan, 2.0 percent; *Gaudryina canadensis* Cushman, 1.9 percent; *Psamminopelta bowsheri* Tappan, 1.4 percent; "*Tritaxia*" *manitobensis* Wickenden, 1.1 percent; *Bathysiphon vitta* Nauss?, 1.0 percent; and *Eurycheilostoma robinsonae* Tappan, 1.0 percent.

CORE TESTS

A résumé of the paleontology of Ikpikpuk core test 1 and Oumalik core tests 1, 2, 11, and 12 was previously given (Bergquist, 1956b, p. 67, 68) and needs no repetition here. The occurrences of microfossils found in samples from Oumalik core tests 2, 11, and 12 are shown on plate 19. Only arenaceous Foraminifera of the *Verneuilinoides borealis* faunal zone were found. Ikpikpuk core test 1 and Oumalik core test 1 are not shown on plate 19 as the only fossils found are nonmarine ostracodes from the Gubik Formation; these ostracodes occurred as contamination in nearly every sample. Those from Ikpikpuk core test 1 were identified as *Condona* cf. *C. candida* (Müller). Samples from Oumalik core (foundation) tests 1–10 were never received at the Fairbanks laboratory.

Cretaceous sections penetrated in the core tests are of middle to late Albian age although they are called "Grandstand Formation (Lower and Upper Cretaceous)" in the earlier report on the Oumalik area. Studies since that time, however, indicate that the section is entirely within the Lower Cretaceous. Only arenaceous Foraminifera were recovered; the fauna consists of 6 species in core test 2, 9 species in core test 11, and 12 species plus 1 radiolarian in core test 12. Tests of *Verneuilinoides borealis* Tappan are most abundant and frequent in the samples, and chambers of the beautifully preserved specimens from the lower part of the core test are filled with pyrite, which shows through the finely textured arenaceous walls with a silvery-yellow sheen.

In core test 11, most specimens of *Verneuilinoides borealis* are compressed, but a few have been preserved by pyrite like the specimens from core test 2. Tests of *Psamminopelta subcircularis* Tappan occurred in only one sample, where they were abundant. Most of the small light-tan tests are compressed and distorted into elongate or ovate shapes; but, because a few are pyritized, the walls have withstood crushing, and these tests are subcircular and have rounded margins. Specimens of *Trochammina* cf. *T. gatesensis* Stelck and Wall exhibit different degrees of preservation, the tests ranging from nondistorted biconvex tests to badly distorted ones. Initial chambers are dark brown on most specimens.

Six species of Foraminifera were common to abundant in core test 12. Most specimens are compressed and show some distortion, but a few are pyritic and have retained the original shape of the test. Of the latter, specimens of *Verneuilinoides borealis*, *Psamminopelta subcircularis* and *Gaudryinella irregularis* Tappan in samples from 76–96 feet have been replaced by pyrite. The pyritized specimens of *G. irregularis* show the biserial to uniserial stages better than specimens from the other core tests or from Oumalik test well 1.

SQUARE LAKE TEST WELL 1

This test was drilled on a seismically defined structure at a site about 32 miles N. 62° W. of Umiat. Upper and Lower Cretaceous rocks were penetrated, and more than 1,800 feet of the section is considered to be of Late Cretaceous age. The test bottomed at 3,987 feet. Data on stratigraphy, cores and cuttings have been published (Collins, 1959), together with a résumé of the paleontologic data (Bergquist, 1959b, p. 479–480). Attention here is directed to the distribution of the microfossils shown in the faunal chart (pl. 22) and to certain changes in fossil identification.

The Cretaceous rock units penetrated in this well are of the following ages: Tuluvak Tongue of the Prince Creek Formation and intertongued Schrader Bluff Formation (25–700 ft), Senonian age; Seabee Formation (700–1,885 ft), Turonian age; Ninuluk(?) Formation and Killik Tongue of Chandler Formation (1,885–2,475 ft), Cenomanian and late Albin age; *Verneuilinoides borealis* zone (2,475–total depth), late Albian age, the only faunal zone definitely recognized in this well.

SENONIAN ROCKS (25–700 FT)

A predominantly nonmarine sequence of sandstone with some shale, a considerable amount of bentonite, and some coal, of a combined thickness of nearly 700 feet, was penetrated in the upper part of the test beneath a thin mantle of alluvium. Carbonaceous prints of plants were found in several samples, and specimens from two cores were identified by R. W. Brown as a species of redwood—*Metasequoia cuneata* (Newberry) Chaney—not uncommon in Upper Cretaceous sediments. From samples of shale cored at 522–550 feet came flattened and distorted specimens of *Haplophragmoides rota* Nauss and *Trochammina ribstonensis* Wickenden, two fragments of questioned *Gaudryina irenensis* Stelck and Wall, and broken specimens of *Spiroplectammina webberi* Tappan, an association which suggests at least one marine tongue of the Schrader Bluff Formation within the lower part of the nonmarine beds.

TURONIAN ROCKS (700–1,820 FT)

SEABEE FORMATION (700–1,820 FT)

A sequence of more than 1,100 feet of bentonitic clay shale with three beds of sandstone—50, 150, and 45 feet thick, respectively—is identified as the Seabee Formation. A thin conglomerate of black chert is inferred to be the base. Fossils occurred mostly in the middle part of the section, and no faunal zones can be distinguished. Much of the upper 400 feet of the clay shale was nonfossiliferous; but a few small specimens of *Saccammina lathrami* Tappan were found in core samples from 699–728 feet, and in ditch samples from 750–820 feet, there were a few flattened and distorted specimens of *Haplophragmoides rota* Nauss and *Trochammina ribstonensis* Wickenden? and pyritic casts of a discoidal radiolarian, "*Zonodiscus*" sp. C.

Most of the microfossils in the formation were from the interval between 1,180 and 1,600 feet, where *Inoceramus* prisms occurred in most samples, and 10 species of Foraminifera and 5 species of Radiolaria were identified. Flattened and distorted tests of *Haplophragmoides rota* make up 30 percent of these fossils; and *Saccammina lathrami*, *Gaudryina irenensis* Stelck and Wall?, and *Trochammina ribstonensis* together account for 45.5 percent of the count. Radiolaria constitute only a minor part of the fauna, but tests of *Cenosphaera* (*Cenosphaera*) sp. A were common at 1,180–1,190, and discoidal pyritic casts of "*Zonodiscus*" sp. C. were common at 1,570–1,580 feet.

Because specimens identified as *Gaudryina* sp. are flattened and distorted, the arrangement of chambers is very difficult to discern, and some of these specimens may be textularian forms. The tests were common at 1,451–1,478 feet and 1,755–1,765 feet and occurred sparingly at other depths. They could belong to a textularian form identified as *Textularia* cf. *T. rollaensis* Stelck and Wall listed on the faunal chart (pl. 22) as occurring in the middle beds of the Seabee Formation. In the same general part of the section were *Praebulimina seabeensis* Tappan and *Neobulimina albertensis* (Stelck and Wall). The last-mentioned three species were formerly recorded as *Textularia gravenori* Stelck and Wall, *Praebulimina carseyae* (Plummer), and *Neobulimina canadensis* Cushman and Wickenden (Bergquist, 1959b, p. 480).

The assemblage of microfossils in the intervals between 1,180 and 1,600 feet and 1,755–1,765 feet is characteristic of the lowest part of the Seabee Formation in some areas and offers the possibility that the lower 100 feet of the section included in the Seabee Formation in this well in previous reports might not be part of the formation. Other than *Trochammina ribstonensis*, which was common in a ditch sample from 1,830–1,840 feet, few fossils were found in the lowest beds of the Seabee Formation of this well.

Recently David Jones identified a specimen of *Arctica* sp. at 1,824 feet and suggested that the containing beds were of Cenomanian age (written commun., 1963). This would place the base of the Seabee Formation at least 60 feet higher than recorded in earlier reports (Collins, 1959, p. 434; Bergquist, 1959b, p. 480) and substantiates the observations that the microfossils at 1,755–1,765 feet may be near the base of the Seabee.

CENOMANIAN(?) AND UPPER ALBIAN ROCKS

NINULUK(?) FORMATION AND KILLIK TONGUE OF CHANDLER FORMATION UNDIFFERENTIATED (1,820–2,400 FT)

A 75-foot interval of sandstone containing a few thin beds of shale penetrated beneath a thin black chert pebble conglomerate has been considered the base of the Seabee Formation in this well (Collins, 1959, p. 434; Bergquist, 1959b, p. 480). This sandstone, which is herein considered part of the Ninuluk Formation, is succeeded by "10 feet of siltstone, about 200 feet of clay shale with a few thin beds of sandstone, and approximately 500 feet of interbedded sandstone and clay shale" (Collins, 1959, p. 426). Part or all of the lower sequence is most likely the nonmarine Killik Tongue of the Chandler Formation. Cores yielded few fossils except in the upper part of the section (1,878–1,886 ft), where there was a flood of flattened tests of *Gaudryina* and *Trochammina* in the lowest foot of the core.

In an earlier report on the paleontology of the Square Lake test well (Bergquist, 1959b, p. 480), the Foraminifera from the core at 1,886 feet were listed as *Gaudryina canadensis* Cushman and *Trochammina rutherfordi* Stelck and Wall, and their presence was cited as evidence of the top of the Ninuluk Formation. The preservation of these fossils is very poor, however, and comparison of specimens with those of other areas indicates that identifications cannot be absolute. In fact, some of the specimens of *Gaudryina* found in ditch samples within the interval of beds of Early Cretaceous age in this well appear to be the same as those from the core at 1,886 feet. As *Gaudryina* found in the Ninuluk Formation of other areas is now referred to *G. irenensis* Stelck and Wall, those from the Square Lake well create difficulty in specific assignment, but the uncertainty of identification does not seem to merit changing the published name for another which is equally uncertain. Thus, the previous identification of *G. canadensis* has been retained on the accompanying faunal chart. Likewise, the specimens of *Trochammina* from this part of the section are listed on the faunal chart as *T. rutherfordi* as previously published, but the flattened specimens cannot be distinguished with certainty from *T. ribstonensis* Wickenden of the higher beds. Furthermore, specimens might be *T. gatesensis* Stelck and Wall of Albian age. In conclusion, in this thin zone of *Gaudryina* and *Trochammina* in the Square Lake well, the fossils are not well enough preserved to place the section positively as Cenomanian; it could even be an intertongue of marine material of Early Cretaceous age.

UPPER ALBIAN ROCKS

Between 1,896 and 2,340 feet the cores and most of the ditch samples yielded no fossils, perhaps because much of this section is a part of the nonmarine Chandler Formation of Early Cretaceous age. A sample from 2,340-2,347 feet yielded a few tests of Foraminifera that are so distorted as to be almost nondescript; presumably, they are from beds of Early Cretaceous (Albian) age. R. W. Brown (written commun., 1955) identified a plant fossil found at 2,346 feet as *Cephalotaxopsis intermedia* Hollick, and referred it to the Upper Cretaceous.

VERNEUILINOIDES BOREALIS FAUNAL ZONE (2,400 FT TO TOTAL DEPTH)

Although the *Verneuilinoides borealis* faunal zone extends through nearly 1,600 feet of section which may represent beds of the Grandstand (and possibly the Tuktu) and the Torok Formations, it is only meagerly developed in this test well, and fewer species and a much smaller number of specimens were recovered than were found in Wolf Creek test well 3 or in test wells in the Umiat area. Twelve arenaceous species and 3 calcareous species of Foraminifera are identified, but only six calcareous specimens were found. Specimens of *Verneuilinoides borealis* Tappan and *Haplophragmoides topagorukensis* Tappan are about equally numerous and together constitute 65 percent of the faunal count. *Gaudryina canadensis* is next, making up 16 percent, and *Ammobaculites wenonahae* Tappan follows, constituting about 8 percent. Specimens of the other eight arenaceous species identified are relatively few.

All the arenaceous tests recovered are flattened and distorted and have very little pyritic replacement; not even one well preserved specimen was found in any of the samples from the faunal zone. So very poorly preserved are most of the specimens, and so obscure are features such as sutures and apertures, that identification had to be made by comparing the general shape and outline of tests and chambers with those of better preserved specimens.

TITALUK TEST WELL 1

Titaluk test well 1 was drilled on the Titaluk anticline at a site 62 miles west of Umiat. Of the rocks penetrated, nearly 600 feet is of Late Cretaceous (Cenomanian) age, and most of the underlying section of more than 3,400 feet of nonmarine and marginal marine beds is of Early Cretaceous (Albian) age. Microfossils were found mostly in the upper few hundred feet of section and in most samples below the depth of 1,850 feet; the distribution and specimen count for all samples are shown in the faunal chart (pl. 22). Preservation of microfossils is relatively poor in most of the samples, and almost all specimens are crushed except a few that have been replaced by pyrite. Identification is therefore difficult, and the specimens have been subjected to recurrent examinations and comparisons. Specimens referred to *Gaudryina canadensis* Cushman in the Ninuluk Formation in the upper part of the well (Bergquist, 1959a, p. 417–418) are now considered to be *G. irenensis* Stelck and Wall, a species described from rocks of Cenomanian age in western Canada. Some specimens in the lower part of the well, however, are believed to be *G. canadensis*, which is an Albian species. Another nomenclatural change concerns the species *Trochammina rutherfordi* Stelck and Wall which was reported in both Upper Cretaceous and Lower Cretaceous rocks; some of the specimens from the Lower Cretaceous section perhaps are better identified as *Trochammina* cf. *T. gatesensis* Stelck and Wall. *T. gatesensis* was described from rocks of Albian age in Canada, but it is similar to *T. rutherfordi* in certain respects. *T. rutherfordi* is reported to be restricted to beds of Cenomanian age (Stelck and Wall, 1955, p. 57). However, to make a clear-cut distinction among the crushed specimens of *Trochammina* is difficult, and until better specimens are recovered, identifications of some of these specimens can only be approximate.

CENOMANIAN ROCKS

GAUDRYINA IRENENSIS–TROCHAMMINA RUTHERFORDI FAUNAL ZONE (40–590 FT)

This faunal zone was previously named the *Gaudryina canadensis–Trochammina rutherfordi* faunal zone (Bergquist, 1959a, p. 417), but is herein renamed to conform to determinations made in the studies referred to above. The zone includes the section identified as the Ninuluk Formation (surface? to 590 ft) and is therefore the thickest faunal zone of this age recorded for any of the test wells. The fauna consists mostly of the two species for which the zone is named, but some specimens identified as *T. ribstonensis rutherfordi* on the faunal chart may be *T. wetteri* Stelck and Wall. This form has a larger umbilical area than is found on *T. rutherfordi*. In addition, there are some biconvex, discoidal pyritic casts that are referred to as "*Zonodiscus*" sp. C. Most specimens of *Gaudryina irenensis* Stelck and Wall are light gray to light brown and are elongate, gently tapered, and flattened; collapsed chambers overlap or have the edges raised in a reticulated pattern on the surface of the test; a few specimens are pyritic and subcylindrical.

UPPER ALBIAN ROCKS

The section between 590 and 1,850 feet is largely clay shale with minor beds of sandstone and siltstone; it has been assigned to the Killik Tongue of the Chandler Formation. Presumably the age of these beds is late Albian. Scattered *Inoceramus* prisms occurred in some of the samples, and specimens of *Gaudryina irenensis* Stelck and Wall were found in ditch samples to a depth of 1,280 feet. The later are almost certainly contaminations from higher beds, even though in a sample from 870–880 feet both *G. irenensis* and *Trochammina ribstonensis* Wickenden subsp. *rutherfordi* Stelck and Wall were found in relative abundance.

MIDDLE TO UPPER ALBIAN ROCKS

VERNEUILINOIDES BOREALIS FAUNAL ZONE (1,850 FT TO TOTAL DEPTH)

Fossiliferous beds of sandstone, siltstone, and clay shale compose the *Verneuilinoides borealis* faunal zone from the depth of 1,850 feet to the total depth at 4,020 feet, but about the upper 300 feet of this zone are only sparingly fossiliferous. An analogous relationship was noted in several test wells, and this relationship may be an indication of intertonguing of marginal marine sediments with those of nonmarine origin rather than an indication of the top of the Grandstand Formation.

As some occurrences of the Foraminifera in the *Verneuilinoides borealis* zone have been summarized previously (Berquist, 1959a, p. 417–418), reference here need only be to the relative abundance of certain species as shown in the faunal chart (pl. 22) of this well. As indicated above, Lower Cretaceous specimens previously identified as *Trochammina rutherfordi* Stelck and Wall are herein referred to *Trochammina* cf. *T. gatesensis* Stelck and Wall.

Fifteen arenaceous species and 5 calcareous species constitute the entire fauna of the *Verneuilinoides borealis* zone in this well, but 5 species are known only from a single specimen or a fragment. Calcareous species occurred only in the lower part of the section penetrated, and the six specimens found constitute only about 1.4 percent of the entire fauna. Approximately 63 percent of the fauna consists of specimens of *Verneuilinoides borealis* Tappan, whereas the next most abundant species, *Haplophragmoides topagorukensis* Tappan, accounts for about 10 percent. The only other noticeable species are *Trochammina* cf. *T. gatesensis* Stelck and Wall, approximately 7 percent; *Gaudryinella irregularis* Tappan, approximately 6 percent; and *Psamminopelta subcircularis* Tappan approximately 5 percent. *Ammobaculites*, which abounds in the *V. borealis* zone of the Umiat area, is a very minor constituent of this well, as are other species of the general Tuktu faunal facies.

Preservation of the tests of the Foraminifera is invariably poor for most samples. In the upper part of the zone, specimens have a granulated surface texture which obscures to a considerable extent the outline of the chambers. In a sample from 2,150–2,160 feet, where *Verneuilinoides borealis* was particularly abundant, many of the specimens are filled with pyrite, which has preserved the normal convexity of the chambers and the subtriangular-elongate shape of the tests. The specimens not replaced by pyrite have a fine texture that reveals the chambers better than does the granulated texture of specimens from higher levels; all the specimens are somewhat compressed. A few pyritized specimens of *Gaudryinella irregularis* also retain fully expanded chambers, and presumably the original shape of the test has been preserved.

Specimens of *Verneuilinoides borealis* from below 3,500 feet are preserved much the same as those in higher beds, but the tests are small for the species. Specimens of *Haplophragmoides topagorukensis* vary in the amount of distortion they have been subjected to and in texture and general preservation; those specimens from a core at 3,657–3,674 feet are very coarse grained.

Specimens of *Ditrupa cornu* Imlay and *Balanocrinus* sp. occurred in siltstone cores from 3,550–3,560 feet and 3,674–3,679 feet. As these fossils were found only in this part of the section and as they are more characteristic of the Tuktu Formation than of the Torok Formation, I believe that the lowest 900–1,000 feet of beds penetrated are equivalent to the Tuktu Formation. Because of this correlation, I consider the entire section below 1,850 feet as Grandstand and Tuktu Formations undifferentiated, although Robinson (1959a, p. 351, 389) has separated the sequence into Grandstand Formation (1,850–3,500 ft) and Topagoruk Formation (3,500 ft to total depth).

WOLF CREEK AREA

Three test holes were drilled in 1951 and 1952 along a tributary of Wolf Creek, on the Wolf Creek anticline west of Umiat. Two shallow tests (1 and 2) may have barely penetrated the Grandstand Formation. Test well 1 (1,500 ft, total depth) started in Upper Cretaceous (Cenomanian) beds of the Ninuluk Formation, and test well 2 (1,618 ft, total depth) started in the lower part of the Upper Cretaceous (Turonian) Seabee Formation. Test well 3, drilled near test well 1, penetrated 3,760 feet of section, starting with beds in the Ninuluk Formation, about 200 feet structurally lower than similar beds in test well 2; this well was abandoned in the Torok Formation.

The Ninuluk Formation and the Killik Tongue of the Chandler Formation are the only units that are common to the three wells. The Ninuluk Formation is about 435 feet thick in test well 1; 520 feet in test well 2; and 470 feet in test well 3. The most fossiliferous section occurred in test well 3, and there the *Gaudryina irenensis–Trochammina rutherfordi* faunal zone is fairly well developed. Approximately 900 feet of more or less nonfossiliferous beds between the Upper Cretaceous *Gaudryina–Trochammina* beds and the Lower Cretaceous *Verneuilinoides borealis* faunal zone are for the most part assigned to the Killik Tongue in each well.

Approximately 2,180 feet of beds in test well 3 are considered in this report to be the Grandstand and Tuktu Formations undifferentiated, and about 180 feet of the lowest part of the section is the upper part of the Torok Formation. These beds are assigned to the Grandstand and Topagoruk Formations by Collins, who places the top of the Topagoruk Formation at 2,760 feet (Collins, 1959, p. 467).

The general fossil data from these wells have been summarized (Bergquist, 1959b, p. 480–482), but certain changes in identification of species have been made since the preliminary work was done. Specimens from the thin beds of the Seabee Formation in the uppermost part of Wolf Creek test well 2 were formerly identified as *Gaudryina irenensis* Stelck and Wall but are now referred to *Textularia* cf. *T. rollaensis* Stelck and Wall. They are compressed and poorly preserved; some are fragmented. In all three test walls the Ninuluk Formation is characterized by two Foraminifera, now identified as *Gaudryina irenensis* Stelck and Wall and *Trochammina ribstonensis rutherfordi* Stelck and Wall. These were previously referred to as *G. canadensis* Cushman and *T. rutherfordi* Stelck and Wall. In the *Verneuilinoides borealis* faunal zone of test well 3, specimens formerly identified as *Trochammina rutherfordi* are now listed as *Trochammina* cf. *T. gatesensis* Stelck and Wall on the faunal chart. Faunal charts for the three test wells are shown on plate 22.

Arenaceous Foraminifera throughout the wells are compressed and distorted, and only rare pyritized specimens retain the original shape of the tests. No calcareous Foraminifera were found in test wells 1 and 2. In test well 3, pyritized specimens of *Gaudryina canadensis* Cushman were found in a core sample from 1,525–1,528 feet, and similar specimens of *G. canadensis*, *Gaudryinella irregularis* Tappan, and *Miliammina awunensis* Tappan were found in a ditch sample from 1,955–1,965 feet. In addition, an occasional pyritized specimen of *Verneuilinoides borealis* Tappan or *Haplophragmoides topagorukensis* Tappan was found, and some very large specimens of these two species occurred in samples below 2,500 feet.

Test wells 1 and 2 penetrated only the uppermost, or declining, phase of the *Verneuilinoides borealis* faunal zone, but in test well 3 approximately 2,700 feet of section is within the zone. From that well, a total of 29 species of Foraminifera were identified from the zone; 11 species are calcareous, but altogether they make up only about 1 percent of the faunal count. *Verneuilinoides borealis* Tappan and *Haplophragmoides topagorukensis* Tappan are the most prolific species in the zone and together constitute approximately 58 percent of the fauna. Three other relatively abundant arenaceous species are: *Gaudryina canadensis* Cushman, *Gaudryinella irregularis* Tappan, and *Trochammina* cf. *T. gatesensis* Stelck and Wall, which together account for about 23 percent of the fauna. Thirteen other arenaceous species were identified, and collectively they make up less than 20 percent of the faunal count.

WOLF CREEK TEST WELL 1

Wolf Creek test well 1 was located about 1,500 feet south of the axis of the Wolf Creek anticline at lat

69°23′11″ N., long 153°31′15″ W. (Collins, 1959, p. 448–449). It penetrated 1,500 feet of rocks of Cenomanian and Albian age.

CENOMANIAN ROCKS

Gaudryina irenensis–Trochammina rutherfordi faunal zone (10–455 ft)

Rocks assigned to the Ninuluk Formation in this test are composed of nearly equal parts of clay shale and interbedded sandstone and siltstone, and a minor amount of coal. A small microfauna is composed mostly of specimens of *Trochammina ribstonensis* subsp. *rutherfordi* Stelck and Wall and fewer specimens of *Guadryina irenensis* Stelck and Wall. These species were previously recorded as *Trochammina rutherfordi* Stelck and Wall and *Gaudryina canadensis* Cushman (Bergquist, 1959b, p. 480). Tests of both species were found in less than half the samples in this well, and most specimens are flattened and rather poorly preserved. However, the fossils appear to be part of the *Guadryina irenensis–Trochammina rutherfordi* faunal zone of Cenomanian age.

UPPER(?) ALBIAN ROCKS

Killik Tongue of the Chandler Formation and intertongues of Grandstand Formation (455 ft to total depth)

Most of the section below the Ninuluk Formation is nonfossiliferous and nonmarine and represents the Killik Tongue of the Chandler Formation. One or more marine tongues of the Grandstand Formation are interbedded within the section, however, and in all probability the lowest samples represent one of these tongues. The marine tongues are indicated by a few Foraminifera of the *Verneuilinoides borealis* faunal zone in certain samples (in the core at 1,080–1,084 ft and other cores) and by *Inoceramus* prisms in a core from 865–870 feet. Glauconite in clay shale at 815–840 feet and in a siltstone core at 1,273–1,278 feet also suggests marine conditions.

Below the Ninuluk Formation this section includes about 75–80 percent clay shale; sandstone and siltstone constitute less than 20 percent. Coal is common in the clay shale, and there is some bentonite in beds between 1,293 and 1,492 feet.

Verneuilinoides borealis faunal zone

The *Verneuilinoides borealis* faunal zone of Albian age, although meagerly represented in the well, was penetrated at 1,080 feet and may occur even higher. Several flattened but fairly distinctive specimens and fragments of *Verneuilinoides borealis* Tappan were found in a core sample from 1,080–1,084 feet, and a few rather poor specimens of the same species came from ditch samples lower in the section (1,205–1,215 ft, 1,293–1,300 ft, and 1,350–1,360 ft). Inflated tests and flattened specimens of *V. borealis* were common in the two lowest microfossil samples (1,435–1,445 ft and 1,485–1,490 ft), where they were associated with poorly preserved specimens of *Gaudryina canadensis* Cushman, flattened specimens of *Trochammina gatesensis* Stelck and Wall, and a few tests of *Miliammina awunensis* Tappan. Tests of some of the *Miliammina* are pyritized and fairly well preserved.

The presence of these fossils in the nonmarine sediments indicates minor intertonguing of the upper part of the *Verneuilinoides borealis* faunal zone (Grandstand Formation) with the Chandler Formation. As interpreted by Collins (1959, p. 451), the fossiliferous samples from the bottom of the test hole may mark the upper part of the Grandstand Formation or may be from another marginal marine tongue in the Chandler Formation.

WOLF CREEK TEST WELL 2

Located on the north flank of the Wolf Creek anticline about 1¼ miles north of test well 1, this test is 213 feet lower structurally and penetrated beds of the Seabee Formation. About 25 feet of sand and gravel mantle the site of the test hole.

TURONIAN ROCKS

Seabee Formation (25–130 ft)

The drill penetrated 60 feet of clay shale and 5 feet of bentonite in the upper part of the formation, and 40 feet of siltstone in the lower part. In the first recovered sample (25–35 ft) and in four other samples below it were compressed and distorted tests of light-colored arenaceous Foraminifera. The fauna is small and includes only *Saccammina lathrami* Tappan, *Haplophragmoides rota* Nauss, and tests of an unidentified *Gaudryina*. Small flattened specimens of *Haplophragmoides rota* were common in a sample from 35–45 feet, and specimens of *Saccammina lathrami* were common at 65–75 feet. Other occurrences were rare. Most of the Foraminifera came from the clay-shale beds, but *Inoceramus* prisms were abundant in the siltstone in the lowest sample (120–130 ft). The Foraminifera are long-ranging species found throughout the Colville Group, but the general assemblage is more commonly found in outcrop samples from the lower part of the Seabee Formation than from any other part of the Colville Group. No faunal zones could be distinguished.

CENOMANIAN ROCKS

Gaudryina irenensis–Trochammina rutherfordi faunal zone (130–655 ft)

Clay shale with minor amounts of bentonite, limestone, and coal (including a 10-foot bed at 310–320 feet) account for about 67 percent of the section assigned to the Ninuluk Formation in this test hole. The rest of the section is sandstone and siltstone. The very few fossils in this part of the section are species that are indigenous to the Ninuluk Formation. Of these species, flattened tests of *Trochammina ribstonensis* subsp. *rutherfordi* Stelck and Wall were common in a sample from 130–140 feet, at the assigned top of the formation, and similarly preserved specimens were abundant in a sample from 605–615 feet. Besides these fossils, there were in the last-mentioned sample a few poorly preserved specimens that are probably *Gaudryina irenensis* Stelck and Wall; a specimen of *Saccammina lathrami* Tappan occurred in each of two other samples. Two specimens of "*Zonodiscus*" sp. C were found in a sample from 160–170 feet; *Inoceramus* prisms were found at several depths. Fragments of fish bones, mollusk shells, and pyritized sponge spicules complete the fauna. Although poorly represented, the few fossils found are part of the *Gaudryina irenensis–Trochammina rutherfordi* faunal zone of the Ninuluk Formation.

UPPER(?) ALBIAN ROCKS

Killik Tongue of Chandler Formation and Grandstand Formation (655 ft to total depth)

The section below the Ninuluk Formation is predominantly clay shale but includes minor beds of sandstone, siltstone, and coal. In the lowest part, which Collins (1959, p. 456) assigned to the Grandstand Formation, about 56 percent of the rock is clay shale. Most of this sequence is unfossiliferous. No fossils were found in the upper 675 feet, but a sample from 1,330–1,335 feet contained four large specimens of *Verneuilinoides borealis* Tappan. Two of these specimens have fairly well-inflated tests. A sample from 1,470–1,475 feet carried two broken specimens of *Gaudryina canadensis* Cushman? and a specimen of *Miliammina awunensis* Tappan. Tests of *V. borealis* and of *G. canadensis* were common in a sample from 1,545–1,550 feet. Below 1,570 feet the samples were barren. Most of the tests of the above-mentioned Foraminifera are compressed, but two specimens of *G. canadensis* from 1,545–1,550 feet are partly pyritized and inflated.

The Foraminifera suggest minor intertongues of the *Verneuilinoides borealis* zone of the Grandstand Formation with the Chandler Formation. Included in this intertonguing are the lowest beds, which Collins assigned to the Grandstand Formation.

The fossiliferous samples are considered to be a part of the *Verneuilinoides borealis* faunal zone, which has its top at 1,330 feet. The zone is poorly represented by these few species, but that is characteristic of the part of the zone that interfingers with the Chandler Formation.

WOLF CREEK TEST WELL 3

Wolf Creek test well 3, located 485 feet west of test well 1, is 30 feet lower structurally; it penetrated a much greater section of beds of Albian age as it was drilled to a depth of 3,760 feet. No cores were taken above 1,475 feet.

CENOMANIAN ROCKS

Gaudryina irenensis–Trochammina rutherfordi faunal zone of the Ninuluk Formation (30–500 ft)

About 58 percent of the rocks logged in the upper part of this test well comprises sandstone and siltstone; this percentage is somewhat higher than the relative percentage logged in test well 1. Clay shale accounts for most of the rest of the Ninuluk Formation in this well; bentonite and coal are very minor constituents.

The highest sample recovered was barren sandstone, but most of the samples below that to the base of the Ninuluk Formation carried specimens of *Trochammina ribstonensis rutherfordi* Stelck and Wall and *Gaudryina irenensis* Stelck and Wall. Flattened and rather poorly preserved specimens of *T. ribstonensis rutherfordi* were common to abundant in half of the samples down through 340–350 feet. The species is so numerous that it is by far the best representative of the *Gaudryina irenensis–Trochammina rutherfordi* faunal zone in the Wolf Creek area, and it seemingly affixes the faunal zone with certainty. Flattened specimens of *G. irenensis* were found in several samples, but only one specimen was found in more than 50 percent of the samples. *Inoceramus* prisms occurred in every sample from 130–510 feet and suggest the presence of *Inoceramus* shells, which characterize the Ninuluk Formation.

Pyritic casts of a few tests of Radiolaria in the Ninuluk beds are not listed on the faunal chart of this well. *Dictyomitra*? sp. fragment occurred at 200–210 feet, and "*Zonodiscus*" sp. C at 240–250 feet, 260–270 feet, and 480–490 feet. Some specimens of the latter were also found in ditch samples from the interval below the Ninuluk Formation in the Killik Tongue of the Chandler Formation.

ALBIAN ROCKS

Killik Tongue of Chandler Formation and Grandstand Formation (500–1,400 ft)

A large part of the interval from 500 feet to the beginning of a continuously cored section at 1,475 feet was barren. This interval is predominantly nonmarine clay shale with a lesser amount of sandstone and siltstone. In this report the section 500–1,060 feet is considered as part of the Killik Tongue of the Chandler Formation, and the section 1,060–1,400 feet as Chandler and Grandstand Formations interbedded.

A few tests of Foraminifera and pyritic casts of Radiolaria ("*Zonodiscus*" sp. C) scattered through a few ditch samples in the upper part of the section are contamination from the overlying beds of the Ninuluk Formation. A few Foraminifera of the *Verneuilinoides borealis* faunal zone were found in the interval 1,220–1,290 feet; and in a sample from 1,300–1,310 feet, tests of *Verneuilinoides borealis* Tappan and *Gaudryina canadensis* Cushman were common. Some of the tests of *V. borealis* are well preserved. The Foraminifera, though few, are indicative of marginal marine beds and of intertonguing of the upper part of the *V. borealis* faunal zone (and of the Grandstand Formation) with the nonmarine and nonfossiliferous beds of the Killik Tongue of the Chandler Formation.

Verneuilinoides borealis faunal zone (1,220 ft to total depth)

Rocks within the interval of this faunal zone include the intertongued lower part of the Chandler Formation and Grandstand Formation and the Grandstand and Tuktu Formations undifferentiated of this report. Possibly the lowest 180 feet of section, which is clay shale and claystone, may be in the upper part of the Torok Formation. Nearly 40 percent of the sequence below 1,400 feet is sandstone and siltstone, and about 60 percent is clay shale. The clay shale furnished most of the fossiliferous samples; the sandstone and siltstone beds yielded few fossils other than some mollusk shell fragments, and in the lower part a few tubes of the worm *Ditrupa cornu* Imlay.

The *Verneuilinoides borealis* faunal zone becomes very conspicuous 75 feet below the top of the Grandstand Formation as defined by Collins (1959, p. 459), where there is a marked increase in specimens. This increase in specimens continues throughout the cored section from 1,475–1,583 feet. Tests of *Verneuilinoides borealis* Tappan, *Miliammina awunensis* Tappan, and *Gaudryina canadensis* Cushman were common to abundant in several of the samples from the cored interval, and specimens of *Trochammina* cf. *T. gatesensis* Stelck and Wall were common in one sample. Scattered specimens of a few other arenaceous species were associated with the above species in a few of the samples.

An assemblage similar to that cited above occurred in a few lower cores and in ditch samples. In a core from 1,655–1,670 feet, eight arenaceous species and five calcareous species of Foraminifera were found; specimens of *Psamminopelta subcircularis* Tappan were abundant, and specimens of *Trochammina* cf. *T. gatesensis*, *Verneuilinoides borealis*, *Miliammina awunensis*, and *Gaudryinella irregularis* Tappan were common.

Below 1,670 feet the number of species was reduced, but a few occurred in relative abundance in some of the samples. *Haplophragmoides topagorukensis* Tappan was found only rarely in the upper part of the zone but increased in numbers below 1,700 feet, and was common in several samples, including the bottom-hole core. For the most part, the fauna is relatively small in the lowest 1,000 feet of section penetrated, possibly because most of the cores are largely sandstone and siltstone.

Calcareous species of Foraminifera of the *Verneuilinoides borealis* zone in this well are relatively few as only 32 specimens were found in all the samples examined. These 32 specimens represent eight species, and five of these species were from one core (1,655–1,670 feet). A total of 29 species of Foraminifera were found in the zone. Of these, two species, *Verneuilinoides borealis* Tappan and *Haplophragmoides topagorukensis* Tappan, are about equal in number and together constitute about 58 percent of the entire fauna. Three other relatively abundant species are *Gaudryina canadensis* Cushman, about 10 percent; *Gaudryinella irregularis* Tappan, about 8 percent; and *Trochammina* cf. *T. gatesensis* Stelck and Wall, about 5 percent. Thirteen other arenaceous species collectively account for a little less than 20 percent of the fauna.

Tests of the arenaceous species found throughout the *Verneuilinoides borealis* faunal zone in this well are generally brown, but a few are gray; most are compressed, and many are distorted. Some are coarsely granular and the sutures are somewhat obscured; most of these coarsely granular tests were found in the lower part of the test well. A small percentage of the specimens are pyritized, which has preserved the original shape of the test. Some of the best preserved are specimens of *Gaudryina canadensis* from a core at 1,515–1,525 feet.

KNIFEBLADE TEST WELLS, 1, 2, AND 2A

Three shallow test wells were drilled on the Knifeblade anticline, about 68 miles S. 80° W. of Umiat. Only Lower Cretaceous rocks were penetrated. These rocks have been differentiated into the Killik Tongue of the Chandler Formation and the Grandstand Formation (Robinson, 1959a, p. 397); but in this report the upper 800 or 900 feet of section in test well 1 and the upper 400 feet of section in test well 2A are regarded as an intertongue of the Grandstand Formation and the Killik Tongue, and the lower beds are considered as Tuktu and Grandstand Formations undifferentiated. Microfossils from these wells have been summarized (Bergquist, 1959a, p. 418–419). The distribution and specimen counts are shown on the faunal charts (pl. 22).

VERNEUILINOIDES BOREALIS FAUNAL ZONE

Presumably each well is entirely within the *Verneuilinoides borealis* faunal zone. No Radiolaria were found, and the fauna is limited to a few species of Foraminifera, most of which are arenaceous forms. Tests of the arenaceous species are for the most part crushed and, as a result, are sometimes distorted; most are dark colored. In scattered samples, a few pyritized specimens of *Verneuilinoides borealis* Tappan have preserved the original shape of the tests, and in two or three samples exceptionally large specimens of *V. borealis* were found.

Twelve species of Foraminifera were found in test well 1, and of these, 3 arenaceous species make up about 83 percent of the fauna. The three species are *Verneuilinoides borealis* Tappan, more than 54 percent; *Haplophragmoides topagorukensis* Tappan, nearly 15 percent; and *Miliammina awunensis* Tappan, more than 12 percent. Three calcareous species make up only about 3 percent of the fauna.

Sixteen species of Foraminifera were found in test well 2A. Seven of these are calcareous, but they make up only about 6 percent inasmuch as the fauna is dominated by *Verneuilinoides borealis* (nearly 45 percent) and *Haplophragmoides topagorukensis* (over 16 percent). *Miliammina awunensis* and *Trochammina* cf. *T. gatesensis* Stelck and Wall each make up about 9 percent of the specimens recorded. Fragmented specimens of *Ammobaculites wenonahae* Tappan are about 4 percent of the fauna; this species is much less abundant than it is in the Umiat field. Its presence, however, along with tubes of *Ditrupa cornu* Imlay and ossicles of *Balanocrinus* sp., suggests the Tuktu faunal facies, as this foraminifer and the two megafossils mentioned either did not occur in outcrop samples of the Grandstand Formation or were found very sparingly.

Specimens of *Trochammina* found in test wells 1 and 2A were cited as *T. rutherfordi* Stelck and Wall in the preliminary summary (Bergquist, 1959a, p. 418) but are now listed as *Trochammina* cf. *T. gatesensis* Stelck and Wall (pl. 22).

GRANDSTAND TEST WELL 1

Grandstand test well 1 was drilled on the Grandstand anticline, at a site on the west side of the Chandler River about 30 miles south of Umiat. Beneath about 90 feet of Recent or Pleistocene (?) sand and gravel, rocks of Early Cretaceous (Albian) age were penetrated to the total depth (3,939 ft). Clay shale is the predominant rock found in this well, but above 1,100 feet about a third of the section is sandstone. Some carbonaceous plant remains and a few microfossils occur in the upper beds, but most of the microfossils were found in samples below 1,200 feet.

Detailed lithologic descriptions of the rocks and samples from this well have been published (Robinson, 1958a) as has a brief discussion of the paleontology (Bergquist, 1958d, p. 337–338). A complete tabulation of the microfossils identified from this test well is given on the accompanying faunal chart (pl. 22).

MIDDLE TO UPPER ALBIAN ROCKS

VERNEUILINOIDES BOREALIS FAUNAL ZONE (227 FT TO TOTAL DEPTH)

Almost the entire well is within the *Verneuilinoides borealis* faunal zone; the extent of the zone and the general range of formations involved are indicated in the faunal chart. Rocks from about 125 to 1,770 feet are referred to the Grandstand Formation; minor interbeds of the Killik Tongue of the Chandler Formation occur in the upper part. Rocks from about 1,770 to 2,712 feet are considered to be the Tuktu Formation; below that the rocks are part of the Torok Formation.

Fossils were found in only about 29 percent of the samples from the Grandstand Formation. In general, only a few fossils occurred in each sample, but in one sample (core at 619–629 ft) Foraminifera were numerous, and six species were common to abundant. Fourteen species of Foraminifera were found within the Grandstand, but about 58 percent of the fauna is composed of: *Verneuilinoides borealis* Tappan, 23 percent; *Haplophragmoides topagorukensis* Tappan, 18 percent; and *Gaudryina canadensis* Cushman, over 16 percent.

Although 26 species constitute the *Verneuilinoides borealis* fauna in its entirety in this well, 5 species make up 93.5 percent of the faunal count. These five species are as follows: *Haplophragmoides topagorukensis* Tappan, 40 percent; *V. borealis* Tappan, 26 percent; *Ammobaculites wenonahae* Tappan, 17 percent; *Gaudryina nanushukensis* Tappan, 5.7 percent; and *Trochammina gatesensis* Stelck and Wall?, 4.7 percent. Only 10 calcareous species were found, and together these constitute 2 percent of the faunal count.

The preservation of Foraminifera in this well varies. Many of the specimens are flattened and distorted, but pyritized specimens retain the normal test shape. In the Grandstand Formation, pyritic specimens of *Miliammina awunensis* Tappan were found in the first fossiliferous sample (227–235 ft), and nicely preserved pyritized tests of *Siphotextularia*? *rayi* Tappan, *Verneuilinoides borealis* Tappan, *Miliammina awunensis* Tappan, and *Gaudryina canadensis* Cushman were found in the very fossiliferous core from 619–629 feet.

In the latter sample the pyritic tests of *G. canadensis* are particularly good and show the cylindrical shape, inflated chambers, and distinct sutures, features that are generally obscured on the flattened nonpyritized tests.

The small fauna from the samples of the Grandstand Formation is virtually the same as the restricted fauna of the *Verneuilinoides borealis* zone found in the outcrop samples (pl. 13) of the Grandstand Formation and its interbeds with the Killik Tongue. Comparison of the fauna of the Grandstand Formation in Grandstand test well 1 with the large fauna of the *V. borealis* zone found in the Tuktu and Torok Formations indicates that several species from the Grandstand Formation that are diagnostic of the Tuktu Formation and the upper part of the Torok Formation are conspicuously absent. A further comparison of the fossils from the Grandstand Formation of this well with the fauna from other subsurface sections which have been referred to the Grandstand Formation by other authors suggests that not much of the Grandstand Formation is represented in the subsurface of northern Alaska. For example, in the Umiat field, most of the section referred to the Grandstand Formation by Collins (1958a) carries a much larger fauna than do the outcrop areas and the Grandstand Formation of Grandstand test well 1. Likewise, the Umiat section has numerous Foraminifera which are indicative of a Tuktu faunal facies—that is, Foraminifera that do not range into the Grandstand Formation. There is, for example, *Trochammina umiatensis* Tappan, which is a very diagnostic fossil in the Umiat field; it can be traced from well to well but does not occur in the Grandstand well. *Ammobaculites wenonahae* Tappan is common in the same section of the Umiat field, but occurs only in the shale beds underlying the Grandstand Formation in the Grandstand well. *Ammobaculites fragmentarius* Cushman, which appeared about 90–100 feet below the top of the section designated as Grandstand Formation by Collins in the Umiat field, was not identified anywhere in the Grandstand well, but it is possible that some of the broken specimens of *Ammobaculites* might be *A. fragmentarius* instead of *A. wenonahae*, the species to which they have been referred. Specimens of *Ditrupa cornu* Imlay commonly occurred within 100 feet of the top of the Grandstand Formation of Collins in the Umiat wells, but in the Grandstand well they appeared first in the lower part of the Grandstand Formation and were found in cores down to at least 1,949 feet.

The above-mentioned faunal differences between the Grandstand Formation of outcrop and that of the Grandstand test well and the sections referred to the Grandstand Formation in the subsurface of most other wells in northern Alaska are cited here as some of the reasons why the youngest Lower Cretaceous beds in most of the wells have a Tuktu faunal facies and seem to be in part equivalent to the Tuktu Formation.

The largest concentration of Foraminifera of the entire well occurred within the interval 1,200–2,000 feet in beds referred to the Tuktu Formation. In contrast to this concentration, the cores below 2,000 feet were barren or contained few Foraminifera other than two common occurrences of *Trochammina gatesensis* Stelck and Wall?. In the ditch samples in the same interval were numerous Foraminifera—especially *Haplophragmoides topagorukensis* Tappan—which were probably introduced as drilling contamination. Of the few species of the *Verneuilinoides borealis* zone found in the shale section of this well, *H. topagorukensis* and *V. borealis* Tappan were the most prevalent, and they were common or abundant in many samples. Specimens of these two species are relatively small in the upper part of the section, and the tests of *H. topagorukensis* look much like tiny grains of brown sand; tests of *V. borealis*, however, are fairly well preserved and are subtriangular in cross section. Below 1,757 feet, the specimens are larger and specimens with fairly well developed physical characteristics were found in the cores from 1,835–1,855 feet and 1,923–1,930 feet. Preservation of fossils is poor in samples from 1,930–1,957 feet, but fairly good specimens were found in the core at 1,957–1,971 feet.

Specimens of *Gaudryina nanushukensis* Tappan were found through 1,800 feet of beds beginning in a ditch sample at 1,570–1,580 feet, where two small specimens occurred. Specimens vary as to size and preservation, but the black manganese oxide particles that mottle the surface of the tests distinguish the species even if the shape is distorted.

Calcareous species of Foraminifera occurred rarely throughout the shale section and they make up only a very minor component of the *Verneuilinoides borealis* fauna in this well. Most frequently present were *Lenticulina macrodisca* (Reuss), *Eurycheilostoma grandstandensis* Tappan, and *Conorboides umiatensis* (Tappan); the most numerous was *Globorotalites alaskensis* Tappan. Seven specimens of *G. alaskensis* were found in a core at 1,751–1,757 feet, and five specimens were found in a core at 1,957–1,971 feet.

In the lowest part of the well, the few Foraminifera found in the cores 3,730–3,740 feet and 3,902–3,939 feet are so poorly preserved that specific identifications are questionable, and most species of the *V. borealis* faunal zone were sparse or absent.

In addition to Foraminifera, a few incomplete shells of pelecypods and an ammonite were found scattered through several of the cores of the section from 1,275 feet through 2,420 feet. These have been tentatively identified by Imlay (1961, p. 37) as follows: *Arctica* sp. (1,275 ft), *Modiolus*? sp. (1,276 ft), *Panope* sp. (1,288 ft), *Psilomya*? sp. (1,279 and 1,606 ft), *Entolium* sp. (1,417 ft), *Cleoniceras*? sp. (1,600 ft), *Thracia* cf. *T. kissoumi* McLearn (1,606 and 2,017 ft), *Inoceramus* sp. (1,607 and 2,210 ft), *Solecurtus*? *chapmani* Imlay (1,926 ft), *Yoldia kissoumi* McLearn (2,413 ft), and *Thracia* sp. (2,420 ft). Some of these are indicative of middle to late Albian age.

THE UMIAT OIL FIELD

The Umiat field is on an east-trending anticline, about 10 miles long and 3 miles wide, north and west of the Colville River. Rocks of Late Cretaceous age crop out along the flanks of the structure, but near the apex along Bearpaw Creek, there are a few exposures of rocks of Early Cretaceous (Albian) age. The structure, which has more than 800 feet of closure, was tested by 11 wells; most of these were shallow tests, but the first two were drilled to more than 6,000 feet, and they penetrated a thick shale sequence of the Torok Formation.

Micropaleontologic studies on the first three wells were made prior to 1950, but some samples were subsequently rewashed and studied later during the drilling of test wells 4–11. A sample of each core was prepared for microfossil inspection unless a core was composed entirely of sandstone; generally every alternate 10-foot interval of ditch samples was examined.

The relative count of fossils is shown for each Umiat well on plate 23. The lower parts of test wells 1 and 2 indicate considerable contamination from higher levels, possibly due to caving beds of the Nanushuk Group while the wells were being drilled or to the circulating drilling mud. For this reason, many of the samples that were obviously contaminated have not been included in the charts but the few that have been plotted are designated as contaminated.

The youngest Upper Cretaceous rocks were found in test well 11, on the north flank of the structure, where more than 500 feet of nonmarine and shallow marine sediments of probable Senonian age were penetrated. In six of the test wells (1, 6, 7, 8, 10, and 11), Upper Cretaceous rocks of Turonian age were found. All the wells penetrated formations of Early Cretaceous (Albian) age. In test wells 1 and 2, the Lower Cretaceous beds of Albian age were from 5,000 to 6,000 feet thick, and the wells were abandoned in these rocks.

A comprehensive report has been published (Collins, 1958a) on data from the test wells and on the rocks penetrated; included in it are micropaleontologic studies (Bergquist, 1958a) of individual wells. The micropaleontology of the field is herein reviewed on a regional basis, and a few species names are revised.

UPPER CRETACEOUS ROCKS

TULUVAK TONGUE OF THE PRINCE CREEK FORMATION AND LOWER PART OF SCHRADER BLUFF FORMATION (SENONIAN)

The youngest sedimentary rocks logged in the Umiat wells are predominantly nonmarine beds penetrated only in Umiat test well 11 (pl. 16), located on the northeastern part of the Umiat structure. The well cut approximately 547 feet of nonmarine sandstone and siltstone beds of the Tuluvak Tongue of the Prince Creek Formation interfingered with a few thin beds of fossiliferous shallow-water marine shale of the lower part of the Schrader Bluff Formation. One ditch sample (420–430 ft) from the latter formation carried a few crushed and distorted specimens of three arenaceous species of Foraminifera. The Schrader Bluff Formation has been assigned a Senonian age by Mrs. Loeblich (Tappan, 1951b; 1960, p. 281). Jones and Gryc (1960, p. 153) suggested a middle Senonian age, probably Santonian to early Campanian.

SEABEE FORMATION (TURONIAN)

Beneath the Tuluvak Tongue are marine shale and sandstone beds of the Seabee Formation; these extend over most of the Umiat structure except along the crest south of the main (east-west) fault. A complete section of 1,495 feet of the Seabee Formation was penetrated in test well 11; the upper 200 feet of shale carried common to abundant specimens of *Haplophragmoides rota* Nauss, common *Arenobulimina torula* Tappan, a few specimens of two species of *Trochammina*, and fragments of *Pseudoclavulina hastata* (Cushman). *P. hasta* is limited to this part of the section and along with *Arenobulimina torula* distinguishes this as the *Pseudoclavulina-Arenobulimina* faunal zone, correlative with that characteristic of the shaly section of the Ayiyak Member of the Seabee Formation. However, the Ayiyak Member is recognized only in the area of outcrop to the south of Umiat, and because of lithologic differences the name of the member has not been applied in the Umiat area.

The Seabee Formation underlying the *Pseudoclavulina* beds in test well 11 is virtually barren of microfossils. About midway in the section were prints of a very small, compressed, unornamented discoidal

Turonian ammonite (*Borissiakoceras ashurkoffae* Cobban and Gryc) that is diagnostic of this part of the Seabee Formation. *Inoceramus* shell fragments were found at a few intervals, and discoidal and spherical white tests of two species of Radiolaria came from samples about midway in the section. In a core in the lower part of the formation, three arenaceous species of Foraminifera and one calcareous species were common to abundant.

The lower 350 feet of the Seabee Formation in test well 11 has only an occasional fossil, whereas in certain outcrop areas the lower 100–300 feet of the Seabee Formation carries numerous specimens of three species of arenaceous Foraminifera. Presumably these beds are represented in test well 11 in the core at 1,670–1,680 feet; but elsewhere in the Umiat field the lowest fossiliferous beds of the outcropping Seabee Formation are absent or, if present, are devoid of fossils.

In test well 1 at the west end of the structure, the upper fossiliferous beds of the *Pseudoclavulina-Arenobulimina* faunal zone are missing from the 915-foot section of the Seabee Formation. Scarcely any fossils were found in the upper 300 feet, but *Inoceramus* prisms occurred in several samples; and shells of *Inoceramus* cf. *I. labiatus* Schlötheim were found in cores from 336–447 feet. These specimens have closely spaced plications which are not as typical of *Inoceramus labiatus* as they are of the Cenomanian species *I. pictus* Sowerby from the Lower Chalk of England and *I. prefragilis* Stephenson from the Woodbine (Cenomanian) of Texas.

Casts of *Borissiakoceras ashurkoffae* were found in cores from 377–417 feet in test well 1, but the occurrence was a little lower in the section than in test well 11. About midway in the section, a few Foraminifera and Radiolaria were found.

In four other test holes in the Umiat field, only the lower part of the Seabee Formation was penetrated. On the south flank of the structure, near the Colville River, test well 6 penetrated 220 feet of the Seabee Formation and test well 7 penetrated 390 feet. The Seabee Formation may not exceed 350 feet in thickness in test well 8, drilled on the crest of the structure; but in test well 10, about 670 yards to the west, 435 feet of the same section was found. *Inoceramus* shell fragments were present in each of these wells in the Seabee Formation, but microfossils were rare except for elongate, triserial, specimens of *Neobulimina albertensis* (Stelck and Wall) in each well. This calcareous foraminifer apparently is most common in the basal or near basal part of the Seabee Formation, as it is present in this position in test wells 1, 8, and 10.

CENOMANIAN(?) ROCKS

In her discussion of the lithologic data of the Umiat test wells, Collins (1958a, p. 74) indicate that the Ninuluk Formation (Cenomanian) is represented by about 100 feet of sandstone and 20 feet of shale over much of the Umiat field. In most of the Umiat wells, the faunal evidence for assigning this part of the section to the Ninuluk Formation is extremely meager as only a few arenaceous or pyritized Foraminifera were found; these Foraminifera were found in two samples in test well 6 and in two samples in test well 10. Most of the specimens belong to the genus *Trochammina*, but two or three other genera are represented. Seemingly the *Trochammina* are similar to species that occur in the Ninuluk Formation elsewhere, but they are also similar to forms in the Seabee Formation. Most of the specimens are badly crushed, making identification difficult and questionable; therefore, it is not certain that these fossils are a part of the *Gaudryina-Trochammina* zone characteristic of the Ninuluk Formation.

LOWER CRETACEOUS (ALBIAN) ROCKS

Immediately beneath the thin sequence which has been referred to the Ninuluk Formation are sandstone and shale of Early Cretaceous age. About 260–280 feet of the section is largely nonfossiliferous and is regarded by Collins (1958a, p. 74) as part of the Killik Tongue of the Chandler Formation; the base is placed at the first occurrence of microfossils near the top of a massive sandstone. The succeeding 660–670 feet of strata, which are in part fossiliferous, have been assigned to the Grandstand Formation (Collins, 1958a, p. 74). This interval consists of two beds of massive to thinly bedded marine sandstone separated by clay shale. The *Verneuilinoides borealis* zone of Albian age extends throughout this unit and into a thick shale sequence below.

Although a virtually uniform thickness has been ascribed to the Killik Tongue in the Umiat area, the base commonly has been taken at the first occurrence of microfossils of the *V. borealis* zone above the massive sandstone. In some of the wells, however, this first occurrence is succeeded by seemingly nonfossiliferous sections of a few feet to 50 or 75 feet thick. This situation suggests continuity of the entire sequence—of shallow marine beds interfingering and grading into a nonmarine facies. Rather than attempt to establish formation limits for the sequence, the beds down to the first massive sandstone are herein regarded as the Chandler Formation. The underlying sandstone and shale sequence is considered to be undifferentiated

Grandstand and Tuktu Formations, instead of only the Grandstand.

VERNEUILINOIDES BOREALIS FAUNAL ZONE

The *Verneuilinoides borealis* faunal zone was penetrated in each test well of the Umiat field, but the entire zone is represented only in test wells 1 and 2, where the fauna is most prolific and abundant. As compared to the number of species in the fauna of the *V. borealis* zone in the coastal wells, however, the number of species in the zone in the Umiat area is smaller, calcareous Foraminifera being few. In test wells 1 and 2, the fauna is mainly composed of numerous specimens of arenaceous Foraminifera and relatively few specimens of calcareous species. Of 22 arenaceous species and 21 calcareous species that have been identified, 5 arenaceous species outnumber the others. In order of abundance these five species are: *Haplophragmoides topagorukensis* Tappan, *Verneuilinoides borealis* Tappan, *Ammobaculites wenonahae* Tappan, *Ammobaculites fragmentarius* Cushman, and *Gaudryina nanushukensis* Tappan; together, they make up nearly 80 percent of the specimens found, and *H. topagorukensis* alone accounts for nearly 50 percent of the specimens.

Only a few species of Foraminifera occur in the uppermost part of the *V. borealis* zone, and they seemingly are representative of the last stages of a dwindling Albian fauna in the marginal marine sediments. In much of the rest of the zone, however, the fauna is larger and has distinctive species that do not occur in the highest beds. Within the upper part of the faunal zone, but a few hundred feet below the top, three species of arenaceous Foraminifera occur at horizons that can be traced in each well; these horizons aid in defining the structure of the field (pl. 16). The highest stratigraphic marker species is *Ammobaculites fragmentarius* Cushman, which has a small initial whorl and relatively long stage of uniserial chambers. Stratigraphically lower is *Ammobaculites wenonahae* Tappan; this has a much larger initial whorl than does *A. fragmentarius* and only four or five broad chambers in the uniserial stage. A little lower, or appearing with *A. wenonahae*, is *Trochammina umiatensis* Tappan, a distinctive trochoid species that has, in the last whorl, four large *Globigerina*-like chambers that are greatly enlarged as compared with small chambers of the closely coiled initial area. *T. umiatensis* seems to be limited to about 100 feet of the section of the *V. borealis* zone in most of the wells in the Umiat field.

Preservation of the Foraminifera is generally poorer in the Umiat wells than in the coastal area wells unless specimens are replaced by pyrite. Arenaceous forms are prevailingly dark brown as opposed to the light-gray to white specimens in the northern wells. Most calcareous specimens in the Umiat wells are also stained a dark color or are partially pyritized, whereas they are light colored in the northern wells. The majority of arenaceous specimens from the Umiat wells are crushed and distorted, and to identify them necessitates careful examination of individuals and frequent cross checking against the variety of shapes that specimens of the same species can have. If only a few specimens were found and if they were greatly distorted or broken, only a questioned identification could be made. Generally the chambers of arenaceous specimens that are filled with pyritic material have withstood collapse and distortion.

In some of the test wells, particularly in 3, 4, 5, and 6, most of the specimens were crushed and distorted or were of erratic occurrence. In test holes 7, 8, 9, 10, and 11, however, specimens were crushed and distorted in samples from the upper beds but were fairly well preserved in the lower beds.

Some species show a range in size. Tests of *Haplophragmoides topagorukensis* Tappan range from rounded involute to flattened and twisted specimens; the diameter of the latter ranges from 0.3 mm to 1 mm, but the average diameter is about 0.6 mm. *Verneuilinoides borealis* Tappan ranges from small wedge-shaped flattened specimens, 0.3 mm in length, to large specimens, 0.6 mm to 0.75 mm in length. The chambers are not very distinct on small specimens but may be excellently outlined on the larger ones, and in tests that have been filled with pyrite the original shape of the inflated chambers is retained. Most of the specimens of *Psamminopelta subcircularis* Tappan, *Miliammina awunensis* Tappan, and *Miliammina manitobensis* Wickenden are flattened or laterally compressed, but the original shape is preserved in pyritic specimens at certain intervals. Probably more tests of *Ammobaculites fragmentarius* Cushman and *A. wenonahae* Tappan are broken than are complete, and the uniserially chambered segments are more abundant than the initial coiled parts. Unbroken specimens of these two species, however, have less apparent distortion than do other arenaceous forms. The narrow elongate tests of *Gaudryina canadensis* Cushman are generally flattened with chambers overlapped, but the few that are pyritic have undistorted chambers and a tapered cylindrical shape.

Specimens of *Trochammina umiatensis* Tappan are distinctive enough that even flattened tests can be recognized; one side has four large chambers, whereas the trochoid spire has only small chambers. (See fig. 37.)

Tuktu and Grandstand Formations undifferentiated

Only a few species of Foraminifera—usually *Verneuilinoides borealis* Tappan, *Psamminopelta bowsheri*

Tappan, *P. subcircularis* Tappan, *Miliammina awunensis* Tappan, *Gaudryina canadensis* Cushman, and *Trochammina gatesensis* Stelck and Wall—occur in the uppermost 100 or more feet of the *V. borealis* zone in each well in the Umiat area. Below this consistently faunally restricted part, however, the sandstone and shale sequence has a larger fauna composed of such species as *Ammobaculites fragmentarius*, *A. wenonahae* Tappan, and *Trochammina umiatensis* Tappan, species which have never occurred in the highest beds of the zone nor have been found in the samples studied from outcrop beds of the Grandstand Formation. In addition, *Haplophragmoides topagorukensis* Tappan occurs in abundance in most of the sandstone and shale unit, but is rare or absent in the uppermost beds of the *V. borealis* zone in each of the Umiat wells and is extremely rare in outcropping beds of the Grandstand Formation. In outcrop samples of the Tuktu Formation, *H. topagorukensis* occurs in abundance along with species of *Ammobaculites*. Thus most of the Grandstand Formation of Collins in the Umiat wells seems to be equivalent to the Tuktu Formation of the outcrop because most of the beds carry the fauna characteristic of that part of the Nanushuk Group, and only the sparingly fossiliferous beds in the uppermost part of the Umiat wells seems to be faunally equivalent to beds in the Grandstand Formation.

A few good horizon markers occur in the Tuktu faunal facies of the *Verneuilinoides borealis* zone. Highest stratigraphically (pl. 16) is *Ammobaculites fragmentarius* Cushman, which was found in most of the wells at a depth of 95–110 feet below the top of the *V. borealis* zone but which was absent in this position in test well 1. *Ditrupa cornu* Imlay, a smooth-shelled worm tube, commonly appears at about the same horizon as *A. fragmentarius*. Specimens of *Ammobaculites wenonahae* Tappan occur between 245 and 285 feet below the top of the zone. From 275 to 335 feet below the top of the zone were the first specimens of *Trochammina umiatensis* Tappan, whose restricted occurrence within a vertical range of about 100 feet in most of the wells makes it an excellent horizon marker. It occurred with *A. wenonahae* in Umiat test well 1 in cores from 1,625 through 1,651 feet and is present in a core more than 700 feet lower, owing to duplication of beds by a fault.

The zone of *Trochammina umiatensis*, in association with common specimens of *Ammobaculites wenonahae*, *Haplophragmoides topagorukensis* Tappan, and *Verneuilinoides borealis* Tappan, seems to be repeated in two other wells, possibly due to minor faulting of the sections. In test well 9 the top occurrence of *T. umiatensis* is in a core at 669 feet. This species and associated fauna are repeated in cores from 1,187–1,218 feet. A less probable suggestion of faulting in the Tuktu Formation is indicated in test well 11, where *T. umiatensis* and associated Foraminifera appeared first in a ditch sample at 2,730–2,740 feet, were common in samples from 2,750–2,800 feet, and were repeated in ditch samples beginning at 3,210 feet, about 410 feet lower.

Besides their value in structural control in the subsurface of the Umiat field, the key fossil horizon markers are of interest in that they appear approximately between the two oil producing sandstone beds. *Inoceramus* prisms are scattered in many samples from the Tuktu-equivalent beds in the Umiat wells and, along with fragmentary tubes of *Ditrupa cornu*, indicate that the *Inoceramus-Ditrupa* subzone of the *Verneuilinoides borealis* faunal zone of the Arctic coastal test holes is meagerly developed in the Umiat area. Mashed shells of *Corbula*? sp. were abundant in cores at 1,703–1,723 feet in test well 1 and at 838–845 feet in test well 9.

Shale sequence (upper part of Torok Formation)

In the lower part of the *Verneuilinoides borealis* faunal zone in the Umiat wells, the section is predominantly clay shale and underlies the lowest thick sandstone of the Tuktu Formation. This section was referred to the Topagoruk Formation by Collins (1958a, p. 75), but it is considered to be the upper part of the Torok Formation in this report. It was found only in test wells 1, 2, and 11. Approximately 2,800 feet of the upper part of the Torok Formation was penetrated in test well 1; but the lower 1,400 feet was not cored, and the ditch samples from that interval were greatly contaminated. In test well 2 the measured thickness is about 3,640 feet because the beds are repeated by at least one fault of more than 500 feet displacement that cuts the section at 2,400 feet. At least 600 feet of fossiliferous beds seem to recur below a depth of 5,580 feet, below beds of the probable lower part of the Torok Formation, and their presence suggests another fault. In test well 11, only the upper 200 feet of the Torok Formation was penetrated.

Although the fauna of the upper part of the Torok Formation of most areas is similar to that of the Tuktu Formation except for the latter's horizon markers, it is not well represented in the Umiat area. The only fossils really diagnostic of the upper part of the Torok Formation are *Gaudryina nanushukensis* Tappan and *Gastroplites* sp., an Albian ammonite. The former extends through the lower ½–⅔ of these beds in test wells 1 and 2, whereas imprints of the ammonite were found in test well 2 at 2,148 feet and at 2,634 feet. Specimens of *G. nanushukensis* are conspicuous because they are roughly triangular in cross section and because they have low broad chambers and black specks of manganese oxide along the sutures or mottling the surface of the slightly concave sides. Small specimens (0.35–0.5 mm in length) show only the triserial stage and a wide apertural end; larger specimens (0.9 mm or more in length) are biserially terminated and are narrower at the apertural end than at the last of the triserial stage. *Haplophragmoides topagorukensis* and *Verneuilinoides borealis* are the only species of Foraminifera found in any abundance; these were mainly scattered through a few cores in the upper part of the beds. Flattened and broken specimens of the tubular *Bathysiphon vitta* Nauss?, which is rare or absent in the upper part of the *V. borealis* zone, is a conspicuous species in the Torok Formation in some wells.

LOWER PART OF THE TOROK FORMATION

The two deep tests in the Umiat field were the only wells which penetrated the lower part of the Torok Formation. About 335 feet of shale in test well 1 and about 400 feet of shale in test well 2 probably represent the lower part of the Torok Formation. These beds were previously referred to the Oumalik Formation by Collins (1958a, p. 76–100) and by me (Bergquist, 1958a, p. 200–201); but because there is very little difference between the shale in this part of the section and that higher in the wells, there seems to be no need to recognize a separate formation. Foraminifera of the *Verneuilinoides borealis* faunal zone were found in the ditch samples as contamination from the upper beds, but a few poorly preserved pyritic casts of a fusiform radiolarian (*Lithocampe*? sp.) were found; this radiolarian is a characteristic fossil of the lower part of the Torok Formation. The radiolarian casts were found in test well 1 in samples from 5,790–5,830 feet and from 5,880–5,890 feet. In test well 2, they were found in scattered ditch samples at 4,840–4,850 feet and 4,960–4,970 feet and as contamination in lower beds. In test well 2 the beds below 5,100 feet are underlain by fossiliferous beds of the upper part of the Torok Formation brought into place by a fault.

UMIAT TEST WELL 1

Umiat test well 1 was drilled near the west end of the structure between two branches of Seabee Creek, at a point now known to be about 5 miles west and several hundred feet below the apex of the anticline. It penetrated both Upper and Lower Cretaceous rocks and bottomed at 6,005 feet in a thick shale sequence. Continuous coring was done in the upper part of the well. This coring started at 31 feet and continued to 1,816 feet with very few breaks, the largest break being an uncored section from 1,474–1,615 feet.

SEABEE FORMATION (TURONIAN) (9–915 FT)

Beds of the Seabee Formation extend from the surface of the well to a depth of 915 feet and are predominantly clay shale, but sandstone makes up more than half of the upper 250 feet. Beds above 350 feet are virtually devoid of fossils. Somewhat lower, however, a small subspherical radiolarian, *Cenosphaera* sp. A, was abundant; two other Radiolaria, *Spongodiscus* sp. and *Dictyomitra* cf. *D. multicostata* Zittel, were common, the latter as pyritic conical casts that have deep transverse septal strictures and fine longitudinal ribs.

Inoceramus prisms occurred in several cores, and shell fragments of *Inoceramus* cf. *I. labiatus* Schlötheim and casts of *Borissiakoceras ashurkoffae* Cobban and Gryc were found in the upper half of the section. Large fish scales (*Tissotia* sp.) nearly an inch in diameter came from a core in this interval, and fishbone fragments occurred in many samples in the power part.

About midway in the Seabee Formation specimens of arenaceous Foraminifera (*Saccammina lathrami* Tappan?, *Textularia* sp., *Trochammina diagonis* (Carsey), and *T. whittingtoni* Tappan) were common to abundant, and a spherical radiolarian (*Cenosphaera* sp. B) was common in one sample. The specimens of *S. lathrami*? are gray to white, and although some are of normal size for this species, others are very small discoidal objects that resemble the radiolarian *Spongodiscus*. All specimens of *T. whittingtoni* are distorted, but the species is distinctive because of its numerous chambers and because it is the largest species (as much as 0.15 mm diameter) of *Trochammina* found in the Colville Group. Specimens of *Textularia* sp. in this well were previously referred to *Gaudryina irenensis* Stelck and Wall (Bergquist, 1958a, p. 200), but on later examination with higher magnification, they do not appear to be triserial in the initial stage. The specimens are poorly preserved, however, being both compressed and distorted or having a granular surface texture that obscures much of the sutures. Most are very narrow at the initial end but flare out rather rapidly.

Two calcareous species (*Praebulimina seabeensis* Tappan and *Neobulimina albertensis* (Stelck and Wall)) were common in two cores in the lower third of the Seabee Formation.

NONFOSSILIFEROUS ROCKS

Between the base of the Seabee Formation and the top of the *Verneuilinoides borealis* zone the section is virtually nonfossiliferous and consists of about one-third sandstone and siltstone and two-thirds clay shale. One hundred and fourteen feet of core was taken in the interval. Except for a few charophyte oogonia in ditch samples, the section was barren. The beds have been differentiated as Ninuluk Formation (915–1,010 ft) and Killik Tongue of the Chandler Formation (1,010–1,305 ft) by Collins (1958a, p. 76) on the basis of lithologic studies.

VERNEUILINOIDES BOREALIS FAUNAL ZONE

The *Verneuilinoides borealis* faunal zone of Albian age begins at about 1,295–1,305 feet and extends through at least 2,900 feet of sandstone and shale. Cored sections indicate that fossiliferous beds alternate with barren beds, but fossils occurred in nearly all the ditch samples, owing to transport by circulating mud.

The *Verneuilinoides borealis* faunal zone extends through an upper predominantly sandy shale and sandstone unit (Tuktu and Grandstand Formations undifferentiated) from about 1,300 to 2,850 feet and a section of marine shale (the upper part of the Torok Formation). The extent of the *V. borealis* zone in the Torok Formation is unknown because of lack of core samples below 4,204 feet, but it continues through that depth.

The *Verneuilinoides borealis* fauna in test well 1 consists of 43 species, of which 22 are agglutinate forms and 21 are calcareous. Nine arenaceous species make up 94 percent of the specimens. In order of abundance these nine species are *Haplophragmoides topagorukensis* Tappan, *Verneuilinoides borealis* Tappan, *Gaudryina canadensis* Cushman, *Ammobaculites wenonahae* Tappan, *Ammobaculites fragmentarius* Cushman, *Miliammina awunensis* Tappan, *Psamminopelta subcircularis* Tappan, *Psamminopelta bowsheri* Tappan, and *Gaudryina nanushukensis* Tappan. The last-mentioned species is confined to the Torok Formation in this well. *H. topagorukensis* and *V. borealis* together constitute 54 percent of the faunal count of specimens shown on the chart (fig. 28).

Tuktu and Grandstand Formations undifferentiated (1,300–2,850 ft with fault duplication)

In a continuously cored section of beds in the upper sandy shale and sandstone unit of the *Verneuilinoides borealis* zone, fossiliferous beds alternate with unfossiliferous, and significant faunal changes occur. In the highest part (through 1,474 feet), the fauna is small and only eight species were found. Of these *Verneuilinoides borealis*, *Psamminopelta bowsheri*, *P. subcircularis*, *Miliammina awunensis*, and *Gaudryina canadensis* each were present in some degree of abundance in one or more samples.

Within the next continuously cored section (1,615–1,816 ft), the beds were all fossiliferous except for an interval of about 60 feet. A marked change occurs in the fauna with the appearance of species that are not found in the highest part of the *Verneuilinoides borealis* zone and that are characteristic of the Tuktu Formation. These include an abundance of *Haplophragmoides topagorukensis* Tappan; *Ammobaculites wenonahae* Tappan, which is common to abundant in the upper 35 feet of the interval; *Trochammina umiatensis* Tappan, which is common in one core; and the worm tube *Ditrupa cornu* Imlay. The last three species are also horizon markers through each well. Another marker in most of the wells is *Ammobaculites fragmentarius* Cushman, which is highest in the sequence, but in test well 1 the species is absent in this position. One species, *Trochammina umiatensis*, in the Umiat field has a restricted range of about 100 feet in most of the wells. Thus its recurrence with *A. wenonahae* in cores about 715 feet lower in the section substantiates the interpretation of a fault at 2,010 feet, which is reported to duplicate about 700 feet of section (Collins, 1958a, p. 76). This fault was overlooked in early studies and was first suggested in 1949 by Karl Vanderahe, chief petroleum engineer for Arctic Contractors, who called attention to possible duplication of potential curves on the Schlumberger record.

Crushed shells of a *Corbula*-like pelecypod were abundant in two cores, and fragments of smooth, tapered cylindrical worm tubes (*Ditrupa cornu*) occurred in three cores.

A continuously cored section from 2,252 to 2,370 feet included nonfossiliferous intervals and had only a small fauna of eight species, consisting largely of *Haplophragmoides topagorukensis*, *Verneuilinoides borealis*, and *Ammobaculites wenonahae* in the fossiliferous intervals. The occurrence of a calcareous species, *Conorboides umiatensis* (Tappan), is unusual in the lower core in that it was common in its first appearance in the well but was rare elsewhere in the section below. A lower cored interval (2,537–2,578 ft) carried only *Haplophragmoides topagorukensis* in part of the footage; but in the lowest core (2,573–2,578 ft) *Verneuilinoides borealis*, *Psamminopelta bowsheri*, *Ammobaculites wenonahae*, and *Gaudryina canadensis* were abundant. Cored sections in the lower part of the Tuktu Formation were barren.

Torok Formation (2,850 ft to total depth)

In the lower beds penetrated in this test well, shale predominates and is part of the Torok Formation. At least 1,350 feet, and possibly as much as 2,000 feet, of this section carries the *Verneuilinoides borealis* fauna, but the base is unknown because of contamination from upper beds and lack of core control. The Torok part of the *V. borealis* zone lacks *Trochammina umiatensis* and species of *Psamminopelta* and *Gaudryina*. In cores about 550–575 feet below the top of the formation, crushed circular tests of *Haplophragmoides topagorukensis*, small flattened specimens of *Verneuilinoides borealis*, and unbroken specimens of *Ammobaculites fragmentarius* were common to abundant. Most of the specimens have sand grains adhering to the normally smooth surfaces. Specimens of *Gaudryina nanushukensis* Tappan, a species not found in the Tuktu Formation of the Umiat area, appeared in ditch material 840 feet below the top of the formation and seems to be diagnostic of the Torok Formation.

The most abundant specimens and species were in cored intervals at 4,085–4,114 feet and at 4,176–4,204 feet. *Gaudryinella irregularis* Tappan occurred sparingly in cores from 4,100 through 4,200 feet and in a core at 4,200–4,204 feet, where several calcareous Foraminifera were found and one species (*Eurycheilostoma robinsonae* Tappan) was common. Both of these species normally are found in the Tuktu Formation but are absent in it in this well. Specimens of *E. robinsonae* are high spired and cone shaped and have a reddish-brown stain on the surface of the tests.

No cores were taken below 4,204 feet except for the bottom one at 5,990–6,005 feet. Thus most of the uncored interval is without accurate faunal control, as ditch samples are greatly contaminated and most of the specimens of Foraminifera found are from younger beds of the *Verneuilinoides borealis* faunal zone. For this reason, most samples from this interval have not been included on the fossil range chart (pl. 23); the exceptions are two samples (4,500–4,510 ft and 5,150–5,170 ft) in which crinoid ossicles were found. These were identified by A. L. Bowsher as *Balanocrinus* sp.

A sample from the lowest core (5,990–6,005 ft) contained only two specimens of calcareous foraminifers; in ditch samples within the interval 5,790–5,830 feet, there occurred a few pyritic casts of *Lithocampe*? sp., a radiolarian which occurs mostly in the lower part of the Torok Formation. Its presence in this well suggests beds of that part of the Torok Formation, but as it is impossible to correlate this section precisely, the shale unit from 2,850 to 6,005 feet is considered as Torok Formation undifferentiated.

UMIAT TEST WELL 2

This test was located on the south flank of the anticline, about midway between the southeast corner of Umiat Lake and the Colville River, and was spudded in beds that are nearly a thousand feet stratigraphically lower than in test well 1. Lower Cretaceous beds were penetrated beneath alluvium at the depth of 80 feet and extended to the bottom at 6,212 feet. The well was cored continuously at three intervals: 297–582 feet, 750–843 feet, and 938–1,066 feet; but throughout the remainder of the section, most of the cores were taken approximately every 200 feet with the lowest at 6,185–6,200 feet.

CHANDLER FORMATION

No fossils were found in the sequence of sandstone and clay penetrated between the base of the alluvium and the first noted occurrences of Foraminifera in a core at 365–375 feet. These nonfossiliferous beds have been considered the Killik Tongue of the Chandler Formation, and a more or less fossiliferous sequence of sandstone and clay shale below has been referred to the Grandstand Formation (Collins, 1958a, p. 100).

VERNEUILINOIDES BOREALIS FAUNAL ZONE

Most of the rocks below the depth of 365 feet in this well are within the *Verneuilinoides borealis* zone. About 22 arenaceous species numerically outnumber the 19 calcareous species of the foraminiferal fauna. Specimen counts on the faunal chart (pl. 23) indicate that specimens of *Haplophragmoides topagorukensis* Tappan alone make up 65 percent of the fauna and with five other arenaceous species—*Verneuilinoides borealis* Tappan, *Gaudryina nanushukensis* Tappan, *Bathysiphon vitta* Nauss?, *Ammobaculites fragmentarius* Cushman, and *Ammobaculites wenonahae* Tappan, named in order of abundance—make up 83 percent of the entire fauna. Only five of these species are the same as those in the zone in test well 1. *Gaudryina canadensis* Cushman, *Miliammina awunensis* Tappan, *Psamminopelta bowsheri* Tappan, and *Psamminopelta subcircularis* Tappan are minor constituents in the zone in test well 2 but are among the leading species in test well 1. *B. vitta*? is prevalent in test well 2 and rare in test well 1. Seven calcareous species—*Lenticulina macrodisca* (Reuss), *Conorboides umiatensis* (Tappan), *Globorotalites alaskensis* Tappan, *Gavelinella stictata* (Tappan), *Marginulina planiuscula* (Reuss), *Globulina lacrima* Reuss subsp. *canadensis* Mellon and Wall, and *Valvulineria loetterlei* (Tappan)—constitute about 76 percent of the calcareous Foraminifera.

Tuktu and Grandstand Formations undifferentiated (365–1,060 ft)

The upper part of the *Verneuilinoides borealis* zone in test well 2 is a more or less fossiliferous sequence of sandstone and clay shale that is nearly 700 feet thick. The section was barren through the 70 feet below the first occurrence of four species of Foraminifera, and thereafter fossiliferous beds were erratic. *Haplophragmoides topagorukensis* appeared in abundance at 433 feet, which was also the first occurrence of *Ammobaculites fragmentarius*, the highest horizon marker in the

Umiat field. Other horizon markers appeared in succession at various depths, *Trochammina umiatensis* occurring about 1,000 feet structurally higher in this well than in test well 1.

Except for *Haplophragmoides topagorukensis* and *Verneuilinoides borealis*, the fauna is sparse from 800 feet to the top of the thick shale sequence of the Torok Formation. Only the cores at 979–992 feet had fossils in the continuously cored interval from 938 to 1,066 feet.

Torok Formation (1,060 ft to total depth)

Although the ditch samples from the upper 1,000 feet of the Torok Formation carried numerous specimens of *Haplophragmoides topagorukensis* and *Verneuilinoides borealis* besides lesser numbers of a few other species, the cores furnished very few fossils. The fauna found in the five cores between 1,850 and 2,950 feet offers nothing to confirm or disprove the interpretation of a reverse fault, which Collins (1958a, p. 100) reported at 2,400 feet and said repeated the section between 1,850 and 2,400 feet again between 2,400 and 2,950 feet.

A specimen of ammonite found at 2,148 feet and another at 2,634 feet were identified by Imlay (1961, p. 37) as *Gastroplites* sp. Small *Inoceramus* shells in a core at 2,784 feet have been identified by Imlay as juvenile forms of *Inoceramus* cf. *I. anglicus* Woods, an Albian species.

In a few cores between 1,400 and 3,000 feet and at 4,610–4,620 feet, small flattened wedge-shaped tests of *Verneuilinoides borealis* were common, and flattened tests of *Haplophragmoides topagorukensis* were common to abundant. Calcareous Foraminifera were relatively rare throughout much of the Torok Formation, but a few tests of *Conorboides umiatensis* (Tappan) and *Lenticulina macrodisca* (Reuss) occurred in scattered samples. Fragments of *Ditrupa cornu* tubes were abundant in a core from 1,429–1,439 feet. A long, broken specimen of *Gaudryina nanushukensis* Tappan about 970 feet below the top of the formation was the first occurrence of the species, but small tests of this species were common at several lower depths, and large specimens were abundant at 2,970–2,990 feet. In the interval between 3,007 and 4,087 feet, the cores were barren or carried very few fossils.

Only six species of Foraminifera were found in a core from 4,087–4,097 feet, but among them was an occurrence of three distorted specimens of *Trochammina umiatensis* that had not occurred below cores at 780–785 feet. This occurrence is unusual, as the species has a restricted range in the upper part of the *Verneuilinoides borealis* zone of the Umiat area. However, the sample was originally washed in October 1947 and reported as barren, but a subsequent sample washed from the same core in December 1947 yielded the fauna mentioned above. Perhaps the explanation is contamination by drilling mud in cracks in the core.

Compressed specimens of *Ammobaculites fragmentarius* were common in a core at 4,610–4,620 feet, small crushed specimens of *Haplophragmoides topagorukensis* were abundant, and specimens of small flattened *Verneuilinoides borealis* were common.

A dark shale from about 4,700 to 5,100 feet may be the equivalent of the lower part of the Torok Formation, but the only fossils found in the two cores from this interval are two specimens of *Haplophragmoides topagorukensis* and a questioned specimen of *Arenobulimina*. Ditch samples carried fossils from the *Verneuilinoides borealis* zone as contamination, but in samples from 4,840–4,850 feet and 4,960–4,970 feet, a pyritic cast of *Lithocampe*? sp. was found in each. Possibly these beds are within the lower part of the Torok Formation, as pyritic casts of *Lithocampe*? sp. are diagnostic of that part of the section if the casts occur in any degree of abundance. However, four of the seven cores in the section below 5,100 feet again carried Foraminifera of the *V. borealis* zone.

Crushed granular arenaceous Foraminifera of the *Verneuilinoides borealis* zone occurred in the core sample at 5,585–5,595 feet. Small, distorted tests of *Haplophragmoides topagorukensis* were abundant, and small brown, somewhat flattened, wedge-shaped tests of *Verneuilinoides borealis* were common. The latter are identified by shape, as the chambers are practically obscured by a granular surficial coating. The core at 5,885–5,893 feet had a fauna of eight arenaceous and five calcareous species of Foraminifera of the *V. borealis* zone. Most of the arenaceous specimens are crushed, and cemented sand grains partly obscure the normally smooth surfaces. The abundant *H. topagorukensis* specimens are small and crushed; the common *V. borealis* specimens are short and flattened. Associated with the Foraminifera are *Inoceramus* prisms and an ossicle of *Balanocrinus* sp.

The reappearance of the *Verneuilinoides borealis* fauna below 5,580 feet, especially of *Gaudryina nanushukensis* of the upper beds of the Torok Formation, in cores in the lower part of the well is good evidence for the fault suggested by Collins (1958a, p. 100) and indicates that shale beds which may be the lower part of the Torok Formation are only a few hundred feet thick between beds of the *V. borealis* zone.

UMIAT TEST WELL 3

This shallow test well was located near the northeast edge of Umiat Lake, about a quarter of a mile N. 70° W. of test well 2. The test was drilled to 572 feet and was continuously cored from 236 feet to the bottom. Some oil was produced from the upper beds.

CHANDLER FORMATION

No samples were taken above 60 feet in this well, and no faunal records or slides are available for most of the section above 230 feet. Apparently the upper beds are barren. This interval, a section of sandstone and clay shale, has been assigned to the Killik Tongue of the Chandler Formation by Collins (1958a, p. 116–117), and the section below 225 feet, to the Grandstand Formation; but the latter is considered as Tuktu and Grandstand Formations undifferentiated in this report.

VERNEUILINOIDES BOREALIS FAUNAL ZONE

Very few microfossils were found above the depth of 429 feet though the *Verneuilinoides borealis* zone begins 200 feet higher. The species that are the horizon markers in the upper part of the faunal zone occurred at 463 feet and lower. The greatest concentration of specimens was below 520 feet, but only 16 species make up the entire fauna of the section penetrated. *Haplophragmoides topagorukensis* Tappan, *Verneuilinoides borealis* Tappan, and *Ammobaculites wenonahae* Tappan, named in order of abundance, constitute 70 percent of the fauna. Six calcareous species occurred in the lowest part, but of these only one (*Gavelinella stictata* (Tappan)) was common in one core.

Most of the Foraminifera found in test well 3 are flattened and distorted and range in color from gray to light tan and brown. Specimens of *Verneuilinoides borealis* are small and dark brown and have rather obscure sutures. Specimens of *Trochammina umiatensis* Tappan are large and distorted; but they are readily recognized by their four greatly expanded chambers in the last whorl. Specimens of *Ammobaculites wenonahae* are in general undistorted, and many are unbroken. Calcareous specimens are not crushed and are stained tan to brown.

UMIAT TEST WELL 4

This test was drilled about 1,000 feet northeast of test well 3, at about 130 feet higher elevation, but it appears to be nearly the same structurally. The well was drilled by cable tool to a depth of 840 feet and produced oil. All cores were in sandstone and were not sampled for microfossils. Only the bailer samples were examined.

CHANDLER FORMATION

The upper part of the well apparently is nonfossiliferous through 320 feet and has been assigned to the Killik Tongue of the Chandler Formation by Collins (1958a, p. 125). The succeeding beds, which Collins placed in the Grandstand Formation but which are herein referred to Tuktu and Grandstand Formations undifferentiated, are within the *Verneuilinoides borealis* faunal zone.

VERNEUILINOIDES BOREALIS FAUNAL ZONE

The *Verneuilinoides borealis* faunal zone was penetrated at 325 feet. In the ensuing 20-foot interval (325–345 ft) of bailer samples was a concentration of a few arenaceous Foraminifera, some of which were common to abundant. This interval was followed by barren samples and erratic occurrences of fossils down to 540 feet. Below that depth, microfossils were found in nearly every bailer sample to the bottom of the hole. The number of specimens recovered is small, however, and the fauna is composed of only 17 species of Foraminifera—*Haplophragmoides topagorukensis* Tappan, *Verneuilinoides borealis* Tappan, and *Ammobaculites wenonahae* Tappan making up 71 percent of the total count. Five calcareous species of Foraminifera were found but in number of specimens are insignificant. The horizon-marking fossils of the upper part of the *V. borealis* zone occur in normal sequence and indicate that the well bottomed slightly below this part of the section.

The Foraminifera from this test hole are in part crushed. Specimens of *Verneuilinoides borealis* are larger than those in test well 3 and have more enlarged chambers; some tests are pyritic and inflated. A few short specimens of *Ammobaculites fragmentarius* Cushman and *A. wenonahae* are complete, whereas others are broken, and some are distorted. All specimens of *Trochammina umiatensis* Tappan are distorted.

UMIAT TEST WELL 5

This cable tool test was drilled near test well 2 to check the sands in which there had been oil shows. Oil was produced from two main sands, and the test bottomed at 1,077 feet. Bailer and core samples were examined for microfossils; all cores examined from this well were barren of the usual microfossils, probably because they were taken in sandstone and siltstone beds. But even in the shale beds below 730 feet, Foraminifera were few and erratic in occurrence, and only *Haplophragmoides topagorukensis* Tappan was common.

CHANDLER FORMATION

The upper 335 feet of more or less unfossiliferous section is largely of the Killik Tongue of the Chandler Formation. The only fossils found were a few fish teeth, fishbone fragments, and a charophyte oogonium, the oogonium being found in a sample at 100 feet.

VERNEUILINOIDES BOREALIS FAUNAL ZONE

Above the upper main oil producing sand (370–425 ft), sparingly fossiliferous beds of the *Verneuilinoides* *borealis* zone were penetrated at 355 feet, where a relative abundance of *Verneuilinoides borealis* Tappan and *Miliammina awunensis* Tappan occurred. Below the nonfossiliferous producing section, relatively few fossils occurred in the beds to 605 feet, but among these were the marker fossils *Ammobaculites fragmentarius* Cushman and *Ditrupa cornu* Imlay. Beds between 605 and 740 feet carried the bulk of the small fauna found in this test, including the horizon marker species *Ammobaculites wenonahae* Tappan and *Trochammina umiatensis* Tappan.

The lower producing sand interval (770–960 ft) was largely barren of microfossils except for a few about midway. The lowest samples in the test hole carried a few Foraminifera, principally *Haplophragmoides topagorukensis* Tappan.

The microfauna found in this test totaled 17 species of Foraminifera, *Haplophragmoides topagorukensis* and *Verneuuilinoides borealis* accounting for 61 percent. Four calcareous species account for 3 percent of the specimen count in the samples examined.

In general, few of the Foraminifera from this well escaped crushing and distortion, and specimens show more of this than do those from test wells 1–4. Many have granular surfaces. The specimens of *Verneuilinoides borealis* are small for the species; they are elongate triangular in outline, are dark brown, and have a granular surface that obscures the sutures and makes identification more difficult than usual. Several large *Haplophragmoides topagorukensis* specimens occurred among the average-sized tests in some samples; all are distorted, and the walls of the chambers of many are somewhat caved, creating a ribbed appearance. *Ammobaculites wenonahae* specimens are compressed, and some are broken but show little distortion. *Trochammina umiatensis* specimens are large, compressed, and distorted, but the last four rapidly expanded chambers make the species distinctive enough to be recognized.

UMIAT TEST WELL 6

This cable tool test was drilled about 3,500 feet southwest of test well 2 and is structurally lower. Only two cores were taken, and these, together with much of the section, were seemingly barren of microfossils. A few occurred in the upper 240 feet of section, where *Inoceramus* prisms and shell fragments prevailed in each sample. Scattered tests of eight species of Foraminifera were found in beds below 640 feet.

SEABEE FORMATION

Microfossils were scare in the section (31–220 ft) assigned to the Seabee Formation, and only a few specimens of *Gaudryina* sp. and *Neobulimina albertensis* (Stelck and Wall) and three species of Radiolaria were found. Previously, the arenaceous foraminifer was cited as *Gaudryina irenensis* Stelck and Wall (Bergquist, 1958a, p. 202), but the two specimens found are so poorly preserved that it seems best to give only the generic designation.

NINULUK FORMATION

A section of 130 feet assigned to the Ninuluk Formation had fossils in only the highest sample (230–240 ft), where there occurred pyritic and crushed arenaceous tests of a species of *Trochammina* herein referred to *T. wetteri* Stelck and Wall. These tests were previously referred to *Trochammina rutherfordi* Stelck and Wall (Bergquist, 1958a, p. 202) but appear to have fewer chambers than that species and to be more like the deeply umbilicate *T. wetteri* described from beds of Cenomanian age in the Peace River area, Alberta, Canada (Stelck and Wall, 1955, p. 59).

KILLIK TONGUE OF THE CHANDLER FORMATION

The 280-foot sequence of the Killik Tongue penetrated between 350 and 630 feet was barren of fossils except for rare *Inoceramus* prisms in the lower samples. These prisms could be contamination.

VERNEUILINOIDES BOREALIS FAUNAL ZONE

The well tested only about 200 feet of the upper part of the *Verneuilinoides borealis* faunal zone and did not reach the lower producing sand of the other test wells. Microfossils are scant, but in their first appearance at 640 feet, two species were common. There are in all, however, only 11 occurrences of fossils in the undifferentiated beds of the Tuktu and Grandstand Formations, and a total of only 77 specimens were found. Seven arenaceous Foraminifera and one calcareous species make up the small fauna, *Psamminopelta subcircularis* Tappan and *Miliammina awunensis* Tappan constituting 53 percent of the specimens and *Haplophragmoides topagorukensis* Tappan and *Verneuilinoides borealis* Tappan, about 30 percent. Only the uppermost of the fossil horizon markers, *Ammobaculites fragmentarius* Cushman and *Ditrupa cornu* Imlay, were reached in the drilling.

UMIAT TEST WELL 7

The test was drilled about 1,300 feet southwest of test well 6 and penetrated both Upper and Lower Cretaceous rocks. The well bottomed at 1,384 feet, a little below the zone of the marker fossils which occur in the upper part of the *Verneuilinoides borealis* faunal zone.

SEABEE FORMATION AND CHANDLER AND NINULUK FORMATIONS UNDIFFERENTIATED

Five specimens of Foraminifera were found in the upper 800 feet of the well in beds assigned to the Seabee Formation (4–385 ft) and to the Chandler and Ninuluk Formations (390–795 ft). One of these, *Neobulimina albertensis* (Stelck and Wall), suggests beds of Turonian age; from the first sample through a sample at 360–370 feet, *Inoceramus* prisms were abundant.

VERNEUILINOIDES BOREALIS FAUNAL ZONE

The *Verneuilinoides borealis* faunal zone was first apparent in a sample at 805 feet, where specimens of *Psamminopelta subcircularis* Tappan were common. In the next interval through 1,040 feet, microfossils were relatively rare; but between 1,040 and 1,200 feet, a concentration of 11 species was found of which 4 species make up most of the fauna. Below 1,200 feet, few specimens were recovered. All four fossil horizon markers were found in this test well, and the lower oil-producing sand of the other wells was penetrated but was water bearing. These beds are considered in this report to be Tuktu and Grandstand Formations undifferentiated.

Three arenaceous Foraminifera, *Haplophragmoides topagorukensis* Tappan, *Verneuilinoides borealis* Tappan, and *Ammobaculites wenonahae* Tappan, account for 75 percent of the fauna in samples of the *Verneuilinoides borealis* zone; and *Haplophragmoides topagorukensis* alone totals 40 percent. Many of the specimens are somewhat crushed and distorted, especially in the upper beds. Specimens of *H. topagorukensis* and *A. wenonahae* Tappan are fairly well preserved; specimens of *V. borealis* are among the poorest preserved.

UMIAT TEST WELL 8

This cable tool test was drilled about a mile northwest of test well 2. Oil and gas were produced on formation tests. The meager paleontologic data obtained from beds assigned to the Seabee Formation and to the Chandler and Ninuluk Formations in this well have been discussed (Bergquist, 1958a, p. 202), and reexamination of material has added no new data. Geologic divisions shown on figure 28 for this part of the well are from Collins' data (1958a, p. 149, 150).

VERNEUILINOIDES BOREALIS FAUNAL ZONE

The *Verneuilinoides borealis* faunal zone apparently was penetrated not far below 700 feet, as three specimens of *V. borealis* were found in a core at 711–716 feet. However, no other Foraminifera of this zone were found in the sample or in the succeeding 100 feet of section; therefore, the occurrence probably represents one of the minor intertongues of marginal marine and nonmarine sediments that must have prevailed during the later stages of marine sedimentation in Albian time in northern Alaska. A concentration of Foraminifera occurred below 845 feet in this test hole.

In the undifferentiated beds of the Tuktu and Grandstand Formations, the four fossil horizon markers in the upper part of the *Verneuilinoides borealis* faunal zone were found, but most specimens of *Ammobaculites fragmentarius* Cushman occurred in the sample in which the species first made its appearance. A total of 16 species were found in beds penetrated in the zone, all but 3 being arenaceous forms. *Verneuilinoides borealis* and *Haplophragmoides topagorukensis* make up 56 percent of the total count; *Ammobaculites wenonahae*, approximately 12 percent; and *Trochammina umiatensis* Tappan, nearly 8 percent. The number of specimens of *T. umiatensis* is unusual as this species is usually subordinate to three or four others in most of the test wells.

Specimens of *Trochammina umiatensis* vary considerably in size and degree of crushing, a few showing some of the original inflation of the large later chambers (see C, fig. 37). The specimens of *Ammobaculites wenonahae* are well preserved and show considerable size range from short tests having only one chamber above the initial whorl to those with four or five chambers in the uniserial stage. Specimens of *Verneuilinoides borealis* in the upper part of the zone are large and relatively smooth, but in the lower samples the tests are smaller and have a granular texture that partially obscures the sutures and chambers.

UMIAT TEST WELL 9

This test was drilled by rotary drill about 2 miles west of test well 2 on the western part of the Umiat anticline. Coring was nearly continuous below 385 feet. The well averaged 217 barrels of oil per day on a pumping test apparently coming from several producing sandstone beds.

NINULUK AND CHANDLER FORMATIONS

Sediments in the upper 425 feet of the section penetrated have been assigned to the Ninuluk Formation and Killik Tongue of the Chandler Formation; paleontologic material in this interval is practically nonexistent. Two fragmentary specimens reported as *Gaudryina canadensis* Cushman? (Bergquist, 1958a, p. 203) from 80–90 feet and 140–150 feet are too poorly preserved for definite generic identification and therefore are not included on the faunal chart of this test well. A distorted specimen of *Trochammina* and a flattened specimen of *Saccammina lathrami* Tappan in the sample at 140–150 feet are the only other microfossils found, but they offer no help in ascertaining whether or not there are sediments younger than the Ninuluk Formation.

VERNEUILINOIDES BOREALIS FAUNAL ZONE

The *Verneuilinoides borealis* faunal zone extends from a core at 423–433 feet to total depth at 1,257 feet. Beds of undifferentiated Tuktu and Grandstand Formations were penetrated from 425 feet to at least 1,090 feet, and a short section of the Torok Formation was penetrated below that. The fossil horizon markers appeared initially in normal sequence, but a recurrence of tests of *Ammobaculites wenonahae* and *Trochammina umiatensis* in cores in the lower part of the well suggests repetition of beds from a higher sequence.

The *Verneuilinoides borealis* fauna here consists of 23 species of Foraminifera; 7 species are calcareous, but together they total only 3 percent of the faunal count. Five arenaceous species make up more than 75 percent of the fauna as follows: *Verneuilinoides borealis* Tappan, 27 percent; *Haplophragmoides topagorukensis* Tappan, 16 percent; *Gaudryina canadensis* Cushman, 12 percent; *Miliammina awunensis* Tappan, 11 percent; and *Ammobaculites wenonahae* Tappan, 9 percent.

Compressed and widely flaring dark-brown granular-surfaced specimens of *Verneuilinoides borealis* and flattened specimens of *Miliammina awunensis* were very abundant near the top of the *V. borealis* zone. Shells of *Corbula?* sp. were numerous at 435 feet. Fragments of *Ammobaculites fragmentarius*, one of the fossil horizon markers, were found below a barren section (464–514 ft), and abundant, well-preserved, unbroken specimens were present in a core at 525–533 feet. In the latter core, there were also common compressed tests of *Haplophragmoides topagorukensis*, small tests of *V. borealis*, and a fragment of *Ditrupa cornu* tube. Although most specimens of *Ammobaculites wenonahae* were broken, they were not crushed. Many are coarser grained than is normal for the species, but the broken tests can usually be distinguished from those of *A. fragmentarius* because of the larger initial whorl and the broader uniserial stage.

Shells of *Corbula?* sp. were abundant from 838 to 848 feet, where most of the specimens were crushed and packed closely together. Specimens of *Gaudryina canadensis* from 829 to 858 feet were beautifully preserved by pyritic filling that has caused them to retain the original shape of the subglobular chambers and subcylindrical tests, features rarely present in specimens from the Umiat wells. At lower depth (949–969 ft), many of the specimens are flattened, and all have a corroded appearance.

In the cores below 979 feet, the *Verneuilinoides borealis* fauna continued sporadically; but in some of the samples below 1,100 feet, *Haplophragmoides topagorukensis* and small dark-brown tests of *Verneuilinoides borealis* were common, and a few tests of calcareous species were found. There, too, in samples from 1,187–1,218 feet, was a recurrence of *Trochammina umiatensis*, about 387 feet below its lowest occurrence in the upper beds. The specimens of *T. umiatensis* found in both intervals are crushed and are more poorly preserved than are specimens from some of the other wells of the Umiat field. However, the trochoid character and the four large final chambers that distinguish the species are visible. Because this species seemingly has a limited vertical range of about 100 feet in the Umiat field and is not known to occur in the Torok Formation, its reccurrence suggests faulting in the lower beds of this well just as in test well 1, where its recurrence more than 700 feet below the lowest initial occurrence is known to be due to faulting.

UMIAT TEST WELL 10

The test was drilled about one-third of a mile northwest of test well 8 and bottomed at 1,573 feet. Oil was produced from two sandstone beds and there was a good showing in a lower sand, but caving prevented its testing.

NINULUK AND SEABEE FORMATIONS

In the upper three-fourths of the well, microfossils were found at about five horizons separated by barren intervals. In samples from 180–210 feet and in a core from 745–750 feet, pyritized and compressed tests of *Trochammina* occurred; these were previously reported as *Trochammina ruthfordi* Stelck and Wall (Bergquist, 1958a, p. 203). However, because the spire is higher and the test has fewer chambers in the final whorl and is more umbilicate than is characteristic of *T. rutherfordi*, it seems more appropriate to consider most of the specimens as *T. wetteri* Stelck and Wall, a species of Cenomanian age from the Peace River area of Alberta, Canada.

The sections in which *Trochammina wetteri* occur in this test well are believed to be part of the Ninuluk Formation, but between them is a section of more than 400 feet of the Seabee Formation; the upper occurrence of the Ninuluk apparently owing its position to thrust faulting. The Seabee Formation extends from 210 to 645 feet, and the beds carried some specimens of *Neobulimina albertensis* (Stelck and Wall) and *Trochammina ribstonensis* Wickenden, both species of Turonian age. Specimens formerly considered to be *Gaudryina* *irenensis* Stelck and Wall (Bergquist, 1958a, p. 203) are now placed questionably under *Verneuilinoides* sp., as the compressed tests are short and seemingly entirely triserial. Similar tests occur at 745–750 feet in beds of the Ninuluk Formation, but these were previously cited as *Gaudryina canadensis* Cushman. Preservation of all the tests is very poor, and reexamination indicates that identification cannot be made with any certainty.

VERNEUILINOIDES BOREALIS FAUNAL ZONE

The *Verneuilinoides borealis* faunal zone was penetrated at 1,035 feet, where the top is marked by the common occurrence of rather granular large dark-brown tests of *Verneuilinoides borealis* Tappan, flattened and somewhat twisted tests of *Miliammina awunensis* Tappan, and flattened, long, narrow tests of *Gaudryina canadensis* Cushman. These Foraminifera, together with *Inoceramus* prisms, were found in the uppermost 15 feet of samples, but the succeeding 100 feet of section was barren.

This is the characteristic sequence that prevails in the upper part of the zone in the Umiat field, that is, barren beds above a concentration of a larger microfauna which includes the fossil horizon markers. The fossil horizon markers appeared in normal sequence in test well 10, and representative species of the *Verneuilinoides borealis* fauna were fairly consistent from 1,145 feet to the bottom of the hole.

Only seven arenaceous Foraminifera and two calcareous species constitute the fauna of the *Verneuilinoides borealis* zone in test well 10. Of these, *Haplophragmoides topagorukensis* Tappan makes up approximately 39 percent of the faunal count, *Verneuilinoides borealis*, 23 percent; *Ammobaculites wenonahae* Tappan, 20 percent; and *Trochammina umiatensis* Tappan, 7 percent. Two calcareous species account for only 1 percent of the fauna.

Although the specimens of *Verneuilinoides borealis* in the upper beds were large, all those occurring in relative abundance below 1,370 feet are short and flattened and have a narrow triangular outline. *Haplophragmoides topagorukensis* specimens show all degrees of distortion from the normal shape, and they have considerable size range; some specimens in the lower beds are relatively large for the species. Many of the *Ammobaculites wenonahae* specimens are broken or have been shortened and slightly twisted by compression. *Trochammina umiatensis* specimens also show a range in size from small to large forms. Many are fairly well preserved, and a few are sufficiently filled with pyrite that the tests have retained the normal *Globigerina*-like shape of the chambers. Compressed specimens are dark colored in the area of the small initial chambers.

UMIAT TEST WELL 11

The test was drilled on the downthrow side of a fault, on Bearpaw Creek, about 3 miles N., 4° E. of the mouth of Seabee Creek, and penetrated a section of more than 2,100 feet of Upper Cretaceous rocks and 1,200 feet of Lower Cretaceous rocks. In the uppermost part, nonmarine sandstone and siltstone beds of the Tuluvak Tongue are the youngest sedimentary rocks logged in the Umiat field. Below this part from 545 to 2,040 feet is the thickest section of the Seabee Formation penetrated in the subsurface. This section is in part fossiliferous. Below 2,040 feet, about 400 feet of sparsely fossiliferous and nonfossiliferous sediments are ascribed to the Ninuluk and Chandler Formations. The lowest few hundred feet of section is in the Tuktu and Grandstand Formations undifferentiated and in the Torok Formation.

UPPER CRETACEOUS ROCKS (SEABEE FORMATION)

Pseudoclavulina hastata–Arenobulimina torula faunal zone

In the uppermost part of the Seabee Formation in this test well, from at least 561 to 700 feet occurred fragments of *Pseudoclavulina hastata* (Cushman) and numerous flattened specimens of *Arenobulimina torula* Tappan, two species which together are the characteristic fossils of a thin zone found in the Ayiyak Member of the formation. All the specimens of *Pseudoclavulina hastata* are broken, but the segments are distinctive enough to identify the species. Tests of *Arenobulimina torula* are high spired, have oblique sutures that are darker than the chamber walls, and have three or four chambers in the last whorl; commonly the tests are flattened to subtriangular. Five or six other species of Foraminifera are associated with these two species, and they occurred in a few ditch samples through 915 feet, but *Haplophragmoides rota* Nauss alone accounts for nearly half of all specimens found.

A core at 1,030–1,050 feet furnished a few microfossils, including two species of Foraminifera not found in higher beds, but between 1,050 and 1,565 feet almost all samples were barren. In the lower part of the Seabee Formation (1,565–2,040 ft), a few additional Foraminifera and Radiolaria were found, including specimens of *Trochammina diagonis* (Carsey) and *Textularia* sp. The specimens of *Textularia* sp. were formerly identified as *Gaudryina irenensis* Stelck and Wall (Bergquist, 1958a, p. 204), but a restudy of all specimens at ×216 fails to indicate any triserial section. The tests are tapered, compressed, and poorly preserved. Specimens of *Trochammina diagonis*, although compressed, are recognized by their comparatively large size, numerous chambers, and brown color.

Most of the arenaceous specimens in the Seabee Formation of this well have light-tan tests, and their surfaces are obscured by surficial sand grains, which, together with distortion of the tests by crushing, make identification somewhat difficult. The radiolarian tests of *Cenosphaera* and *Spongodiscus* are white and seemingly well preserved for the genera.

Faunal counts for all specimens found in the Seabee Formation of test well 11 indicate that *Haplophragmoides rota* Nauss constitutes nearly 39 percent of the fauna. Three species of *Trochammina* (*T. ribstonensis* Wickenden, *T. whittingtoni* Tappan, and *T. diagonis* (Carsey)) account for 34 percent of the faunal count, and specimens identified as *Textularia* sp. make up 10 percent. There are only three species of calcareous Foraminifera in the fauna, and together the specimens make up only about 2 percent of the count.

The small ammonite, *Borissiakoceras ashurkoffae* Cobban and Gryc was found in cores at 1,230–1,235 feet and at 1,427 feet. *Inoceramus* shell fragments were found in cores from 805–825 feet and at 1,015–1,025 feet; *Inoceramus* prisms were in a few ditch samples.

Ninuluk Formation (2,040–2,190 ft ±)

The upper 100 feet of Ninuluk Formation was barren of microfossils, but in the lower part *Trochammina ribstonensis rutherfordi* Stelck and Wall was abundant in cores at 2,135–2,145 feet and at 2,153–2,163 feet. Specimens in both samples are flattened and have the same color, texture, and preservation. In a sample from 2,173–2,192 feet, small specimens of *Spongodiscus* cf. *Spongodiscus* B were common. These fossils have not been found in beds below the Ninuluk Formation.

LOWER CRETACEOUS ROCKS

Verneuilinoides borealis faunal zone

Tuktu and Grandstand Formations undifferentiated (2,420–3,075 ft).—In the Tuktu and Grandstand Formations undifferentiated, the top of the *Verneuilinoides borealis* faunal zone is marked by common large specimens of *Verneuilinoides borealis* Tappan and by flattened tests of *Psamminopelta subcircularis* Tappan and *Miliammina awunensis* Tappan all of which occur below approximately 230 feet of the Killik Tongue. A core at 2,529–2,545 feet carried abundant specimens of *Psamminopelta subcircularis* and common *Miliammina awunensis*, plus a few crushed specimens of *V. borealis* and *Gaudryina canadensis* Cushman. Tubes of *Ditrupa cornu* Imlay appeared first at 2,655–2,665 feet. In the core at 2,701–2,721 feet were common occurrences of distorted *Haplophragmoides topagorukensis* Tappan, small *V. borealis* specimens, and both whole and broken tests of *Ammobaculites wenonahae* Tappan, along with a few flattened and distorted specimens of *G. canadensis* Cushman; tests of *Lenticulina macrodisca* (Reuss), *Gavelinella stictata* (Tappan), and *Praebulimina nannina* (Tappan) and fragments of *Ditrupa* tubes are a minor group in the sample. A single crushed specimen of *Trochammina umiatensis* Tappan was found in a ditch sample at 2,695–2,700 feet, but in ditch samples from 2,750–2,800 feet, the crushed and distored tests of this marker species were common. Small dark-brown tests of *V. borealis* and specimens of *H. topagorukensis* were common in the same interval. At 2,820–2,830 feet, flattened specimens of *G. canadensis* and pyritic and crushed specimens of *Miliammina awunensis* were abundant. A very small rounded lenticular radiolarian (*Spongodiscus*? sp.) was common in the same samples. Lower cores carried relatively few Foraminifera, and the arenaceous specimens all have a very granular appearance. The lowest core (2,989–3,009 ft) was sandy and unfossiliferous.

Torok Formation (3,075 ft to total depth).—The ditch samples from the Torok Formation carried a small fauna of the *Verneuilinoides borealis* zone, but much of this could be contamination, especially in the samples in which *Trochammina umiatensis* Tappan were found. *Haplophragmoides topagorukensis* Tappan and *Verneuilinoides borealis* Tappan were common in ditch samples from 3,190–3,280 feet. The bottom-hole core (3,290–3,303 ft) had common occurrences of *Bathysiphon brosgei* Tappan, *Saccammina lathrami* Tappan, *H. topagorukensis*, *V. borealis*, *Miliammina manitobensis* Wickenden, and *Gavelinella stictata* (Tappan), and a few specimens of each of eight other species of the *V. borealis* faunal zone. Specimens of *Miliammina manitobensis* are very well preserved and are about the best specimens of the species found in any of the Umiat wells.

GUBIK TEST WELLS 1 AND 2

Two test wells were drilled in 1951 on the Gubik anticline, a structure that extends eastward to the Anaktuvak River from the confluence of the Colville and Chandler Rivers. The tests penetrated Upper and Lower Cretaceous rocks and produced commercial quantities of gas from two sandstone beds that are separated 1,500 feet stratigraphically. Gubik test well 1 was drilled near the apex of the anticline on the west side of the Chandler River, about 1 mile above its mouth; Gubik test well 2, also drilled on the west side of the Chandler River, was located on the south flank of the anticline at a point approximately 1⅛ miles S. 53° E. of test well 1.

Descriptions of the cores and cuttings, core analyses, formation tests, and drilling operations have been published (Robinson, 1958a) as well as a brief résumé of significant microfossils found in the cores and cuttings (Bergquist, 1958b, p. 259–261). Since 1958, however, changes have been made in names or identifications of a few of the Foraminifera found in the Gubik wells. These changes are as follows: In the Schrader Bluff Formation, *Nonionella austinana* Cushman is now identified as *Nonionella taylorensis* Hofker, and specimens of *Verneuilinoides fischeri* Tappan are for the most part now listed as *Gaudryina* sp; in the Ninuluk Formation, *Gaudryina canadensis* Cushman is now identified as *Gaudryina irenensis* Stelck and Wall?, and *Trochammina rutherfordi* Stelck and Wall is now identified as *Trochammina ribstonensis* Wickenden; in the *Verneuilinoides borealis* faunal zone, *Ammobaculites fragmentarius* Cushman is identified as *Ammobaculites wenonahae* Tappan, *Trochammina rutherfordi* Stelck and Wall is identified as *Trochammina* cf. *T. gatesensis* Stelck and Wall, and *Nanushukella umiatensis* Tappan is now identified as *Conorboides umiatensis* (Tappan). Species counts for the microfossils are given on plate 24.

In both the test wells, thin surficial Pleistocene deposits were found beneath which a sequence of about 3,300 to nearly 4,000 feet of the Colville Group was penetrated. Underlying the Upper Cretaceous beds, approximately 2,700 feet of the Nanushuk Group was penetrated in test well 1 and a litle more than 1,000 feet of beds of the same group in test well 2. Foraminifera and some Radiolaria occurred at intervals throughout the Colville Group in both wells, but they were abundant in only a few samples. Foraminifera were more common in the Nanushuk Group but were poorly preserved.

STRATIGRAPHIC PALEONTOLOGY

Lithologic and paleontologic data indicate that in the Gubik test wells the youngest Cretaceous rocks are of the Barrow Trail Member of the Schrader Bluff Formation. Faunal zones are not well represented in the wells, a fact which may be due in part to prevailing poor preservation of the microfossils and in part due to assemblages smaller than might be considered normal for the zones. Without well-defined faunal zones, only the broader aspects of the units can be determined from the fossils, and contacts as such cannot be defined. For example, *Neobulimina canadensis* Cushman and Wickenden was not found in the Gubik wells, but the faunal zone of that name can be recognized from associated Foraminifera in the upper beds. These include *Anomalinoides pinguis* (Jennings), *Nonionella taylorensis* Hofker, *Gavelinella tumida* Brotzen, and *Eoeponidella linki* Wickenden; only the first named occurred in any degree of abundance, however, and in only one sample. Likewise the *Pseudoclavulina hastata–Arenobulimina torula* faunal zone of the Seabee Formation was identified in test well 2 but not in test well 1, although the equivalent rock beds must have been penetrated there also.

Foraminifera found in the Schrader Bluff Formation identify the rocks as Senonian. A few species of Radiolaria of the sort occurring in the Barrow Trail Member in Fish Creek test well 1 were found in Gubik test well 1 between 525 and 845 feet and in test well 2 between 760 and 1,060 feet. Rocks of Turonian age were identified by the fossils *Pseudoclavulina hastata* (Cushman) and *Arenobulimina torula* Tappan found in test well 2 because by comparison with other areas it is known that these fossils are from an interval containing ammonites of Late Cretaceous (early Turonian) age.

Although more than 1,500 feet of the section in the Gubik wells may belong to the Seabee Formation, most of the cores in this interval were barren, and few microfossils were found in the ditch samples. An exception, however, is the occurrence of numerous broken, elongate coiled arenaceous tests in a core at 3,100–3,110 feet in test well 2; these tests are doubtly referred to *Gaudryina irenensis* Stelck and Wall?

A thin fossiliferous section, which may possibly represent the Ninuluk Formation of Cenomanian age, occurs at 3,310–3,352 feet in test well 1 and at 3,620–3,640 feet in test well 2. In that interval were found poorly preserved tests that are referred questionably to *Gaudryina irenensis* Stelck and Wall and *Trochammina ribstonensis* Wickenden or to *Trochammina rutherfordi* Stelck and Wall, *T. rutherfordi* now being regarded by Mrs. Loeblich (Tappan, 1962) as a subspecies of *T. ribstonensis*. The crushed and distorted condition of the tests of these arenaceous Foraminifera prevent positive identification, however, and these fossils from the Gubik wells are referred to the *Gaudryina irenensis–Trochammina rutherfordi* faunal zone of the Ninuluk Formation with uncertainty.

The *Verneuilinoides borealis* faunal zone of Albian age is the oldest fossil zone found in the Gubik wells. The zone is best developed in test well 1, where it appears rather abruptly within a 100-foot interval and then extends to total depth through nearly 2,200 feet of section. Twenty-two species were found in the zone, but 4 species account for 78.8 percent of the faunal count. These are as follows: *Trochammina* cf. *T. gatesensis* Stelck and Wall, 33.6 percent; *Verneuilinoides borealis* Tappan, 28.4 percent; *Haplophragmoides topagorukensis* Tappan, 10.6 percent; and *Trochammina umiatensis* Tappan, 6.2 percent. Five other species, *Gaudryinella irregularis* Loeblich and

Tappan, *Gaudryina canadensis* Cushman, *Miliammina ischnia* Tappan, *Reophax troyeri* Tappan, and *Valvulineria loetterlei* (Tappan) together make up 14.6 percent of the fauna. Four species, *Ammobaculites wenonahae* Tappan, *Conorboides umiatensis* (Tappan), "*Tritaxia*" *manitobensis* Wickenden, and *Globorotalites alaskensis* Tappan, constitute 4.5 percent, and seven other species account for 1.5 percent. This fauna as compared to the usual faunal assemblage of the *V. borealis* zone, has a conspicuous absence of good specimens of the genera *Ammobaculites*, *Psamminopelta*, and *Miliammina*.

UPPER CRETACEOUS (CENOMANIAN AND SENONIAN) ROCKS

Schrader Bluff Formation

In Gubik test well 1 the part considered by Robinson (1958a, p. 214) to be the Barrow Trail Member (67–295 ft) of the Schrader Bluff Formation is unfossiliferous except for a few *Inoceramus* prisms in two or three of the samples, but the Rogers Creek Member (295–890 ft) carried a few Foraminifera of Senonian age in the upper part, and three species of Radiolaria (Spumellina) were common in a sample at 525–535 feet. In a core at 721–741 feet, very poorly preserved, flattened specimens of *Trochammina diagonis* (Carsey)? were common and tests of *Dorothia*? sp. were abundant. The latter are small, tapered, and cylindrical; the chambers are not inflated, and the sutures are flush or slightly raised and are a darker brown than the walls. Most specimens are broken or compressed; the largest measures 0.4 mm in length. A few Radiolaria and Foraminifera were found in the basal part of the member, and *Inoceramus* shell fragments came from several samples.

In Gubik test well 2 the Barrow Trail Member includes about 500 feet of beds so sparsely fossiliferous that only one or two species of Foraminifera and scattered *Inoceramus* shell fragments were found. In the Rogers Creek section (555–1,135 ft) of the same well, the Foraminifera are rare; but in a core at 810–820 feet, poorly preserved, broken, compressed tests of *Dorothia*? sp. were common. Small tests of *Praebulimina venusae* (Nauss), a few distorted tests of *Nonionella taylorensis* Hofker, and a few tests of *Gavelinella tumida* Brotzen in ditch samples indicate the Senonian age of this section. Specimens of *Anomalinoides pinguis* (Jennings) found in these beds in both wells give further evidence of a Senonian age as the species occurs in beds of Navarro and Taylor age in Texas.

Two species of milky-white Radiolaria, small spherical *Cenosphaera* (*Cenosphaera*) sp. A and discoidal *Spongodiscus* (*Spongodiscus*) sp. B were common at 780 feet and at 1,000 feet, respectively, in ditch samples from Gubik test well 2. The solid, elliptical, milky-white shells of *Spongurus* (*Spongurantha*) sp. were common at 1,060 feet. In all, about eight species of Radiolaria occurred in the lower part of the Schrader Bluff Formation, but most of these species were relatively rare.

Schrader Bluff Formation and Interbedded Schrader Bluff and Prince Creek Formations

In Gubik test well 1, a few Foraminifera and Radiolaria were found in ditch samples of the section, referred to the Tuluvak Tongue (Robinson, 1958a, p. 210), but the cores were unfossiliferous except for *Inoceramus* fragments at 1,444–1,457 feet and at 1,711–1,738 feet. In Gubik test well 2 in the section from 1,135–2,010 feet, fossiliferous beds alternate with nonfossiliferous beds and are herein considered as interbedded parts of the Schrader Bluff Formation and the Prince Creek Formation. Specimens of *Dorothia smokyensis* Wall? and *Trochammina ribstonensis* Wickenden were common in a core at 1,340–1,351 feet, and a flood of these two species of various sizes and shapes occurred at the base of the core. Specimens identified as *D. smokyensis*? (see fig. 49) range in size from short, stout individuals to elongate, tapered, and subcylindrical forms up to 1.5 mm long; some of the elongate forms have a biserial chamber arrangement in the later stage. Specimens are light tan, and many have sharply defined chambers; most, however, are flattened and distorted and have a granular texture that obscures the chambers. Some of the specimens from the core at 1,351 feet are listed as unfigured paratypes of *Verneuilinoides fischeri* Tappan by Mrs. Loeblich (Tappan, 1962), but I believe these should also be considered *D. smokyensis*?. This interpretation is justified because a suite of specimens from Gubik test well 2 shows a size range, variation in shape, and arrangement of chambers which is the same as those given in the description of *D. smokyensis* Wall from the Puskwaskau Shale and the upper part of the Kaskapau Shale (Wall, 1960), both of early Senonian age, from Smokey River, Alberta.

Most of the tests of *Trochammina ribstonensis* in the sample from 1,351 feet are flattened, granular, light-tan discs, but associated with them are small circular trochoid specimens that have few chambers in the last whorl and a few highly trochoid pyritized specimens that are conical in peripheral view. All these conical specimens may be young forms of *T. ribstonensis*, as the early part of the tests seem to have fewer chambers than the adult stage. They closely resemble *T. albertensis* Wickenden from the Bearpaw Formation of Alberta.

Crushed and distorted specimens of *T. ribstonensis*? were common to abundant in core samples from 1,482–

FIGURE 49.—*Dorothia smokyensis* Wall?, showing range in size, and variation in shape of tests due to distortion, Schrader Bluff Formation, Gubik test well 2, core at 1,351 feet. × 20.

1,502 feet in test well 2, and a few specimens are sufficiently pyritized to have preserved the original high trochoid spire and globular shape of the tests. A few Foraminifera came from a core at 1,578–1,580 feet, and common specimens of *Trochammina whittingtoni* Tappan? and *Saccammina lathrami* Tappan were found in a core sample from 1,731–1,737 feet. All the specimens of *T. whittingtoni?* are crushed and identification is somewhat indefinite; the small gray tests of *Saccammina lathrami* are subspherical to discoidal. A plant fossil from 1,484 feet was identified by R. W. Brown as *Credneria elegans* Hollick; and one from a core sample at 1,915 feet, as *Trapa? microphylla* Lesquereux, a water plant. The latter was the only fossil in the cored interval from 1,813–1,984 feet.

Pseudoclavulina hastata–Arenobulimina torula faunal zone

At the time that the Gubik wells were drilled, the fossiliferous beds penetrated at 1,910–2,030 feet in test well 1 and at 2,079–2,218 feet in test well 2 were placed in what is now regarded as the lower part of the Schrader Bluff Formation. By the present definition of the Seabee Formation and from fragments of *Pseudoclavulina hastata* (Cushman) and a few specimens of *Arenobulimina torula* Tappan in cores from 2,129–2,218 feet in Gubik test well 2, these beds are now included in the upper part of the Seabee Formation of Turonian age. These two distinctive species give the name to the faunal zone that is characteristic of the Ayiyak Member of the Seabee Formation in outcrop and its subsurface stratigraphic equivalent in Umiat test well 11. The zone is not considered to include all the Seabee Formation. Other microfossils found in this zone in Gubik test well 2 are abundant specimens of *Haplophragmoides rota* Nauss in cores at 2,170–2,218 feet; specimens of *Praebulimina seabeensis* Tappan and pyritic casts of the radiolarian "*Zonodiscus*" sp. A were common in a core at 2,180–2,190 feet.

By correlation, it is apparent that the ditch sample interval 1,910–2,030 feet in test well 1 is the same faunal zone, although the zone is poorly developed in that well. Crushed and distorted specimens of *Haplophragmoides rota* were common in two ditch samples in test well 1; associated in the same interval were a few specimens each of *Trochammina whittingtoni*, *Trochammina ribstonensis*, and pyritic casts of two species of Radiolaria. All are very poorly preserved.

Specimens of *Haplophragmoides rota* from test well 2 are so numerous that, although most are crushed and distorted, some of the flattened tests can be identified from their narrow periphery, triangular outline of chambers, and depressed central part. The spiral tests of *Arenobulimina torula* are approximately cup shaped; the apertural end is shallow and concave, and three or four chambers make up the last whorl; the sutures are distinct and diagonal to the axis. Flattened specimens have a roughly triangular outline and crushed specimens have a lumpy appearance, but the spiral arrangement of chambers in the specimens is usually discernible. Specimens of *Pseudoclavulina hastata* are distinctive, even though fragmentary or crushed. Tests are subcylindrical, tapered at the initial biserial end, and the sides are parallel on elongate uniserial sections; the sutures are a darker color than the walls. Specimens of *Praebulimina seabeensis* are triserial and tapered or slightly fusiform; they are light tan but dark when filled by pyrite. The pyritic casts of "*Zonodiscus*" sp. A are circular discs with flat edges; the slightly raised central areas are medially depressed.

Throughout the remainder of the Seabee Formation below the *Pseudoclavulina hastata–Arenobulimina torula* zone in each well, there were only intermittent occurrences of a few Foraminifera and Radiolaria which are common to the entire Colville Group. Some of the cores contained *Inoceramus* shell fragments, and fishbone fragments were common in many ditch samples in Gubik test well 1. In Gubik test well 2, distorted tests of a large unusually coarse-grained species of *Trochammina* (*T. diagonis* (Carsey)?) were abundant, and flattened, twisted, coarse-grained specimens of *Gaudryina irenensis* Stelck and Wall? were common in a core at 3,100–3,110 feet and abundant in one at 3,620–3,630 feet. The coarse texture of the specimens obscures the sutures and much of the walls of the tests. In a core at 3,368–3,380 feet, small tests of *Neobulimina albertensis* (Stelck and Wall) were common.

A few Radiolaria occurred in test well 2 samples. Tiny subspherical gray tests are *Spongurus* (*Spongurantha*) sp. A, which were common at 3,030–3,040 feet; and at 3,060–3,070 feet, there occurred pyritic casts of a conical species (*Dictyomitra* sp.) that has four or five joints but lacks the longitudinal ridges of *D. multicostata* Zittel. Pyritic discs, common in a sample at 3,150–3,155 feet, are the casts of "*Zonodiscus*" sp. C; they are 0.1–0.2 mm in diameter and have convex sides and flattened edges.

Gaudryina–Trochammina zone, Ninuluk and Chandler Formations undifferentiated

The abrupt appearance in both wells of a fauna that is dominantly composed of two arenaceous species may represent the faunal zone that characterizes the Ninuluk Formation. Tests are poorly preserved and characteristics are difficult to discern; with some hesitation specimens are identified as *Gaudryina irenensis* Stelck and Wall? and *Trochammina ribstonensis* Wickenden. The latter may possibly be *T. ribstonensis* subsp. *rutherfordi*. To the west in Titaluk test well 1 and Wolf Creek test well 3, the *Gaudryina irenensis–Trochammina rutherfordi* faunal zone is conspicuously developed through a few hundred feet of section of the Ninuluk Formation. If the formation is present in the Gubik wells, it is limited to an interval 40–50 feet thick, at the top of a sequence of nonfossiliferous sandy beds.

In beds that may be the Ninuluk Formation in the Gubik wells, specimens of *Gaudryina irenensis*?, *Trochammina ribstonensis*, and *Saccammina lathrami* Tappan are common to abundant; a few specimens of *Miliammina* sp. and pyritic casts of "*Zonodiscus*" sp. C are associated with them. Casts of a small unidentified pelecypod occurred a few feet below the microfossils in each test hole. The Foraminifera are more poorly preserved than are those usually found in the *Gaudryina irenensis–Trochammina rutherfordi* zone, and specimens from test well 1 are more crushed and distorted than those from test well 2. The tests of *Gaudryina irenensis*? are brown, very narrow, elongate, and flattened; they have collapsed chambers, and none show the cylindrical shape of the normal test as preserved in pyritized specimens. In fact, it cannot be determined with certainty whether the tests are triserial in the initial part. The tests identified as *Trochammina ribstonensis* are so flattened and distorted that specific identifications are not certain. They might be the subspecies *T. ribstonensis rutherfordi*, but this inference is only by comparison with similar specimens associated with well preserved tests in samples from the Ninuluk Formation in other areas. The fine-textured gray tests of *Saccammina lathrami* are compressed and distored, and few have the normal circular outline.

As most of the standstone beneath the thin fossil zone of *Gaudryina* and *Trochammina* may be part of the nonmarine Chandler Formation, a sequence of approximately 440 feet of beds lying above the *Verneuilinoides borealis* faunal zone is considered as undifferentiated Ninuluk and Chandler Formations. This designation follows Robinson's interpretation (Robinson, 1958a, p. 211) of the section.

LOWER CRETACEOUS (MIDDLE TO UPPER ALBIAN) ROCKS

Verneuilinoides borealis faunal zone

Beds of Albian age in the Gubik wells are those in which the shallow-water marine *Verneuilinoides borealis* fauna prevails. The *V. borealis* faunal zone includes rocks which might be considered the Tuktu faunal facies of the Grandstand and Tuktu Formations undifferentiated and a part of the Torok Formation. The term Topagoruk Formation as used by Robinson (1958a) is not considered applicable here.

In the upper part of the *Verneuilinoides borealis* zone in the Gubik wells, the fauna is sparse and is composed almost entirely of arenaceous species; the specimens are generally very poorly preserved and are much like the poorest found in some intervals of the zone in wells of the Umiat field.

In Gubik test well 1 the first common foraminifer of the faunal zone is *Verneuilinoides borealis* Tappan at 3,845–3,850 feet, about 110 feet below the top of what Robinson (Robinson, 1958a, p. 214) designated the Grandstand Formation. Specimens, however, are not typical as they are small and poorly preserved. Fragments of *Ammobaculites wenonahae* Tappan were found in ditch samples from 3,805–3,870 feet, and tiny flattened specimens of *Trochammina* cf. *T. gatesensis* Stelck and Wall occurred in numerous samples. This species was very abundant in the core samples from 3,900–3,920 feet, where pyritic casts of "*Zonodiscus*" sp. C and of *Reophax troyeri* Tappan were common. Distorted small tests of *Haplophragmoides* found in ditch samples from 3,845–3,890 feet may be immature forms of *Haplophragmoides topagorukensis* Tappan.

Tiny tests of *Trochammina umiatensis* Tappan appeared first in test well 1 in a ditch sample from 3,885–3,890 feet and were common to abundant in the aforementioned core at 3,900–3,920 feet. Most of these specimens are distorted and difficult to identify, but a few pyritic casts match rather well with the smaller specimens of *T. umiatensis* from wells in the Umiat field; there the species is an important horizon marker in the Tuktu faunal facies of the Grandstand and Tuktu Formations undifferentiated, and large specimens are easily identified because the tests are very bulbous and show a sudden expansion of the last four chambers. This expansion is not well developed on the small specimens from either of the Gubik wells.

A small size or dwarfed condition seems to be a characteristic of many of the Foraminifera in the upper part of the *Verneuilinoides borealis* zone of both wells. All specimens of *Verneuilinoides borealis* are much shorter than the typical form, and the sutures and outline of the chambers are indistinct.

All the cores and most of the ditch samples between 3,955 and 4,305 feet in test well 1 were barren of microfossils except for a very rare occurrence of a half dozen badly preserved specimens in the core at 4,020–4,034 feet and except for one specimen of *Frondicularia guestphalica* Reuss, embedded in a chip of claystone from a core at 4,269 feet. The specimen of *F. guestphalica* was found by C. A. Everett, well geologist, during the drilling operations.

Most of the Foraminifera found in the upper part of the *Verneuilinoides borealis* zone in test well 2 came from samples grouped through 180–190 feet of section (4,060–4,243 ft). Near the top of this interval were fragments of the smooth, tapered shells of *Ditrupa cornu* Imlay; high in the zone, in the core from 4,060–4,075 feet, flattened specimens of *Haplophragmoides topagorukensis* were common, and fragments of *Ammobaculites wenonahae* and a few specimens of *Verneuilinoides borealis* occurred in the same sample. Small, very poorly preserved specimens of *V. borealis* were common in two samples, at 4,150 feet and at 4,210 feet, and pyritic casts of *Trochammina umiatensis* were common at 4,210 feet and 4,225–4,230 feet. Some specimens of the latter are a little larger than the average-sized specimen found in test well 1, but none are equal to the large bulbous specimens found in the Umiat wells or in Fish Creek test well 1.

The predominantly shale sequence below 4,315 feet in test well 1 and 4,395 feet in test well 2 has been referred to the Topagoruk Formation by Robinson (Robinson 1958a, p. 212) but would be within the upper part of the Torok Formation as used in this report. Species of the *Verneuilinoides borealis* faunal zone were found throughout these beds but only rarely was one relatively abundant. In test well 1, small distorted tests of probable *Haplophragmoides topagorukensis* were very abundant in the first core at 4,352–4,372 feet and were common in a ditch sample at 4,410–4,415 feet. Small distorted tests of *Trochammina* cf. *T. gatesensis* were also common in the latter sample. Pyritic casts of a stichocorythidian radiolarian (*Dictyomitra* sp.) were common at 4,375 feet and cannot be distinguished from the pyritic casts that constitute an indefinite zone in the lower beds of the Torok Formation and the "Oumalik" Formation of the subsurface. Small compressed, and somewhat granular tests of *Verneuilinoides borealis* and small distorted tests of *Haplophragmoides topagorukensis* were common in a core at 5,100–5,115 feet and were abundant in a ditch sample at 5,270–5,280 feet. As many of these specimens are as poorly preserved as those in the upper beds of the *V. borealis* zone, they are questionably identified.

Foraminifera were relatively few in samples from the interval between 4,410 and 5,100 feet and from 5,115 feet to the total depth of test well 1. Exceptions, however, are the numerous small specimens of *Haplophragmoides topagorukensis* and very abundant small specimens of *Verneuilinoides borealis* at 5,270–5,280 feet and the very abundant specimens of *Trochammina* cf. *T. gatesensis* at 5,510–5,520 feet. Two cores (5,100–5,115 ft and 5,441–5,448 ft) contained a few calcareous *Foraminifera* from the *Verneuilinoides borealis* faunal zone. Radiolaria in a core at 5,758–5,768 feet include common specimens of *Theocampe?* sp., but Foraminifera were very rare. The lowest core at 5,982–6,000 feet had only a few specimens of *Trochammina* cf. *T. gatesensis* Stelck and Wall, one specimen of *Conorboides umiatensis* (Tappan), and few questionably identified specimens. In the samples from 225 feet of clay shale (Torok(?) Formation) penetrated in the lower part of test well 2, only a very few poorly preserved arenaceous Foraminifera were found, but all were species of the *V. borealis* faunal zone. The last two cores (4,502–4,522 ft and 4,600–4,620 ft) were barren.

SELECTED REFERENCES

Bergquist, H. R., 1951, Recent developments in paleontological studies: Naval Petroleum Reserve No. 4, Alaska, spec. rept. 29, U.S. Geol. Survey open-file report.

——— 1952, Micropaleontological studies in 1952: Naval Petroleum Reserve No. 4, Alaska, spec. rept. 39, U.S. Geol. Survey open-file report.

——— 1956a, Microfossil zones in Cretaceous rocks of northern Alaska [abs.]: Geol. Soc. America Bull. v. 67, no. 12, pt. 2, p. 1670.

——— 1956b, Paleontology of test wells and core tests in the Oumalik area, Alaska, *in* Robinson, F. M., Core tests and test wells, Oumalik area, Alaska: U.S. Geol. Survey Prof. Paper 305–A, p. 65–68.

——— 1958a, Micropaleontologic study of the Umiat field, northern Alaska, *in* Collins, F. R., Test wells, Umiat area, Alaska: U.S. Geol. Survey Prof. Paper 305–B, p. 199–204.

——— 1958b, Micropaleontologic study of the Gubik test wells, northern Alaska, *in* Robinson, F. M., Test wells, Gubik area, Alaska: U.S. Geol. Survey Prof. Paper 305–C, p. 259–261.

Bergquist, H. R., 1958c, Micropaleontologic study of the Topagoruk wells, northern Alaska, *in* Collins, F. R., Test wells, Topagoruk area, Alaska: U.S. Geol. Survey Prof. Paper 305–D, p. 311–314.

———1958d, Micropaleontologic study of Grandstand test well 1, northern Alaska, *in* Robinson, F. M., Test well, Grandstand area, Alaska: U.S. Geol. Survey Prof. Paper 305–E, p. 337–338.

———1958e, Micropaleontology of Meade test well 1, and Kaolak test well 1, northern Alaska, *in* Collins, F. R., Test wells, Meade and Kaolak areas, Alaska: U.S. Geol. Survey Prof. Paper 305–F, p. 373–374.

———1959a, Micropaleontologic study of test wells in the Titaluk and Knifeblade areas, northern Alaska, *in* Robinson, F. M., Test wells, Titaluk and Knifeblade areas, Alaska: U.S. Geol. Survey Prof. Paper 305–G, p. 417–419.

——— 1959b, Micropaleontology of Square Lake test well 1 and the Wolf Creek test wells, northern Alaska, *in* Collins, F. R., Test wells, Square Lake and Wolf Creek areas, Alaska: U.S. Geol. Prof. Paper 305–H, p. 479–482.

——— 1960, Occurrence of Foraminifera and Conodonts in Upper Paleozoic and Triassic rocks, northern Alaska: Jour. Paleontology, v. 34, no. 3, p. 596–601, 1 text fig.

Bowsher, A. L., and Dutro, J. T., Jr., 1957, The Paleozoic section in the Shainin Lake area, central Brooks Range, Alaska: U.S. Geol. Survey Prof. Paper 303–A, p. 1–39, pls. 1–6, 4 figs.

Campbell, A. S., 1954, Radiolaria, *in* Campbell, A. S. and Moore, R. C., eds., Treatise on Invertebrate Paleontology, pt. D, Protista 3: p. 11–163.

Campbell, A. S., and Clark, B. L., 1944, Radiolaria from Upper Cretaceous of middle California: Geol. Soc. America Spec. Paper 57, 61 p.

Chapman, R. M., and Sable, E. G., 1960, Geology of the Utukok-Corwin region, northwestern Alaska: U.S. Geol. Survey Prof. Paper 303–C, p. 47–167, 13 pls., 18 figs.

Chapman, R. M., and others, 1964, Geology of the Killik-Etivluk Rivers region, Alaska: U.S. Geol. Survey Prof. Paper 303–F, p. 325–407.

Clark, B. L., and Campbell, A. S., 1942, Eocene radiolarian faunas from the Mt. Diablo area, California: Geol. Soc. America Spec. Paper 39, 112 p.

Cobban, W. A., and Gryc, George, 1961, Ammonites from the Seabee Formation (Cretaceous) of northern Alaska: Jour. Paleontology, v. 35, no. 1, p. 176–190.

Collins, F. R., 1958a, Test wells, Umiat area, Alaska: U.S. Geol. Survey Prof. Paper 305–B, p. 71–198, 5 pls., 4 figs.

——— 1958b, Test wells, Topagoruk area, Alaska: U.S. Geol. Survey Prof. Paper 305–D, p. 265–309, 2 pls., 4 figs.

——— 1958c, Test wells, Meade and Kaolak areas, Alaska: U.S. Geol. Survey Prof. Paper 305–F, p. 341–371, 4 pls., 5 figs.

——— 1959, Test wells, Square Lake and Wolf Creek areas, Alaska: U.S. Geol. Survey Prof. Paper 305–H, p. 423–477, 2 pls., 6 figs.

——— 1961, Core test and test wells, Barrow area, Alaska: U.S. Geol. Survey Prof. Paper 305–K, p. 569–644, 5 pls., 3 figs.

Dall, W. H., 1919, Mollusks, Recent and Pleistocene: Report of the Canadian Arctic Expedition 1913–18, v. 8, pt. A, Ottawa.

Detterman, R. L., 1956, New and redefined nomenclature of Nanushuk Group, *in* Gryc, George, and others, Mesozoic sequence in Colville River region, northern Alaska: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 2, p. 209–254.

Detterman, R. L., Bickel, R. S., and Gryc, George, 1963, Geology of the Chandler River region, Alaska: U.S. Geol. Survey Prof. Paper 303–E, p. 223–324, 16 pls., 21 figs.

Eicher, Don L., 1960, Stratigraphy and micropaleontology of the Thermopolis Shale: Yale Univ. Peabody Mus. Nat. History, Bull. 15, 126, p., 5 pls.

Geroch, S., 1957, *Uvigerinammina jankoe* Majzon (*Foraminifera*) in the Carpathian Flysch: Soc. géol. Pologne Ann., v. 25, pt. 3, p. 231–244, pls. 14, 15.

——— 1959, Stratigraphic significance of arenaceous Foraminifera in the Carpathian Flysch: Paläont. Zeitschr., v. 33, no. 12, p. 113–122, pls. 12, 13, text figs. 1, 2.

Gryc, George, Patton, W. W., Jr., and Payne, T. G., 1951, Present Cretaceous stratigraphic nomenclature of northern Alaska: Washington Acad. Sci. Jour., v. 41, no. 5, p. 159–167.

Gryc, George, and others, 1956, Mesozoic sequence in Colville River region, northern Alaska: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 2, p. 209–254.

Imlay, R. W., 1955, Characteristic Jurassic mollusks from northern Alaska: U.S. Geol. Survey Prof. Paper 274–D, p. 69–95, pls. 8–13, 1 fig.

——— 1961, Characteristic Lower Cretaceous megafossils from northern Alaska: U.S. Geol. Survey Prof. Paper 335, 71 p., 24 pls., 1 fig. [1962].

Imlay, R. W., and Reeside, J. B., Jr., 1954, Correlation of the Cretaceous formations of Greenland and Alaska: Geol. Soc. America Bull., v. 65, p. 223–246; 2 figs., 1 pl.

Jones, D. L., and Grantz, Arthur, 1964, Stratigraphic and structural significance of Cretaceous fossils from Tiglukpuk Formation, northern Alaska: Am. Assoc. Petroleum Geologists Bull., v. 48, no. 9, p. 1462–1474, 3 pls., 4 figs.

Jones, D. L., and Gryc, George, 1960, Upper Cretaceous pelecypods of the genus *Inoceramus* from northern Alaska: U.S. Geol. Survey Prof. Paper 334–E, p. 149–165, pls. 15–23, figs. 30–33.

Keller, A. S. Morris, R. H., and Detterman, R. L., 1961, Geology of the Shaviovik and Sagavanirktok Rivers region, Alaska: U.S. Geol. Survey Prof. Paper 303–D, p. 169–219, 6 pls., 7 figs.

Leffingwell, E. de K., 1919, The Canning River region, northern Alaska: U.S. Geol. Survey Prof. Paper 109, 251 p., 33 figs., 35 pls.

Loeblich, A. R., Tappan, Helen, and others, 1964, *in* R. C. Moore, ed., Treatise on invertebrate paleontology, Part C, Protista 2 (Sarcodina, Thecamoebians, Foraminiferida): Geol. Soc. America Bull. and Univ. Kansas Press, 2 v., 931 p.

Loeblich, H. N., 1948, Comments on Mrs. Plummer's report on micropaleontology of the Simpson area: Naval Petroleum Reserve No. 4, Alaska, spec. rept. 1, U.S. Geol. Survey open-file report.

——— 1949, Progress report on microfossil studies in Washington: Naval Petroleum Reserve No. 4, Alaska, spec. rept. 11, U.S. Geol. Survey open-file report.

MacNeil, F. S., 1957, Cenozoic megafossils of northern Alaska: U.S. Geol. Survey Prof. Paper 294–C, p. 99–125, pls. 11–17.

Mellon, G. B., and Wall, J. H., 1956, Foraminifera of the upper McMurray and basal Clearwater formations, pt. 1 *of* Geology of the McMurray formation: Alberta Research Council Rept. 72, p. 1–29, 4 figs., 2 pls.

Morris, R. H., 1955, Reconnaissance study of the Marsh anticline, northern Alaska: U.S. Geol. Survey open-file report, 6 p.

Nauss, A. W., 1947, Cretaceous microfossils of the Vermillion area, Alberta: Jour. Paleontology, v. 21, no. 4, p. 329–343, pls. 48, 49.

Patton, W. W., Jr., 1956a, New formation of Jurassic age, *in* Gryc, George, and others, Mesozoic sequence in Colville River region, northern Alaska: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 2, p. 213–219.

——— 1956b, New and redefined formations of Early Cretaceous age, *in* Gryc, George, and others, Mesozoic sequence in Colville region, northern Alaska: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 2, p. 219–223.

——— 1957, A new Upper Paleozoic formation, central Brooks Range, Alaska: U.S. Geol. Survey Prof. Paper 303–B. p. 41–45.

——— 1959, Geology of the upper Killik-Itkillik region, Alaska: U.S. Geol. Survey open-file report.

Patton, W. W., Jr., and Matzko, J. J., 1959, Phosphate deposits in northern Alaska: U.S. Geol. Survey Prof. Paper 302–A. 17 p., 6 pls., 3 figs.

Payne, T. G., and others, 1951, Geology of the Arctic slope of Alaska: U.S. Geol. Survey Oil and Gas Inv. Map OM–126. 3 sheets.

Plummer, H. J., 1948, Stratigraphy and paleontology in the Simpson area: Naval Petroleum Reserve No. 4, Alaska. spec. rept. 1, U.S. Geol. Survey open-file report.

Robinson, F. M., 1956, Core tests and test wells, Oumalik area, Alaska: U.S. Geol. Survey Prof. Paper 305–A, p. 1–64, 6 pls., 6 figs.

——— 1958a, Test wells, Gubik area, Alaska: U.S. Geol. Survey Prof. Paper 305–C, p. 207–260, 4 pls., 3 figs.

——— 1958b, Test well, Grandstand area, Alaska: U.S. Geol. Survey Prof. Paper 305–E, p. 317–336, 2 pls., 5 figs.

——— 1959a, Test wells, Titaluk and Knifeblade areas, Alaska: U.S. Geol. Survey Prof. Paper 305–G, p. 377–416, 4 pls., 5 figs.

——— 1959b, Test wells, Simpson area, Alaska; U.S. Geol. Survey Prof. Paper 305–J, p. 523–568, 4 pls., 5 figs.

——— 1964, Core tests, Simpson area, Alaska: U.S. Geol. Survey Prof. Paper 305–L, p. 645–730, 7 pls., 6 figs.

Robinson, F. M., and Collins, F. R., 1959, Core test, Sentinel Hill area and test well, Fish Creek area, Alaska: U.S. Geol. Survey Prof. Paper 305–I, p. 485–521, 4 pls., 5 figs.

Robinson, F. M., Rucker, F. P., and Bergquist, H. R. 1956, Two subsurface formations of Early Cretaceous age, *in* Gryc, George, and others, Mesozoic sequence in Colville River region, northern Alaska: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 2, p. 210–254.

Rubey, W. W., 1929, Origin of the siliceous Mowry shale of the Black Hills region: U.S. Geol. Survey Prof. Paper 154–D, p. 153–170.

Rust, A., 1892, Radiolaria from the Pierre Formation of northwestern Manitoba: Canada Geol. Survey Contr. Micropaleontology, pt. 4, p. 101–111.

Sable, E. G., 1956, New and redefined Cretaceous formations in western part of northern Alaska: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 11, p. 2635–2643.

Schrader, F. C., 1904, A reconnaissance in northern Alaska: U.S. Geol. Survey Prof. Paper 20, 139 p., maps.

Smith, P. S., and Mertie, J. B., Jr., 1930, Geology and mineral resources of northern Alaska: U.S. Geol. Survey Bull. 815, 351 p., 22 figs., 34 pls.

Stelck, C. R., and Wall, J. H., 1954, Kaskapau Foraminifera from Peace River area of western Canada: Alberta Research Council Rept. 68, 38 p., 2 pls., 5 text figs.

Stelck, C. R., and Wall, J. H., 1955, Foraminifera of the Cenomanian *Dunveganoceras* zone from Peace River area of western Canada: Alberta Research Council Rept. 70, 62 p., 3 pls.

Stelck, C. R., and Wall, J. H., Bahan, W. G., and Martin, L. J., 1956, Middle Albian Foraminifera from Athabasca and Peace River drainage areas of western Canada: Alberta Research Council Rept. 75, 60 p., 2 figs., 5 pls.

Swain, F. M., Jr., 1949, Ostracods from well, shot hole, and outcrop samples in Naval Petroleum Reserve No. 4: U.S. Geol. Survey open-file report 27.

——— 1959, Quaternary Ostracoda from Naval Petroleum Reserve No. 4, northern Alaska [abs.]: Canadian Oil and Gas Industries, v. 12, no. 12, p. 61–62.

——— 1963, Pleistocene Ostracoda from the Gubik Formation, Arctic Coastal Plain, Alaska: Jour. Paleontology, v. 37, no. 4, p. 798–834, pls. 95–99, 13 text figs.

Tappan, Helen, 1940, Foraminifera from the Grayson formation of northern Texas: Jour. Paleontology, v. 14, no. 2, p. 93–126, pls. 14–19.

——— 1943, Foraminifera from the Duck Creek formation of Oklahoma and Texas: Jour. Paleontology, v. 17, no. 5, p. 476–517, pls. 77–83.

——— 1951a, Northern Alaska index Foraminifera: Cushman Found. Foram. Research Contr. v. 2, pt. 1, p. 1–8, pl. 1.

——— 1951b, Micropaleontology, *in* Payne, T. G., and others, Geology of the Arctic Slope of Alaska: U.S. Geol. Survey Oil and Gas Inv. Map OM–126, 3 sheets

——— 1951c, Triassic Foraminifera, general introduction and pt. 1 *of* Foraminifera from the Arctic slope of Alaska: U.S. Geol. Survey Prof. Paper 236–A, p. 1–20, pls. 1–5, 2 figs.

Tappan, Helen, 1955, Jurassic Foraminifera, pt. 2 *of* Foraminifera from the Arctic slope of Alaska: U.S. Geol. Survey Prof. Paper 236–B, p. 21–90, pls. 6–28, text figs. 3–9; 1 chart.

——— 1957, New Cretaceous index Foraminifera from northern Alaska: U.S. Natl. Mus. Bull. 215, p. 201–222, text fig. 29, pls. 65–71.

——— 1960, Cretaceous biostratigraphy of northern Alaska: Am. Assoc. Petroleum Geologists, Bull., v. 44, no. 3, p. 273–297, text figs. 1–7, pls. 1, 2.

——— 1962, Cretaceous Foraminifera, pt. 3 *of* Foraminifera from the Arctic slope of Alaska: U.S. Geol. Survey Prof. Paper 236–C, p. 91–209, pls. 29–58, text figs. 10–18.

Todd, Ruth, 1957, Foraminifera from Carter Creek northeastern Alaska: U.S. Geol. Survey Prof. Paper 294–F, p. 223–235, pls. 28, 29, text figs 81.

Wall, J. H., 1960, Upper Cretaceous Foraminifera from the Smoky River area, Alberta: Alberta Research Council Bull. 6, 43 p., 5 pls.

Whittington, C. L., 1956, Revised stratigraphic nomenclature of Colville group, *in* Gryc, George, and others, Mesozoic sequence in Colville River region, northern Alaska: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 2, p. 244–253.

Wickenden, R. T. D., 1945, Mesozoic stratigraphy of the eastern plains, Manitoba and Saskatchewan: Canada Geol. Survey Mem. 239, pub. 2472, 4, 87 p., 5 pls., 2 figs., 3 maps.

——— 1948, *Eoeponidella*, a genus from the Upper Cretaceous: Royal Soc. Canada Trans., 3d ser., v. 42, sec. 4, p. 81–82, fig. 1.

Woolson, J. R., and others, 1962, Seismic and grativity surveys of Naval Petroleum Reserve No. 4 and adjoining areas, Alaska: U.S. Geol. Survey Prof. Paper 304–A, p. 1–25 [1963].

INDEX

[Italic page number indicates major reference]

775-799 O - 66 - 13

Exploration of Naval Petroleum Reserve No. 4 and Adjacent Areas Northern Alaska, 1944-53

PART 2, REGIONAL GEOLOGY

GEOLOGICAL SURVEY PROFESSIONAL PAPER 302

This volume was published as separate chapters A-D

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

William T. Pecora, *Director*

CONTENTS

[The letters in parentheses preceding the titles designate separately published chapters]

U.S. GOVERNMENT PRINTING OFFICE: 1966 O—775-799