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Preliminary Report 41

STRATIGRAPHY AND STRUCTURE OF THE GRANDSTAND AND HAWK ANTICLINES AND VICINITY, ALASKA

by

Robert L. Detterman and Robert S. Bickel

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CONTENTS

ILLUSTRATIONS

STRATIGRAPHY AND STRUCTURE OF THE GRANDSTAND AND HAWK ANTICLINES AND VICINITY, ALASKA

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INTRODUCTION

During the 1952 field season, U. S. Geological Survey Navy Oil Unit party 2 made stratigraphic and structural studies of the rocks in the area between the easternmost fork of Ninuluk Creek and the Anaktuvuk River. This area is drained by the Ayiyak, Chandler, Siksikpuk, Tuluga, and Anaktuvuk Rivers, the Chandler and Anaktuvuk being the two major rivers of the area. The work was conducted in a rectangular area of approximately 2,000 to 2,500 square miles, which lies wholly within the Northern Foothills section of the Arctic Foothills province; within this area approximately 200 square miles was structure-contoured, covering all of Hawk and the central part of Grandstand anticlines.

The party consisted of six men: R. L. Detterman and R. S. Bickel, geologists; H. K. Lucas and C. S. Wimberley, field assistants; P. E. Peterson, cook-field assistant; and J. Kunz, weasel mechanic. The party utilized three weasels for transportation of equipment and personnel throughout the season, during which time eleven camps and several spike camps were established. Owing to the late spring, work was not started until June 9, when the party arrived on the Ayiyak River; investigations were concluded on Fossil Creek on August 27.

In 1945, G. Gryc, E. J. Webber, and K. Steffanson made reconnaissance studies of the rocks along the Chandler River, and R. E. Fellows, R. M. Chapman, and C. T. Bressler along the Anaktuvuk River 1/. G. Gryc spent a few days along Fossil Creek in the fall of 1946, and the next year the same area was revisited by R. L. Detterman and D. E. Mathewson 2/. In 1948, R. L. Detterman and W. W. Patton, Jr., spent the first part of the season traversing the Chandler River, from Tuktu Bluff to the Colville River 3/. These studies were made by the Navy Oil Unit of the U. S. Geological Survey in conjunction with the petroleum investigations of Naval Petroleum Reserve No. 4.

1/ Payne, T. G., Gryc, G., Fellows, R. E., et. al, Stratigraphy and structure of the area of the Killik, Chandler, Anaktuvuk, and Colville Rivers, Alaska: U. S. Geol. Survey Navy Oil Unit Rept. 1, 1946.

2/ Detterman, R. L., Mathewson, D. E., and Webber, E. J., Stratigraphy and structure of the area of the Colville River between Ninuluk Creek and Umiat Mountain, Alaska: U. S. Geol. Survey Navy Oil Unit Rept. 15, April 1948.

3/ Unpublished manuscript.

The primary objective of the 1952 party was (1) to field check the photogeologic structure-contour maps prepared in the Washington office by W. P. Brosge and H. N. Reiser [4], and to ascertain whether these maps were sufficiently accurate to warrant work of the same nature in the future, and (2), to carry on a limited amount of stratigraphic study of the rocks encountered. Shortly after the start of the season's work it became apparent that it would be impossible to study all three anticlines in detail; consequently, as Hawk and Grandstand anticlines seemed to be the more favorable structures, it was decided to spend most of the season investigating them. The last two weeks were spent studying Big Bend anticline. The party was slowed down somewhat by a necessary increase in the amount of stratigraphic studies when it became apparent there were some discrepancies in the earlier work, involving zones E, F, and G. (This will be discussed in full under stratigraphy).

The photogeologic structure-contour maps were found to be accurate in areas where the structures are relatively uncomplicated by faulting, and also, where there is good vertical control. In areas of little vertical control the maps were somewhat inaccurate; however, they were sufficiently accurate to warrant their use as an aid in future structure contouring. They make a good working base map for the field geologist. Details of the structure-contour maps will be discussed on page 13.

The area was mapped at a scale of 1:20,000 on vertical photographs, and transferred to trimetrogon drainage maps at scales of 1:48,000 and 1:96,000. A triangulation net was established over the southern part of the area. An altimeter traverse was carried concurrently with the triangulation net and is tied into it at all triangulation points. Poor weather and lack of time at the end of the season necessitated closing the triangulation net before the entire area was covered. Altitudes obtained from the altimeter traverses, after corrections had been made for daily pressure changes, are believed to be sufficiently accurate for the 1952 work. By this method one altimeter was always left in camp and the pressure recorded from it at frequent intervals throughout the working day. These readings were then used in making corrections for the altimeter traverse.

GENERAL GEOLOGY

Topography.--The area traversed during the 1952 field season is entirely within the Northern Foothills physiographic section. The southern edge of this section falls along the Tuktu escarpment where maximum relief is from 1,500 to 1,800 feet between the Chandler and Siksikpuk Rivers. Northward the section becomes more open with low rolling hills and reduced featureless lowlands, the monotony of which is broken only by the resistant rocks that form the core of Grandstand

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4/ Brosge, W. P., and Reiser, H. N., Progress report on photogeologic studies in the Chandler River area: U. S. Geol. Survey Navy Oil Unit Special Rept. 32, April 1952.

and Big Bend anticlines, and the mesas and synclinal ridges of basal conglomerates of zone G. The more or less featureless lowlands are in most places underlain by nonresistant shale of zone F, with numerous small lakes and small, deeply entrenched streams. The northern part of the area has a maximum relief of 400 to 500 feet.

Drainage.--The major streams of the area are mature consequent streams with well-developed floodplains. Small ice fields have developed in the wide floodplain of the Anaktuvuk River with stratified ice as much as 8 to 10 feet thick. The Tuluga River valley is much wider than a stream of its size would indicate, and there are several sets of high-level terraces, therefore, it is believed that the Siksikpuk River once flowed northward through the Tuluga drainage area. Gravel terraces are common along the major drainages. The terraces are composed of well-sorted gravels, derived at least in part from glacial moraines to the south.

Glaciation.--Pleistocene glaciers covered the southeastern part of the area traversed. Although extensive montane glaciers were known to exist to the south along the Brooks Range and Southern Foothills section, they were not heretofore known to extend this far north. Glacial deposits in this area, therefore, mark the earliest and most northerly extend of the ice in the foothills section. The advance was confined to the Anaktuvuk River valley and extended as far north as Rooftop Ridge and the ridge formed by Grandstand anticline. Glacial deposits cover an area of approximately 100 square miles, and are found at an altitude of 1,500 to 1,600 feet on Rooftop Ridge. The deposits have lost all their morainal features, existing only as low, rolling, tundra-covered hills of glacial detritus. Glacial striations have been removed from the large erratics by weathering and wind erosion, with the formation of a thin rind on the surface. The erratics are predominantly conglomerate from the Kanayut formation. The large lake just west of the Anaktuvuk River and Rooftop Ridge, and the group of lakes just south of it are believed to be glacial in origin.

STRATIGRAPHY

Sedimentary rocks in the area of Hawk, Grandstand, and Big Bend anticlines include Lower Cretaceous zone A shale and Nanushuk group (Chandler and Umiat formations); and Upper Cretaceous Colville group (Prince Creek and Schrader Bluff formations). As no detailed macrofossil or microfossil examinations have yet been completed, it must be emphasized that the positions of mapped contacts, as well as the age of some of the zones, may be subject to change. The geologic contacts and ages of rocks are based on direct field analysis. Correlated columnar sections are presented on plate 3.

Recent changes in stratigraphy

As a result of the 1952 investigations some important changes have been made involving zones E, F, and G. The conglomerate at Ayiyak Mesa, originally mapped as the uppermost bed in zone E, is now placed in the

basal part of zone G. The conglomerate can be traced eastward to the East Fork of the Tuluga River where it overlies the zone F black "paper" shale which has an abundant macrofauna including *Inoceramus labiatus*, *Scaphites* cf. *S. delicatulus*, and several other genera of ammonites. Westward from Ayiyak Mesa the same conglomerate overlies a series of shale beds that contain a microfauna believed to be typical of zones F and G. 5/

A concentrated study of zone E macrofaunas during the past year has resulted in the shifting of that zone from the uppermost part of the Lower Cretaceous to basal Upper Cretaceous. This is based on the identification of *Inoceramus* sp. (linguiform) as *Inoceramus athabaskensis* McLearn, which is found in the basal part of the Upper Cretaceous in the Kuskokwim region, northwestern Alberta and northeastern British Columbia, and also in the Upper Cenomanian of England 6/. Consequently, the contact between Upper and Lower Cretaceous is conformable and lies within the Nanushuk group. The major unconformity between zones E and F is wholly within the Upper Cretaceous.

Lower Cretaceous rocks

Zone A shale

The zone A shale sequence in the area under discussion was mapped south of Tuktu Bluff in 1948 7/. Approximately 3,500 feet was measured in a series of cut banks along the Chandler River; intricate folds within this shale unit make an accurate measurement impossible. In the past this sequence of rock was referred to as the Upper Torok unit of the Lower Cretaceous 8/. The present authors believe that the shale unit forms a continuous sequence of deposition with the overlying Nanushuk group and thus should be called zone A; however, it must be emphasized that this does not necessarily mean an age different from that suggested by Patton for the unit. It is thought that an unconformity may exist between this sequence and the graywacke sandstone-chert granule conglomerate section underlying the shales. However, this cannot be definitely proven owing to poor exposures over part of the area.

The zone A rocks are a monotonous sequence of clay and silt shale with numerous thin interbeds of limy siltstone and hard dense limestone. Downward the shale becomes progressively more silty, brittle, and has a distinctive hackly fracture. Ironstone and marcasite concretions are commonly found in layers in the silt shale sections. The clay shale is blue gray with an occasional ferruginous band, and crumbly to well indurated. The beds vary from paper thin to several inches in thickness. Commonly the siltstones are micaceous and more rarely carbonaceous.

5/ Bergquist, H. R., Memorandum on microfossils from zone E along the Ayiyak River, August 1952.
6/ Imlay, R. W., Memorandum to George Gryc, May 27, 1952.
7/ Detterman, R. L., and Patton, W. W. Jr., op cit., p. 3.
8/ Patton, W. W. Jr., and Tailleur, I. L., Stratigraphy and structure of the Okpikruak and Kiruktagiak Rivers area, Alaska: U. S. Geol. Survey Navy Oil Unit Prelim. Rept. 25, November 1949.

Macrofossils are absent from the section and of the 105 microfossil samples collected approximately 85 percent were barren. The samples that were not barren contained only a few genera of long-ranging Lower Cretaceous microfossils.

Nanushuk group

Sedimentary rocks of the Nanushuk group are exposed throughout much of the area traversed. North of the junction of the Ayiyak, Chandler, and Siksikpuk Rivers they occur primarily as the resistant cores of Grandstand and Big Bend anticlines. The southern limit of this group is the prominent Tuktu escarpment, composed of zone B marine sandstone and shale, which are capped by resistant zone C sandstones. The Nanushuk group differs considerably from the underlying rocks, but the change is more or less gradational. Whereas the older rocks are true graywackes, the Nanushuk group is more a subgraywacke.

Zone B.--The zone B Tuktu Bluff section measured in 1948 is shown in this report on plate 3, column 5. Inasmuch as no major time break is indicated between zone A shale and zone B the contact has been put arbitrarily at the first appearance of the marine fossiliferous sandstone. The sandstone is separated from the shale outcrops by several hundred feet of covered area. There may be an unconformity between the units as the shale dips northward from 30° to 50°, whereas the sandstone has a 10° to 15° dip to the north. This discrepancy may indicate an angular break or may have resulted from the relative incompetency of the shale unit.

The marine zone B section at Tuktu Bluff is approximately 1,040 feet thick and consists of interbedded shaly to massive sandstone, siltstone, and silt shale. Sandstone, comprising about 60 percent of the total thickness, is a subgraywacke, very fine grained, silty, argillaceous, slightly calcareous, dark gray to green, and commonly weathers rusty brown. It is predominantly thin-bedded to shaly bedded, becoming somewhat more massive toward the top. A thin seam of chert pebble-granule conglomerate occurs near the base of the section. Oscillation ripple marks, worm trails, plant fragments, and ironstone nodules are common features of these sandstones; cross bedding occurs in the thin-bedded part. Sandy siltstone and silt shale comprise the remainder of zone B at Tuktu Bluff.

The entire zone B section is marine; however, it is not fossiliferous throughout. The fossils are moderately abundant in several well-defined zones associated with the sandstone in the lower part of the section. Cleoniceras sp., Dentalium sp., and the pelecypods, Inoceramus sp., Pleuromya sp., and Tellina sp. have been found in these horizons.

Zone C.--The type zone C section measured along the Chandler River in 1948 has been included in this report (pl. 3, column 5); it is 1,000 to 1,100 feet thick. In addition, two incomplete sections were measured; one of approximately 200 feet near the axis of Big Bend anticline on the Chandler River, and one of 300 to 400 feet on the south side of the axis of Grandstand anticline on the Anaktuvuk River.

In the type section, zone C is defined as that part of the Nanushuk group that includes the strandline sandstones and marginal deposits. The lower contact is placed at the first appearance of the coarse-grained, heavy-bedded, salt-and-pepper sandstone that caps Tuktu Bluff, and the upper contact is arbitrarily placed at the base of the first massive conglomerate. To the north this sequence becomes more marine. The lower, heavy-bedded, clean-appearing, salt-and-pepper sandstone becomes progressively finer grained and more silty higher in the section. Near the top it is fine-grained, dirty, dark yellow-red, typically nonmarine sandstone that weathers to a rusty brown. Interbeds of siltstone and silt shale are common in the upper part. Some coal float was noted about the middle of the section and ironstone concretions are common in the silt shale sections. A few sandstone concretions up to 2 feet in diameter were found in the lower part; some of these contained Inoceramus sp. (subround).

The northernmost occurrence of zone C differs considerably from the type locality (pl. 3, column 7). Here it is a marine section similar in appearance to the zone B type section at Tuktu Bluff, and consists of a series of interbedded sandstone, mudstone, siltstone, and silt shale. The sandstone is typically marine, thin- to medium-bedded, dirty, calcareous, dark gray to greenish brown, and weathers brown; some of the beds are laminated. Siltstone and mudstone comprise about 60 percent of the total thickness. They are dark gray, micaceous, carbonaceous, and show a ropy flow structure. Ironstone nodules and marcasite concretions are moderately abundant throughout the section.

The megafossil assemblage, typical of zone B to the south, again occurs in this section, with Cleoniceras sp. ?, Inoceramus sp. (subround), Dentalium sp., Pecten sp., Protocardium sp., and Tellina sp., found throughout the sandy part of the sequence.

The section of zone C on the Anaktuvuk River, (pl. 3, column 13), is about midway between the two exposures on the Chandler River, and it represents a transitional stage from the nonmarine southerly facies to the northerly marine. Here it is predominantly a sandstone section, thin- to heavy-bedded, fine- to medium-grained, medium yellow-red to gray with a greenish cast, somewhat argillaceous to clean. A few siltstone beds occur near the base. Fossils are absent from this unit.

Zone D.--In its type locality zone D is defined as the nonmarine conglomerate, sandstone, and coal sequence immediately above zone C, and underlying the marine zone E sequence (pl. 3, column 5). The contact with zone C is gradational and is arbitrarily placed at the first appearance of the massive white quartz conglomerate. The thickness of zone D in the area traversed ranges from 1,750 to 1,900 feet. Owing to the resistant nature of the conglomerate and sandstone, it is one of the best exposed units in the area, and numerous sections were measured and mapped in the field. In addition to the normal northward shaling, there is shaling, to a lesser extent, toward the east. This indicates a north-south structural high west of the Chandler River. Hawk anticline would be on this trend which probably extends at least as far north as the Umiat area.

The massively bedded conglomerate is not restricted to the basal part of the unit but reoccurs at regular intervals throughout the section, with interbeds of sandstone, siltstone, and coal. This gives the appearance of rhythmic units, five of which occur in the type locality. The conglomerate forms vertical ledges with sandstone, siltstone, and coal rubble between them, giving the over-all picture of steps in a giant staircase. The diagnostic feature of the conglomerate is the relatively high percentage of white quartz (as much as 40 percent in the lower beds decreasing to 20 percent in the highest bed). Along with the decrease in percentage of white quartz is a proportional decrease in size of the conglomeratic constituents. The lowermost conglomerate bed consists primarily of cobbles up to 5 inches in length; in the uppermost bed the rock fragments are predominantly 1/4 to 1/2 inch in length. Gray, black, and green chert comprise the bulk of the pebbles, along with an occasional fragment of Lisburne limestone. All are well-rounded. The interconglomerate sequence is a series of interbedded sandstone, siltstone, silt shale, and coal. The sandstone beds are thin, dirty, fine-grained, and dark yellow-red; they weather rusty brown and many are carbonaceous. Siltstone and silt shale constitute the bulk of this section. In one interconglomerate sequence no less than seven distinct coal seams were noted. Ironstone, as nodules and layers, is very abundant. Many of these layers contain well-preserved plant fossils.

A nearly complete sequence of zone D is exposed at Grandstand angicline where the Chandler River breaches the structure (pl. 3, column 6). Some of the more resistant beds were used as horizon markers in structure contouring. This sequence is approximately 12 miles north of the type locality, and within this distance the massive conglomerate beds completely disappear except for occasional chert pebbles in a sandstone near the top. In general the section has become finer grained, with a relatively higher percentage of shale; however, its rhythmic appearance is retained. Associated with the shale are small coal seams; however, they are not as numerous as to the south.

Following is a brief lithologic description of the horizons shown on plate 5:

Horizon 9570.--Rubble of a medium-grained, light-gray, salt-and-pepper sandstone, moderately clean, and somewhat friable.

Horizon 9460.--Light-gray salt-and-pepper sandstone, heavy-bedded, coarse-grained, clean, moderately well indurated, with occasional chert pebbles. Below this is a thinner-bedded, medium-grained, yellow-red sandstone.

Horizon 9030.--Rubble of a medium-bedded, fine- to medium-grained, moderately argillaceous, salt-and-pepper sandstone.

Horizon 8960.--Sandstone, very fine grained, thin-bedded, highly argillaceous; almost a siltstone, dark gray with slight greenish cast. Interbedded with this are thin siltstone and silt shale.

<u>Horizon 8850</u>.--Thin-bedded, fine-grained, dirty, dark-gray sandstone, interbedded with siltstone and silt shale.

<u>Horizon 8560</u>.--Medium- to heavy-bedded sandstone, fine- to medium-grained, light tan to yellow red, weathers brown, somewhat argillaceous, and friable.

<u>Horizon 8540</u>.--Thin-bedded, silty, dirty, very fine grained greenish sandstone.

<u>Horizon 8340</u>.--Twenty feet of siltstone and sandstone. The latter is a medium-bedded, fine- to medium-grained, salt-and-pepper rock.

<u>Horizon 8270</u>.--Ten feet of interbedded siltstone and fine-grained, thin-bedded, dirty sandstone.

It must be emphasized that nearly everywhere the horizons are rubble traces, therefore with several exceptions, accurate thickness measurements are unobtainable. The surface expression of these traces is often nothing more than a vegetational trace, so it is quite possible that different horizons have been correlated.

A section of 1,750 feet of zone D is exposed along the Chandler River on the south flank of Big Bend anticline (pl. 3, column 7). As seen there it is a series of interbedded sandstone, siltstone, silt shale, and mudstone, with ironstone both as nodules and layers, and a few thin seams of coal in the upper part. The unit is not well exposed and no attempt was made to tie the sandstone beds to the horizons at Grandstand. The sandstones are thin- to medium-bedded, fine- to medium-grained, yellow red to dark gray with a greenish cast, and usually quite dirty. There are, however, a few heavy-bedded, coarse-grained, clean, salt-and-pepper sands in the section; one of these, near the top, contains a limited faunal assemblage. <u>Protocardium</u> sp. and an unidentified pelecypod were found here. The sandstone constitutes less than 40 percent of the section.

In comparing the Grandstand and Big Bend sections with the type locality, it will be noted that the rate of northward shaling is greatest in the lower part of the sequence. The massive cobble conglomerates shale to fine-grained, silty sandstones, and the pebble conglomerates of the top are represented by coarse-grained, salt-and-pepper sands. The cobble conglomerates represent a stage of rapid deposition, probably due to a sudden change in gradient of the streams as they come from an adjacent highland on to a plain, with only the fine sediments carried to the north. By the time the pebble conglomerates were deposited the streams had attained a more uniform gradient and the sediments were more homogeneous.

Upper Cretaceous rocks

Nanushuk group

Zone E.--As previously stated, zone E has been delegated to the Upper Cretaceous on the identification of Inoceramus athabaskensis McLearn as a basal Upper Cretaceous fossil 9/. In this report the old name, Inoceramus sp. (linguiform), will be used in preference to Inoceramus athabaskensis McLearn. This is the diagnostic fossil for zone E and is found only in the basal part. The contact with zone D is arbitrarily placed at the first appearance of this fossil. It apparently lived along the strandline, as it commonly occurs only with a moderately clean sand.

Zone E in the area traversed is defined as the marine and marginal section immediately overlying zone D. The contact is conformable and gradational. Without Inoceramus sp. (linguiform) it would be difficult to place the contact. Zone E is present throughout much of the area traversed. Owing to the major unconformity at the top the thickness ranges from about 200 to almost 1,000 feet. This unconformity is within the Upper Cretaceous, and was preceded by an orogenic movement of considerable magnitude. Following this uplift a long period of erosion removed most of zone E in some localities.

In the southern part of the area the base of the zone is well defined by a massively bedded white quartz-pebble conglomerate as much as 40 feet thick. The conglomerate is quite lenticular and contains lenses of coarse-grained salt-and-pepper sandstone. The latter is sometimes almost a coquina of perfectly preserved Inoceramus sp. (linguiform). Above this the section is a series of interbedded sandstone, siltstone, and silt and clay shale, with minor amounts of coal and bentonite. The sandstone is shaly to moderately heavy bedded, very fine to medium-grained, silty, dark gray, sometimes having a greenish cast, and weathering rusty brown to maroon. Ripple marks, mud lumps, and ironstone and marcasite concretions are common in the section. Siltstone, silt and clay shale comprise about 70 percent of the unit. The clay shale is dark blue-gray, crumbly, with siltstone interbeds. The thin stringers of coal and bentonite are mostly in the clay shale sequence. One hundred fifty feet of this lithology occurs about 500 feet above the base of the zone. Above this sequence is another 140 feet of marine sandstone rubble, the upper part of which has a limited fauna. Volsella sp., Protocardium sp., and Tellina sp. are quite common (pl. 3, column 1). This section compares quite favorably with the zone E section measured on the Colville River in 1948 10/.

The composition of the other sections of zone E mapped in the area traversed is quite similar to that described. The rate of northward shaling is considerably less than that of zone D, with the basal conglomerate extending as far north as the south limb of Big Bend anticline, where a few chert pebbles occur in a salt-and-pepper sandstone. There appears to be little or no eastward shaling of the unit. It is only the more resistant basal part of the section that is preserved in many places.

9/ Imlay, R. W., op. cit., p. 6.
10/ Detterman, R. L., Mathewson, D. E., Webber, E. J., op. cit., p. 1.

Colville group

The rocks of the Colville group crop out over large areas north of the junction of the Ayiyak and Siksikpuk Rivers with the Chandler. Mesas and synclinal ridges of zones G and H rise abruptly above the low, featureless valleys typical of zone F. The contact with the Nanushuk group is marked by a major unconformity that has removed a large part of zone E over much of the area. The rocks of the Colville group, in the area traversed, are in general less folded and more poorly consolidated than are the Nanushuk group rocks, and they have a high percentage of volcanic constituents--bentonite and tuff.

Zone F.--The broad featureless valleys are a topographic expression of the incompetent marine shale of zone F. They often contain numerous small shallow lakes and narrow deeply entrenched streams. These characteristics, along with the tendency of the bentonitic clay shales to form "boils or blisters" on the surface, make it possible to recognize the unit without good surface exposures. Good exposures of zone F are extremely rare; even the river cuts are badly slumped. Zone F is entirely marine in origin, and was probably deposited in shallow quiet embayments of the seas surrounding islands of more resistent Nanushuk group rocks.

The thickness of zone F varies somewhat over the area traversed. Although the thickness mapped in the field ranges from 200 to 400 feet, a maximum of approximately 800 feet is inferred in one of the cross sections (pl. 2, sec. A-A'). A slight angular break was noted between zones F and G along the lower Chandler River, north of camp 9. This is believed to represent a small unconformity in the northern part of the area. This angular break was not seen to the south, where the two zones appear to be conformable.

The most complete exposures of zone F are along the Ayiyak River, between camps 3 and 4 (pl. 3, col. 1). Three hundred eighty feet of the unit is exposed in a series of cut banks along the stream. The basal 70 feet is clay shale, fissile, soft, dark blue gray, with a few thin siltstone interbeds. Several beds of bentonite occur in the shale; one such bed of pure, greenish yellow bentonite is near the top. The remainder of the section is a harder, brittle, somewhat ferruginous clay shale interbedded with silt shale and siltstone. The section is more silty near the top, with beds of darkgray carbonaceous and micaceous siltstone 3 to 12 inches thick occurring at regular intervals. An occasional Inoceramus labiatus occurs in the siltstone. The black "paper" shale and the large limestone concretions typical of zone F were not seen in this southern unit. Forty feet of this fissile black "paper" shale was seen immediately underlying zone G on the East Fork of the Tuluga River. That section contains limestone concretions that are as large as 8 feet in diameter. The cores of some of these concretions are made up of thousands of perfectly preserved fossils. Inoceramus labiatus and an unidentified Inoceramus sp., Scaphites cf. S. delicatalus and several other ammonites comprise the bulk of the fauna. Many of the specimens still retain the original shell material. This same concretion-bearing shale horizon was seen at several places in the area traversed; it was always in the upper part of the sequence, but at varying depths below the zone G contact. The black "paper" shale is very fissile and

soft, with numerous ferruginous bands. The surface of the rock is commonly coated by white and yellow salt crystals. Some of the black "paper" shales have an organic odor. The black "paper" shale is the northerly equivalent of the clayshale-siltstone unit to the south.

Zone G.—Zone G is here defined as the marginal sequence of rocks that overlies the marine shale of zone F. As previously stated, a slight angular break is indicated, in the northern part of the traverse, between the two zones. About 70 to 100 feet of largely marine sandstone and siltstone occur below the basal conglomerate in the northern part of the area. To the south the same section is 360 feet thick. Although there may be some northward thinning of the section, it is believed that the decrease in thickness is due to an erosional unconformity. The strata are nearly flat lying and form mesas capped by the resistant conglomerate. The mesas and escarpments are found along the axes of all the major synclines in the area studied. These topographic expressions of zone G rise abruptly 500 to 700 feet above the low, flat valleys underlain by zone F, and form the only relief north of the area of Nanushuk group rocks.

The incomplete Ayiyak River section (pl. 3, column 4) is 1,000 feet thick. At Outpost Mountain the unit is 1,260 feet thick (pl. 3, column 12). The basal 360 feet is largely marine sandstone, siltstone, and silt shale with a few limestone lenses. The sandstone is thin-bedded, very fine grained, silty, calcareous, greenish gray, and commonly weathers rust brown. A few pelecypods occur in the limestone lenses. They are Panope sp., Legumen sp., Pholadomya sp., and others unidentified. Immediately above the marine section is 40 to 70 feet of massive cobble-pebble conglomerate. This is the conglomerate forming Ayiyak Mesa, the distinctive feature of which is the relatively high percentage (up to 50 percent) of gray quartzite cobbles, some of which are 12 inches in length. White quartz comprises about 5 percent of the conglomeratic constituents, with black, gray, and green chert forming the remainder. To the north it thins to only a few feet and consists entirely of well-rounded black chert pebbles 1/4 to 1/2 inch in diameter. A second pebble conglomerate occurs over the entire area 300 feet higher stratigraphically. The thickness and size of constituents remain fairly constant. The primary difference is in the rock types. In the southern part the second conglomerate has up to 30 percent white quartz, the remainder being black and gray chert. In the Outpost Mountain section, the conglomerate is composed of 60 percent black chert, 3 percent white quartz, and 37 percent gray and green chert. Between the two conglomerates is a series of interbedded sandstone, siltstone, and silt shale, all more or less tuffaceous, with a marked increase in tuffaceous content toward the north. Thick beds of coal and bentonite also occur in this interval. The sandstone is thin- to medium-bedded, very fine to coarse, hard and brittle to loosely consolidated, light tan to greenish, and usually quite dirty. A tendency to weather chocolate brown is a common characteristic of many of the sands. Tuffaceous material occurring as small white flakes in the rock gives it a mottled appearance.

Above the second conglomerate the section is predominantly shale and siltstone with a few interbedded sandstones. This sequence is never well exposed. Coal and bentonite float occur sporadically in this unit.

Zone H.--Zone H, as here described, will be defined as the marine sandstone and tuffaceous siltstone sequence immediately overlying zone G. It would be impossible to separate the two zones on a lithologic basis, although the contact has been placed arbitrarily at a white, hard, cherty, tuffaceous siltstone that occurs just under the first prolific faunal horizon. The contact is conformable and gradational.

Zone H occurs only in the extreme northern part of the area traversed. The Outpost Mountain topographic high is a gently folded syncline that exposes rocks of this unit. The section, 1,020 feet thick, is incomplete, as the contact with zone I was not seen. A partial section 1,240 feet thick was mapped on the Chandler River in 1948 11/.

The section on the Chandler River (pl. 3, col. 11), is fairly well exposed in a series of river cut banks north of camp 9. The bottom 120 feet is a series of interbedded silt and clay shale and thin bedded, dirty, tuffaceous sandstone. Near the top is a thin bed of intraformational conglomerate containing shale and sandstone pebbles. Above this the section consists almost entirely of interbedded tuffaceous siltstone and claystone with minor amounts of shale and sandstone. The siltstone and claystone are dark gray, carbonaceous, commonly laminated. The sandstone is also tuffaceous, thin- to shaly bedded, fine-grained, and light yellow red to greenish. A prolific macrofauna occurs throughout the section and many of the fossils retain their original shell material. Inoceramus lundbreckensis, the diagnostic fossil for the zone, occurs in several places along with Legumen sp., Pholadomya sp., Nucula sp., Panope sp., Mytilus sp., the gastropod Gyrodes sp., an unidentified ammonite, and a starfish. Coal float was noted near the top of the sequence associated with the upper sandy section.

The Outpost Mountain section (pl. 3, col. 12) is less well exposed, particularly the basal part. The mountain is formed by the more resistant sandstone beds in the upper part, of which 450 feet is exposed. They are shaly to about medium-bedded, very fine to fine-grained, tuffaceous, silty, friable, light gray to greenish yellow, and weather almost white. Thinly laminated, greenish yellow siltstone occurs as interbeds. It is usually quite hard and brittle. Some coal and bentonite float was noted in the upper part of the sequence. The same prolific megafauna as on the Chandler River occurs throughout the sandstone section.

11/ Detterman, R. L., Patton, W. W., op. cit., p. 2.

STRUCTURE

The orogenic movements associated with the deformation of the Brooks Range to the south are reflected in the faults and folds in the younger rocks to the north. As major periods of deformation preceded Nanushuk time, it is to be expected that structures in Nanushuk and younger sediments be relatively less complex than structures in older rocks. This is clearly so. In the area traversed Nanushuk and Colville group rocks form the major part of the bedrock.

As has been previously stated, the primary objective of the party was to check the photogeologic structure-contour maps prepared in the Washington office, and to obtain enough additional data to accurately structure contour Hawk, Grandstand, and Big Bend anticlines. At the time the party left for the field it had a set of preliminary structure maps, based on uncontrolled planimetry made by tracing the streams, bedding traces, faults, and structural axes directly from photographs, for Hawk anticline and for parts of Grandstand and Big Bend anticlines. The Trimetrogon Section of the Topographic Division of the Survey was to set up a control net over the area by photoalidade, and to give precise determinations of altitudes of points picked by Brosge and Reiser 12/, by Kelsh plotter and multiplex. This information was received the latter part of the summer. It is suggested that all future photogeologic structure contouring be based on uncontrolled mosaic maps unless better are available. The field geologist can use them directly with the photographs in checking strikes, dips, altitudes, and stratigraphic intervals between traces. It must be emphasized, however, that it takes adequate vertical ground control in preparing a preliminary map of this nature.

In general the same methods were used in all the structure-contour work. The numbered traces and points of elevations were taken from the photogeologic map and plotted on photographs. These were then checked in the field by the geologist, insofar as was practicable; it is impossible to locate some of the points, as the traces usually show more clearly on a photograph than they do on the ground. In addition to the photogeologic control points, numerous other points were picked on the numbered traces and also on traces that were not shown on the photogeologic map. A triangulation net was established and the altimeters used to determine the altitudes of the points were checked at the triangulation stations.

The horizon contoured is the same for both anticlines; it was arbitrarily numbered as horizon 10,000, and is the contact between zones D and E as established by the first occurrence of the fossil Inoceramus sp. (linguiform). It was realized that in using such an occurrence to locate the datum plane, there was a chance that the horizon would migrate slightly upward toward the north; however, any change in the structure contours as a result of this migration is believed to be insignificant and well within the limits of error of the mapping.

12/ Brosge, W. P., and Reiser, H. N., op. cit. p. 2.

Hawk anticline

Hawk anticline is a small fold, approximately 10 miles in length, along the north flank of the Ayiyak anticlinorium. At both ends the structure flattens and merges with the monoclinal north dips of the major structure.

The preliminary photogeologic structure map indicated a closure of 600 feet. As a result of the field studies, the anticline was recontoured and shows a closure of slightly over 1,000 feet. The primary cause for this discrepancy on the photogeologic structure map was a lack of vertical control away from the Chandler River, and also steeper dips than had been indicated along the flanks of the structure. The altitudes of some of the reference points at the west end of the structure were off as much as 200 to 300 feet. The field investigations showed a further complication to the anticline in the form of a small thrust fault along the south flank of the structure. This fault is approximately 6,000 feet south of the axis in the area of the structural high; it has a stratigraphic throw of about 300 feet. The hade is 64°. A steepening of the dips approximately the same distance north of the axis is not interprsted as a fault, as the strata appear to be in normal sequence.

At the axis the contoured surface has an elevation of 2,600 to 2,650 feet. According to the thickness of the measured section to the south, this contoured horizon would be 3,900 feet above the base of zone B. Depending on the location of a test well, its position would be about 2,830 to 2,950 feet above the base of zone B. Inasmuch as the anticline is about 7 to 8 miles north of the type zone B, the section encountered would probably be somewhat more shaly. A geophysical line about 9 miles east of the Hawk anticlinal trend (party 144, line 4, 1952) could be interpreted as indicating a slight reversal at depth. If the surface structure is an expression of the structure at depth, then it would be a good site for a deep test. A second interpretation of the geophysical line might indicate an unconformity at about 8,000 feet along the line of the uniformly flat dips. This would fall somewhere in the Torok-Okpikruak section.

The planimetry for the Hawk anticline map was taken from the original uncontrolled mosaic map prepared in the Washington office in the winter of 1951-52. A check on the photographic scale of a number of flight lines was made by picking two or more distinct points on a photograph, and then comparing the photoscaled distance to the distance as determined by plane table and alidade. The photoscale was accurate to within 2 to 3 percent; consequently, there will be only minor changes in the structure contours when plotted on controlled planimetry.

Grandstand anticline

Grandstand anticline is a major structure about 50 miles long involving complexly folded and faulted Nanushuk group sedimentary rocks. The resistant conglomerates of the southern area are shale facies here, and the incompetent beds do not form good traces. Generally the

structure traces are a series of discontinuous rubble lines appearing to be of similar composition, but in some places may be only a vegetational trace. Since any one trace cannot be followed for a great distance it is necessary to jump traces. This may introduce a certain amount of error in computing section thickness, and this makes correlation between horizons extremely difficult.

There is an axial fault along the greater part of the anticline. In the Chandler River area one fault is about 1,600 feet north of the axis; this joins the axis west of the river and continues westward to the Ayiyak River. East of the Chandler River the fault extends about 3 miles before it is cut out by a transverse fault; from that point the anticline is apparently normal as far as the Tuluga River. From this latter point the axial fault continues eastward to where the anticline plunges under Racetrack Basin syncline 4 miles east of the Anaktuvuk River. Several small tear faults occur just west of the Chandler River. A transverse fault displaces the anticlinal axis near the west end of the structure. North of the above-mentioned fault in the breach at the Chandler River is an area 1,000 feet wide of complex drag folds and faults. This is in turn bounded on the north by another high-angle reverse fault. The fault that produces the escarpment just south of Grandstand Test Well No. 1 is a low-angle thrust. If the better exposed parts of the anticline, where it is breached by the major rivers, are any indication of its complex nature, then it is likely to be more faulted than is shown to be on the geologic map (pl. 1). There are several reversals of plunge along the anticline, all of which are fairly gentle. One is between the Chandler and Tuluga Rivers, with the slight east plunge continuing to the Anaktuvuk River. There it steepens just before the anticline plunges under Racetrack syncline. From the Chandler the west plunge continues almost to the west end of the structure where another reversal occurs.

An over-all closure of about 200 to 300 feet is indicated for Grandstand anticline, east of the Chandler River. Greater closure is possible as the east plunge apparently continues; however, as there are no apparent structure traces for a distance of 3 to 4 miles in the valley of the Tuluga River, it is impossible to continue the contoured horizon. The area of closure is cut near the west end by both a transverse and a thrust fault. In both cases the maximum stratigraphic displacement is not in excess of 100 feet. West of the Chandler River the stratigraphic throw on the axial fault is in the order of 500 to 600 feet. The hade of the various faults is as follows: at the Ayiyak River, 45°; Chandler River from south to north, 40°, 17°, 60°, and 87°; east of the Chandler River no hade readings were obtained.

Grandstand Test Well No. 1 is believed to be located on the north side of the northernmost thrust fault, in north-dipping strata. At this point the structure contours indicate no effective closure on the structure. However, as stated previously, the continued east plunge of the anticline increases the possibility of closure.

The contoured surface has an elevation at the axis on the high of 3,050 to 3,100 feet. Using the thickness of measured sections to the south, which are tied into the contoured horizon at Grandstand, the contoured horizon would be 3,900 feet above the base of zone B. Grandstand Test Well No. 1 starts about 2,600 to 2,650 feet above the base of zone B. The sandstone, siltstone, and coal sequence encountered in the hole to a depth of 500 feet is correlated directly with the basal part of zone D that has the same sequence of lithology as shown in the core of Grandstand anticline, and also to the south in the type locality. A well located on the structural high east of the Chandler River would be approximately the same stratigraphic distance above the base of zone B.

On the Grandstand structure the photogeologic map is quite different from the structure-contour map resulting from the field studies. This is primarily due to the complex nature of the structure, and also, to a better field interpretation of the structure. The axis had originally been placed farther north where the low-angle thrust fault forms the escarpment south of Grandstand Test Well No. 1. The investigations this year placed it in its true position about 6,000 feet further south, in line with the axis on both sides of the river. A good reversal was found just south of the area of complex drag folds and faults on the east side of Chandler River.

The planimetry for the Grandstand structure-contour map, in the part west of the Chandler River, was taken from uncontrolled mosaics. East of the river the maps prepared by the Trimetrogon Section were used. This created somewhat of a problem in tying the two maps; it was expected that the Trimetrogon Section would have the maps for the west side of the river completed in time for this report, however, as the maps were not ready, it was decided to use an uncontrolled mosaic. It must be emphasized that the position of the contours west of the river may change somewhat when transferred to a controlled planimetry.

Big Bend anticline

As was previously stated, there was insufficient time to check the photogeologic structure-contour map of Big Bend anticline. The last 2 weeks of the field season were spent studying the anticline from the Tuluga River to Fossil Creek. Only a cursory examination was possible at that time.

The field investigation in general confirmed the photogeologic interpretation of the structure. One major difference is that the axis of the structure is offset at the big bend in the Chandler River by a graben. The structure is somewhat more complex in that locality than previously thought. Numerous small drag folds and faults near the axis in this area probably resulted from the formation of the graben. The northernmost of the two major faults is normal, and is one of the few places in northern Alaska where the north side of a fault has moved up in respect to the south side. The same situation is present about 15 miles farther west along the structure where Nimuluk Creek syncline

is formed by another graben. East of the Chandler River Big Bend anticline is apparently unfaulted, and a reversal in plunge is indicated approximately where Trouble Creek breachs the structure. The field party has not, as yet, structure-contoured that part of the anticline; however, a cursory examination indicates that from 200 to 500 feet of closure does exist on the anticline between the Chandler and Tuluga Rivers. An attempt will be made to structure contour this part of the anticline, from the data on hand, for the final report on the area next spring (1953). If it is contoured on the same horizon as Grandstand and Hawk anticlines, the D-E contact, the high will be roughly at the same position above the base of zone B as are the highs of the other two anticlines.

REPORTED OIL SEEP

When the party arrived at the Grandstand camp on July 11, 1952, Mr. Gifford, the camp foreman, reported the location of an oil seep about 3 miles north of the camp. While the spot was not visited in company with Mr. Gifford, the point he located on a vertical photograph was visited on August 18, 1952. It is the belief of the geologist in charge of the party that this is not an oil seep, but is merely the remnant of a peat deposit in a filled-in lake. The river is actively eroding the deposit at the present time a strong organic odor was noted in the immediate area. The tundra is stained brown at that point, and the material does give a brown stain in carbon tetrachloride; however, this can also be obtained from peat. About 1 mile north of this point the river was cutting into a peat deposit, and this had all the characteristics of the point located by Mr. Gifford.

POROSITY-PERMEABILITY

A number of sandstone samples were sent to the Fairbanks laboratory for determinations of effective porosity and permeability. All the samples had a relatively high porosity by the water-drop method in the field. The list is as follows:

Sample no.	Location	Stratigraphic position	Effective porosity (percent)	Air permeability
52ADt 3	68°50'N., 152°04'W. Ayiyak River	Zone D middle	10.75	less than 1 md.
52ADt 10	68°50'N., 152°11'W. Trib. of Ayiyak R.	" D "	11.79	3.5 md.
52ADt 18	68°49'N., 152°08'W. Trib. of Ayiyak R.	" D lower	13.60	375 md.
52ADt 40	68°47'N., 152°23'W. Between right fork of Wolverine Creek	" D lower middle	12.30	impermeable

Sample no.	Location	Stratigraphic position	Effective porosity (percent)	Air permea-bility
52ADt 48	68°52'30"N., 152°40'W. Tidbit Mesa	Zone G lower	17.58	400 md.
52ADt 80	68°57'N., 152°55'W. E. fork of Niñuluk Cr.	" E lower	16.52	190 md.
52ADt 95	68°54'N., 152°24'W. Wolverine Creek	" G lower	14.44	150 md.
52ADt 182	69°07'N., 152°18'W. Tuluga River	" D upper	18.92	too friable

PETROLEUM POSSIBILITIES

Stratigraphy

Some of the rocks of the Nanushuk group, particularly in the southern part of the area, have good reservoir potentialities. Both porosity and permeability are moderately high in several samples tested and the conglomerates of zone D are very porous. The section shales northward, but along the north-south high the sands are sufficiently porous to produce oil. Umiat is on this north-south high. The high is probably the result of Paleozoic deformation with only slight modification during Mesozoic time.

Colville group rocks are in general much finer grained than the Nanushuk group. The relatively high percentage of bentonite and tuff tends to make them impermeable even where they have a moderately high porosity.

Structure

The structural aspect of the major anticlines has been discussed in full under the section on structure, and no further mention of it will be made here.

SUMMARY

1. Rocks exposed in the area of Hawk, Grandstand, and Big Bend anticlines include all the zones from zone A, Lower Cretaceous, to zone H, Upper Cretaceous.

2. Macrofossil determination of Inoceramus sp. (linguiform) as Inoceramus athabaskensis McLearn of the basal Upper Cretaceous has given a new age determination to zone E. The contact between Upper and Lower Cretaceous is gradational; the erosional unconformity between zones E and F is within the Upper Cretaceous. In some localities most of zone E is eroded.

3. The grey quartzite conglomerate at Ayiyak Mesa is not the top of zone E, as originally interpreted, but falls about 300 feet above the base of zone G; thus zone E is thinner than formerly believed.

4. Thickness of stratigraphic units have been established as follows: zone A shale, about 3,500 feet; zone B, Tuktu member, 1,000-1,050 feet; zone C, 1,000-1,200 feet; zone D, 1,750-1,900 feet; zone E, 200-1,000 feet; zone F, 200-400 feet; zone G, 1,000-1,260 feet; and an incomplete zone H, 1,000 feet in thickness.

5. Hawk anticline is a closed structure with at least 1,000 feet of closure. A well located on the high point of the structure would start about 2,830 to 2,950 feet above the base of zone B.

6. Grandstand anticline is a complexly folded and faulted structure with maximum closure of 200 to 300 feet in the area of the Chandler River. Grandstand Test Well No. 1 is located on the north side of the thrust fault, and the top of the hole is approximately 2,600 to 2,650 feet above the base of zone B.

7. Big Bend anticline is complexly folded and faulted from the Chandler River to the west end. A reversal in plunge is indicated east of the Chandler River with closure of about 200 to 500 feet.

8. The presence of a north-south structural high is indicated west of the Chandler River. Hawk anticline would be on this high.

9. Sandstone and conglomerate of the Nanushuk group shale toward the north and do not, in general, possess the qualities of a good reservoir rock north of the type locality.