United States

Department of the Interior

U.S. Geological Survey

Washington

Geological Investigations

Naval Petroleum Reserve No. 4

Alaska

Report No. 38

STRATIGRAPHY AND STRUCTURE OF THE AUPUK ANTICLINE

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By

G. Donald Eberlein, Robert M. Chapman,

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CONTENTS

ILLUSTRATIONS

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INTRODUCTION

In addition to conducting an examination of the surface geology in the Southern Foothills province between the Killik River and east fork of the Etivluk River, Navy Oil Unit Party No. 5 was requested to map the Aupuk anticline during the 1950 field season, for the purpose of evaluating the petroleum possibilities thereof from the standpoints of favorable stratigraphy and possible structural closure. Field mapping of the Aupuk anticline began on August 1, and about 1 month was devoted to the study. Party personnel consisted of G. Donald Eberlein and Charles D. Reynolds, geologists, W. L. D'Olier and W. D. Carter, field assistants, Richard Olsen, camp cook, and Max H. Davis, weasel mechanic. Robert M. Chapman, geologist, visited the party for 1 week early in August to help start the work and shared, with Eberlein, the responsibilities associated with the final compilation of this report.

Three weasels were used for daily transportation to the field and for moving camp. A 10-foot Link boat equipped with 5 hp. outboard motor was used to cross the Colville River. As field work progressed from west to east it became apparent that the camp equipment and weasels would have to be gotten across the Colville River if field work was to be completed by early September. This crossing was effected without incident at a point approximately 10 miles below the confluence of the Kurupa and Colville Rivers on August 26. The party reached Umiat on September 5.

Previous work.--The area of the Aupuk anticline comprises about 160 square miles between parallels 69°00'N. and 69°07'N. and meridians 154°10'W. and 155°20'W., approximately 70 miles southwest of Umiat. (See index map, pl. 1.) Earlier field work in the area by Chapman and Thurrell[1/] delimited the anticline and inferred a medial saddlelike structural low along its axial zone. Estimated probable closure on the eastern high was considered to be between 100 and 200 feet. Closure west of the Kurupa River was also suggested but the nature of the structure in this region could not be adequately determined in the time available. Thurrell's 1947 field work[2/]

1/ Chapman, Robert M., and Thurrell, Robert F., Jr., Stratigraphy and structure of the area of the Kurupa, Oolamnagavik, Killik, and Colville Rivers: U. S. Geological Survey, Navy Oil Unit, Report No. 5, 1947.

2/ Thurrell, Robert F., Jr., Preliminary report on the stratigraphy and structure of the area of the Colville River from Ipnavik to Kurupa Rivers, Alaska: U. S. Geological Survey, Navy Oil Unit, Report No. 15, October 1947.

covered the western end of the Aupuk structure but failed to yield additional data pertinent to closure. In the same year James Zumberge spent 2 days collecting microfossil, porosity, and permeability samples from a Cretaceous section along the Kurupa River. This section is shown as section 1, plate 3 in this report.

Field methods and control.--During the present investigation, all outcrops, bedding traces, and other features of geologic significance were mapped on a scale of 1:20,000 by means of the plane table and telescopic alidade. All stations were field located on U. S. Navy-flown vertical aerial photographs at an approximate scale of 1:20,000. Low-angle oblique aerial photographic coverage was available for part of the area to facilitate working some of the higher river bluffs.

Primary control consisted of a fourth-order triangulation net established by E. G. Sable in 1946 when Party No. 4 of that year ran a controlled traverse down the Kurupa and Colville Rivers to the Killik River. This net was extended approximately 6 miles west up the Colville River to establish the necessary additional control on the west end of the structure. The over-all control and photographic information was submitted to the Trimetrogon Section of the U. S. Geological Survey for compilation of the planimetric base of plate 1 which accompanies this report.

An assumed datum of 796 feet at the mouth of the Kurupa River was established by the 1946 triangulation work and was computed on the basis of an assumed elevation of 623 feet at the junction of the Colville and Killik Rivers. The latter figure was the result of computations based on a Colville River gradient of 3.8 feet per mile throughout a map-measured distance of 78.5 miles along its course from the mouth of the Killik River to Umiat, where the altitude above sea level is 325 feet. A re-examination of these computations indicates that 78.5 miles is probably in error and that a river distance of 56 miles is more nearly correct. Thus the datum at the mouth of the Killik River is based on an assumption of distance which is probably in error, and an assumption of stream gradient which could also be considerably in error.

Topography.--The Aupuk area lies wholly within the Northern Foothills section of the Arctic Foothills physiographic province. Over most of the area the average relief ranges from 100 to 200 feet. The surface configuration is dominated by low rolling tundra-covered hills, separated by intervening rather well drained lowlands and marshy flats. Principal drainage in the area is the Colville River, which follows a sinuous eastward course approximately along the axial plane of the Aupuk anticline. The Colville valley ranges in width from 1 to 3 miles. Locally, bluffs as much as 75 feet high are formed where the main channel has undercut the upstream side of meander spurs. The Kurupa River is considerably smaller but, in general, has the same braided and mature pattern. Adjacent river flats are characterized by low level terraces that are 10 to 50 feet above the rivers and are studded by numerous small lakes, sloughs, and swampy areas.

All other significant streams are tributary to the Colville and Kurupa Rivers and tend to flow in narrow incised channels. The dendritic drainage pattern is quite apparent on plate 1.

Nearly flat lying high level gravels, ranging in thickness from a few feet to almost 50 feet, occur as perched terrace remnants 75 to 300 feet or so above the valleys of main streams and small creeks. These unpaired terraces tend to be most persistent and best developed along the east side of northward drainage. This is well illustrated by the terraces along the east side of the Kurupa River valley near its junction with the Colville River, the small creek draining northward into the Colville approximately 1 mile west of the Kurupa River, and several other north-draining creeks between the Kurupa River and Aupuk Creek. In general these gravels are dominantly well-rounded quartzite and chert debris ranging in size from a fraction of an inch to 4 inches in mean diameter.

It was not the purpose of this investigation to study these high-level gravel terraces and veneers, but it is suggested that their investigation throughout the Northern and Southern Foothills sections might yield information of significant value in interpreting recent tectonic history of the Arctic Foothills.

In this section of the foothills province, outcrops are generally very poor and exposures of bedrock are almost entirely confined to bluffs along the Colville and Kurupa Rivers. A few scattered exposures are also found along some of the more deeply incised creek channels. The more resistant lithologic units tend to form fairly conspicuous bedding traces, marked by steep slopes, linear rubble distribution, and changes of vegetation.

GEOLOGY

Stratigraphy

Rocks of zones D and E of the Lower Cretaceous Nanushuk group, and possibly zones F and G of the Upper Cretaceous Colville group, are exposed in the area. Zones B and C rocks were examined south of the area mapped and will be discussed for evaluation of prospective drilling. Columnar sections showing thicknesses and relationships, together with all available microfossil, macrofossil, porosity, and permeability data, are presented in plate 2 and keyed to the geologic map (pl. 1).

Due to the paucity and discontinuity of rock exposures, it was not possible to obtain adequate composite stratigraphic information within the area mapped. Accordingly, advantage was taken of a good section of about 7,400 feet of Cretaceous rocks exposed in river cuts approximately 14 miles south of the Colville River where the Kurupa River has transected the Kurupa anticline. The information gained from these exposures is shown in section 1 and keyed to the index map of plate 1. Most of the stratigraphic data gathered from isolated exposures along the Colville and lower Kurupa Rivers have been placed in the stratigraphic columns of plate 2 in their appropriate positions with respect to this reference section. It should be pointed out that in many cases it has been necessary to project dips of less than 10° several miles to effect this relative placement.

Zone B.--A 650-foot thickness of greenish-gray, fine- to very fine-grained argillaceous marine zone B sandstones is exposed along the Kurupa River near the crest of the Kurupa anticline. This well-bedded sandstone unit contains thin siltstone, shale, and silt shale partings. Cross laminations present between the more prominent parallel bedding planes and ripple marks are not uncommon in some of the shale layers. Calcium carbonate is present as cement. Upon weathering the sandstones assume a light yellowish-green color. Invertebrate marine fossils are locally abundant as are carbonized plant remains and wood impressions.

The results of U. S. Geological Survey laboratory studies on samples of this sand indicate virtually no air permeability and a range in effective porosity from 2.56 to 9.54 percent. Although winnowed phases of this unit would undoubtedly have more favorable porosity and permeability, the distribution of these facies would be hard to predict. Accordingly, this member is not considered a very favorable prospect for reservoir rocks for oil.

At least 85 feet of silt shale and medium-gray clay shale are exposed beneath the Tuktu sandstone along the axial zone of the Kurupa anticline. These lithologically resemble shales of the Torok formation but have been correlated with zone B on the basis of the following microfossils:

"Tritaxia" manitobensis (common)
Haplophragmoides I
Haplophragmoides B
Verneuilinoides F
Trochammina sp.

This strongly suggests that the prominent bluff-forming sandstones that are commonly accepted as the base of the Nanushuk group along Tuktu bluff shale out northward. Hence the base of the prominent sandstone section along the Kurupa anticline is probably stratigraphically higher than it is to the south.

Zone C.--Approximately 1,840 feet of zone C rocks is believed to overlie the marine standstone and shale of zone B about 13 miles above the Kurupa River mouth. In general this formation consists of an interbedded near-shore marine and nonmarine transitional lithologic sequence between zone B and the overlying lagoonal and continental facies of zones D-E, undifferentiated. The B-C contact has been placed where the first nonmarine sands appear; the top of zone C has been placed at the top of the uppermost bona fide marine sediments.

The basal 500-feet of zone C is dominantly nonmarine and is characterized by relatively massive, coarse- to fine-grained, poorly sorted sandstones. Interbedded fine- to very fine-grained subgraywacke type sandstones and shales with local lenses of conglomeratic sandstone and granule to pebble conglomerates are common. These sandstones show marked local variations in degree of cementation. They range in color from yellowish to dusky yellowish green. Thin beds of low-grade coal and coaly shale are also present in the lower part of the section.

These basal rocks are overlain by approximately 1,300 feet of interbedded marine and nonmarine fine- to very fine-grained yellowish-green to greenish-gray sandstone, shale, conglomeratic sandstone and occasional thin (½ to 2 in.) beds of calcareous shale or marlstone. The upper marine sands are locally quite fossiliferous. Carbonized plant fragments are common throughout the entire section.

The variable lithologic characteristics of zone C rocks are reflected in their porosity and permeability values. Although all samples were found to be impermeable, they showed a range of porosity from 1.94 to 19.2 percent. In most samples, however, the effective porosity was found to be less than 9 percent.

Zones D and E undifferentiated.--The dominantly marine sedimentary sequence described above is overlain on the north flank of the Kurupa anticline by an estimated 5,000-foot thickness of nonmarine siltstone, medium- to fine-grained sandstone, silt and clay shale, conglomerate, and conglomeratic sandstone. Beds of coal and bone ranging in thickness from a few inches to 8 feet occur throughout this part of the column, but appear to be most abundant in the upper stratigraphic horizons. This conclusion is based on a series of discontinuous sections logged along the Kurupa River from the Awuna syncline axis southward to the zone C-D contact.

Beds similar to the zone D-E beds just described are exposed in the Aupuk anticline. Massive to thinly bedded, dirty, yellowish-gray, fine- to very fine-grained sandstones are interbedded with clay and silt shale, and lenses of conglomerate and coal. The finer-grained clastics tend to be darker in color and locally contain considerable mica, which gives them a characteristic sheen. Many fine- to medium-grained sandstones show cross laminations of the current type as well as penecontemporaneous slump or hassock structures. Ironstone, in the form of nodules, irregular concretions, lenses and thin beds, is abundant throughout the section. Associated beds of coal and bone range in thickness from a few inches to 8 or 9 feet and are usually underlain by a variable thickness of clay or clay shale. The coal beds are commonly poorly exposed, but their presence may in places be recognized by coaly float in the talus or in the soil of slumped areas. At a few places beds of burned coal are enclosed by sandstone and shale that have been baked and bleached to brilliant hues of red and orange. A good example of this may be observed at the locality of columnar section 7.

Many of the coarser sandstones are calcareous and tend to be highly cross bedded. Locally they contain carbonaceous debris as disseminated specks in sufficient amount to justify their being termed "salt and pepper" sandstones. Occasional zones contain numerous concretions of ironstone (iron oxide), siderite (iron carbonate), or pyrite (iron sulfide). These are associated with layers of abundant carbonaceous material, and the cores of many of the iron concretions are composed of carbonized plant fragments. Apparently these carbonaceous concentrations effected local reducing environments which controlled the precipitation of iron as the carbonate and/or sulfide. In general the concretions appear to be most abundant in the rocks exposed along the western part of the anticline.

Beds of conglomerate and conglomeratic sandstone up to 35 feet thick are common in the western part of the area, but much less numerous in the eastern part. The best exposures of conglomerate occur in river bluffs on the south side of the Colville River approximately 4½ miles west of its confluence with the Kurupa River, in scattered outcrops on the north bank of the Colville River between meridians 155°N. and 155°21'N., and along the west bank of Kurupa River approximately 2 miles above its mouth.

These nonmarine conglomerates are characterized by moderate to poor sorting. Most of the pebbles and cobbles are of chert and white vein (?) quartz. Pebbles several inches in diameter are common but those an inch or less in diameter are more typical. Some cobbles up to 8 inches in diameter have been seen.

In all but one place chert was found to be more abundant than white quartz in the conglomerates. Estimated ratios of chert to quartz range from 2:1 to 5:1. Most of the chert is dark gray to black, but pebbles of medium- to pale-green, tan, medium- to dark-gray, and even red chert are present. In general, the chert pebbles are not as well-rounded as are those of white quartz, and they tend to be slightly larger.

At one locality a well-rounded pebble of limestone that contained a few poorly preserved crinoid columnals was found in a lens of highly cross bedded conglomeratic sandstone. This and also the abundant dark chert were probably derived from the Lisburne limestone. The varicolored cherts are not typical of the Lisburne, however. The source for these was more likely in the cherty zones of the Shublik and Okpikruak formations. The source of the white quartz pebbles is not known but they may possibly have come from the "sandstone-conglomerate member" of the Noatak formation, in which white quartz pebbles are not uncommon.

Regional changes in thickness of zones D-E

In the Killik-Chandler-Anaktuvuk area, zones D and E rocks have average thicknesses of 2,000 feet and 1,700 feet respectively. Thus it would appear that 1,300 feet more of zones D-E sediments are present in the Awuna syncline at the Kurupa River. This excessive thickness of zones D-E might possibly be accounted for by assigning the upper part of this section in the Awuna syncline to zones F, G, and even H. The evidence for doing this is not entirely satisfactory, however. The white quartz pebble conglomerate considered to be diagnostic of upper zone E rocks on the Oolamnagavik River 24 miles to the east and in the area north of Knifeblade Ridge is not present in the Kurupa River section. The marine black paper shales of zone F are also lacking, or else do not outcrop. Further, beds of bentonite and tuff, considered to be characteristic of Upper Cretaceous rocks, have not been seen. There accordingly remains the possibility that (1) rocks of zones D and E in the Kurupa area are thicker than they are farther to the east and/or (2) the zones C-D contact should be placed stratigraphically higher than has been done in the Awuna syncline area. There is some substantiation for this second possibility on the basis of the facies concepts for the Nanushuk group as proposed by T. G. Payne. If the hypothetical nearly east-west shoreline of zones B-C time had shifted to a more northwest-southeast direction in zones D-E time as Payne believes, it would not only account for the observed facies change from marine zones B-C to continental zones D-E in going up the stratigraphic column in a given area, but it would imply a westward component of thickening of nonmarine rocks at the expense of marine rocks. Accordingly, a zone C-D contact, determined on the basis of marine versus nonmarine fossils and facies, would apparently occur at a stratigraphically lower level in the Kurupa River section than in the Killik-Chandler-Anaktuvuk area to the east. Obviously an apparent thickening of zones D-E would result.

It is not possible at present to fully evaluate the effect that these considerations would have in accounting for the entire 1,300 feet of D-E section in question. They might conceivably account for the entire thickness. If these factors have any influence they would certainly reduce the likelihood of finding zone H rocks at the surface in the axial zone of the Awuna syncline on the Kurupa River.

The facies concept also suggests a replacement of nonmarine by marine facies both northward and eastward beneath the Aupuk anticline. Thus marine rocks may be slightly higher stratigraphically beneath this structure than indicated by projection of thickness figures as measured in the reference section on the Kurupa River to the south.

STRUCTURE

The geologic structure of the Aupuk anticline is indicated on plate 1 as completely as possible with the field data available. As previously noted, outcrop control is poor and discontinuous in the area. Structure contouring of the anticline has been impossible because key horizons are lacking. Obtaining strike and dip data in the field was difficult, and in places impossible because of the cross-bedded nature of the rocks and because of slumping. In a majority of places the indicated dip of strata is less than 10° and is variable within the same outcrop, thereby making it almost impossible to project trends very far with accuracy. "Three pointing" has been possible in only a few places because bedding traces tend to be confined to steep slopes and bluffs that are nearly linear. Accordingly, it is not possible to give precise data regarding amount of closure on the anticline, drilling depths, and so forth. It cannot be emphasized too strongly that any figures presented in the discussion that follows below have had to be based upon (1) extrapolation of information over long distances, and (2) assumptions of symmetrical structure. They represent crude approximations at best and should not be considered otherwise.

The shape of the Aupuk structure is that of an anticline with a relative structural high near both the east and west ends. The axial zone of the anticline has been breached by the Colville River and can be traced or inferred eastward from the mouth of the Kurupa River for a distance of approximately 20 miles.

The western high on the Aupuk anticline is believed to be located approximately 1 mile west of the Kurupa River where the axial plane of the fold begins to swing northward across the Colville River. Based upon stratigraphic thickness measurements made on the north flank of the Kurupa anticline, and projections northward that have been tied to exposures along the west bank of the Kurupa River from its mouth to the axial zone of the Awuna syncline, it would appear that approximately 2,300 feet of sediments of zones D-E undifferentiated underlie the western high at the mouth of the Kurupa River. This is shown in section A-A' (pl. 3). The minor fault shown therein is considered to have little structural significance.

Western plunge of the anticline, thus making a closed structure of the western high described above, cannot be proved. There is in fact little evidence either for or against western plunge. On the basis of observed bedding trends in this area, it is likely that the trace of the axial plane swings northward across the Colville River and into a generally anticlinal zone of longitudinal and transverse faulting that can be traced photogeologically for approximately 14 miles. Such a swing is not incompatible with regional trends of the Awuna and Sugar synclines to the south and north respectively.

There was not sufficient time in the field to fully investigate more than the eastern part of this anticlinal zone north of the Colville and the relation of the Aupuk structure to the fault that is known farther to the northwest was not clear. In the vicinity of triangulation stations Nos. 6 and 7, beds dipping south at approximately 30° are exposed almost to the top of the valley side. The uppermost bedding traces generally dip northward from 4° to 20°. Above these traces there is no additional outcrop information. West of the transverse fault shown in this area on plate 1, apparently north-dipping beds change in strike from N.60°W. to almost north and are terminated against through-going N.60°W. traces with steep southward dips. This truncation is highly suggestive of a high-angle south-dipping reverse fault, the trace of which roughly follows the crest of the bluff.

A similar relationship is considered to exist southeast of the transverse fault although there is no positive evidence of truncation. The reversal in dips noted in the upper bedding traces could conceivably be a manifestation of drag along a southeastward continuation of the high-angle reverse fault described above.

It is possible that western structural closure of the Aupuk anticline may be effected by faulting, but this cannot be established without additional information. It is doubtful that this information would be forthcoming from further field work in the area.

To the east, a structural saddle occurs along the anticline in the vicinity of triangulation stations Nos. 67 and 69. These stations are located on the south bank of the Colville River about a mile below its confluence with the Kurupa River. If averages of convergent bedding trends north and south of the axial plane are computed and treated as intersecting planes, an approximate eastward plunge of $2\frac{1}{2}^{\circ}$ may be deduced for the western high. This would mean a little less than 1,600 feet of eastern structural relief between the "saddle" and western high. The zones C-D contact would thereby occur about 3,800 feet below the surface at this structural low. These relations are diagrammatically shown in section B-B' (pl. 3), which has been drawn slightly west of the apparent "low" to take advantage of better elevation and outcrop control. The northward structural relief to the Sugar syncline has been exaggerated in this diagram. It is probably not over 500 to 600 feet.

An eastern structural high on the Aupuk anticline is located north of triangulation station No. 79. If the same methods are employed in dealing with this eastern high, the computed depth to the zones C-D contact would be between 2,000 and 2,100 feet (see section C-C', pl. 3). A discrepancy is here immediately apparent. If we assume average thickness figures of 2,000 and 1,700 feet for zones D and E, respectively, the surface rocks at the eastern structural high should be very close to the D-E contact. This is not compatible with the regional geology indicated on the photogeologic map for quadrangle J-14. Rocks of zones C and D are exposed in the core of the Killik Bend anticline. This area was mapped by Chapman and Thurrell in 1946[3/] and zone C-D contact is considered by them to be well located on the basis of fossils and lithology. If this contact is geometrically projected northward to the eastern high of the Aupuk structure, using even the most conservative data but without considering possible structural complications, rocks of zone C should be present within 500 feet of the surface. This position for the zone C-D contact, although necessarily based on very approximate figures, is supported by two other lines of evidence:

(1) On the basis of bedding information derived from outcrops in the vicinity of section 6 and to the east, an approximate over-all eastward plunge of 2° to $2\frac{1}{2}^{\circ}$ is indicated for the structure in this area. If zone C rocks were within 500 feet of the surface of the eastern high, such a plunge would effect sufficient eastward structural relief to locate the zone D-E contact approximately as shown on the photogeologic map.

(2) Although numerous microfossil samples have been collected along the Aupuk anticline, all were barren except those taken from localities near the eastern high (see stratigraphic sections 5, 6, and 7). In the Kurupa River reference section, no microfossils have been reported above

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3/ Chapman, R. M., and Thurrell, R. F., Op. cit.

the basal 135 feet of zones D-E, undifferentiated. Further, the specific identifications in sections 1, 5, 6, and 7 match quite well. These species are considered to be long ranging and not very diagnostic, but there is nevertheless a suggested local correlation on the basis of their uppermost stratigraphic occurrence. Such a correlation would effectively place sections 5, 6, and 7 close to the zone C-D contact as established in reference section 1 instead of 2,000 feet or so above it as indicated on plate 2.

From the foregoing discussion, it is quite likely that the zones C-D contact is approximately 1,600 feet closer to the surface at the east end of the anticline than indicated by eastward extrapolation of reference stratigraphic information (section 1, pl. 2), based on the best available field data. Any attempt to resolve this discrepancy between the two structural highs would have to effect an approximate 1,600-foot increase of structural relief east of the medial saddle over that east of the western high. This is not possible without adjusting the computed relief figures so that they would be completely out of accord with triangulation-controlled field data. On the other hand, a transverse fault located between the two structural highs and having the correct relative vertical displacement could conceivably account for the apparent lack of agreement in depth figures to the zones C-D contact beneath the eastern high. There is no field evidence that directly suggests such a fault. One could exist in the area of virtually no exposures where the structural low is considered to be present, and the Knifeblade Ridge transverse fault if projected southward would cross the Aupuk anticline in this structural low. There is also a zone of shearing and crumpling exposed in a river bluff east of the locality of stratigraphic section 4, thus also suggesting faulting in this vicinity which could be a transverse fault.

The entire above discussion has not taken into account the effect of a longitudinal fault mapped north of the axial trace near the eastern stratigraphic low. This fault may have affected bedding trends in such a manner as to render computations of eastward plunge inaccurate. However, on the basis of the regional distribution of younger rocks to the east, minimum plunge of 1,000 feet to the east can be inferred. This is in keeping with the tendency for structures east of the Meade River to have eastern plunge and is of the same order of magnitude as has been established for the Knifeblade Ridge, Weasel Creek, Titaluk, and Wolf Creek structures north of the Aupuk anticline. Inasmuch as this magnitude compares favorably with that computed from a field-determined angle of plunge, the effect of the longitudinal fault is considered to be comparatively small. If the fault were to be extended to the west and slightly south so that it crossed the anticline, the relative movement indicated would be in the wrong direction to account for the thickness discrepancies previously considered. Accordingly, this fault is considered to have relatively little effect upon the problem.

Gas seeps

Two seeps of dry gas have been reported at the eastern end of the Aupuk anticline. The most active of these is located at the southeast end of a small lake about 1 3/4 miles above the mouth of Aupuk Creek (see pl. 1). This seep was mapped by Navy Geological Party No. 3 in 1945 and again by Navy Oil Unit Party No. 4 in 1946.4/ It was also examined by R. F. Thurrell during 1947 caching operations. At the time of the 1946 investigation gas bubbles rose to the lake surface at the rate of about one per second in 20 or more spots within an area of 150 square feet. When visited during the 1950 field season the seep was apparently more active. The area of bubbles was found to include approximately 300 square feet of lake surface. Five spots were observed to be bubbling continuously. Bubbles were rising at a rate of one every two or three seconds in two other spots. No trace of oil was observed at the surface.

A sample of this gas was collected in 1946 and analyzed by the National Bureau of Standards. The results of the analysis by Mass Spectrometer on a dry, air-free basis were as follows:

Methane	98.8
Ethane	0.07
Nitrogen	0.7
Oxygen	-
Argon	0.06
Carbon dioxide	0.4
	100.03 percent

Calculated heating value = 986.7 B.T.U. / cu. ft.

Calculated specific gravity = 0.5622

R. F. Thurrell, in May 1947, reported a second gas seep located in a small lake on the north side of the Colville River approximately 3¼ miles west of the Aupuk seep. The lake was frozen at the time of his visit and the gas was observed to be bubbling intermittently at the lake surface in a small ice-free area. Attempts were made to revisit this occurrence during the 1950 season but it could not be located. Occasional bubbles were observed to rise to the surface of several lakes in the vicinity but no obvious seepage was noted.

Thurrell's reported seep has been located on plate 1 as closely as possible on the basis of his brief description. Samples of the gas he collected at this occurrence and at the Aupuk seep were submitted to the National Bureau of Standards and analyzed by Mass Spectrometer on a dry air-free basis. The results were as follows:

4/ Chapman, R. M., and Thurrell, R. F., Op. cit.

	North Colville seep	Aupuk seep
Methane	98.5	99.4
Ethane	--	0.06
Propane	--	--
Butanes	--	--
Pentanes	--	--
Carbon dioxide	1.3	0.4
Argon	0.2	0.1
Helium	--	--
Others	--	--
	100.0 percent	100.5 percent
Calculated heating value B.T.U. / cu. ft.	889	987

(No specific gravity determination)

It is of interest to note that both seeps occur on the eastern structural high of the Aupuk anticline and are evidently structurally controlled by the longitudinal fault.

RESERVOIR POSSIBILITIES

No oil sands or other petroliferous indications were observed during the field investigation of this area. The results of porosity and permeability determinations on samples collected from rocks of zones B, C, and D-E undifferentiated are generally low and considered to be unfavorable from a reservoir standpoint.

There is, however, good evidence for eastern closure of the Aupuk anticline. There is also a suggestion that marine sediments occur sufficiently close to the surface beneath the eastern high of the structure to be penetrated by a shallow 1,500-foot prospect rig. The presence of gas seeps in this area also makes it appear favorable as a shallow test site. If such a test were to be favorably considered, its location should be restricted to the axial zone of the eastern high south of the longitudinal fault that is thought to control the gas seeps.

The best available data indicates that marine sediments do not occur sufficiently close to the surface beneath the western high to be penetrated by a shallow test. A 1,500-foot test hole would undoubtedly yield valuable stratigraphic information, however. A suggested location would be on the south bank of the Colville River approximately one-half mile upstream from its confluence with the Kurupa River.

SUMMARY

Navy Oil Unit Party No. 5 devoted 1 month to a study of the stratigraphy and structure of the Aupuk anticline during the 1950 field season. On the basis of good stratigraphic control on the north flank of the

Kurupa anticline approximately 14 miles south of the area mapped, rocks exposed in the Aupuk anticline have been assigned in age to zones D and E, undifferentiated, of the Lower Cretaceous. Nonmarine massive to thinly bedded, medium- to fine-grained sandstones are interbedded with clay and silt shale, and lenses of conglomerate, conglomératic sandstone and coal. Their color is predominantly dirty, yellowish gray.

The anticline is an east-trending structure that has been breached by the Colville River along a distance of about 23 miles. Structure contouring was not possible because distinctive horizons are lacking and outcrops are both poor and discontinuous. The anticline possesses two structural highs, separated by a medial saddle that has an estimated 1,500 feet of structural relief along the axial zone. The western high is located approximately 1 mile west of the Kurupa River mouth, where a thickness of approximately 2,300 feet of zones D-E, undifferentiated, is believed to underlie the structure. Approximately 1,840 feet of zone C rocks and 650 feet of zone B rocks are also believed to be present. Accordingly, drilling depth to marine rocks of zone B in this part of the structure is estimated to be about 4,340 feet.

There is little evidence for or against western closure for the anticline. The western extension of the structure is believed to trend into a general anticlinal zone of longitudinal and transverse faulting, which may or may not effect closure.

If the thickness data presented for the western high is projected to the eastern high on the basis of the available field information, a depth of approximately 2,000 to 2,100 feet for the zones C-D contact is inferred, or ~~2,650-2,700~~ 3,840 feet to the B-C contact.

Assuming average thickness figures of 2,000 feet and 1,700 feet for zones D and E, respectively, this computed depth is incompatible with the regional geology, part of which is partly controlled by earlier field work. Three lines of evidence are presented that suggest that rocks of zone C may actually be within 500 feet of the surface at the eastern high. An explanation of the apparent discrepancy is offered by the possibility of transverse faulting between the eastern and western structural highs of the anticline.

On the basis of limited field information and the regional distribution of younger rocks to the east, a minimum of 1,000 feet of eastern closure can be inferred for the anticline.

Two "dry" gas seeps are located on the eastern structural high and are apparently controlled by a high-angle longitudinal fault. Analyses of these gases are presented in the report.

A location is suggested for a 1,500-foot core test on the eastern structural high where zone C and possibly even zone B sands might be penetrated. A similar test on the western high would probably not penetrate marine sediments but might yield valuable stratigraphic information.