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Naval Petroleum Reserve No. 4

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STRATIGRAPHY AND STRUCTURE OF THE DRIFTWOOD ANTICLINE

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By

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E. G. Sable and M. D. Mangus

INTRODUCTION

Navy Oil Unit Party 1 was assigned to spend part of the summer field season of 1950 in mapping the Driftwood anticline, in the upper Utukok River area north of Driftwood Creek. The purpose of the study was to make a detailed examination of the structure to determine possible closure of this anticline. In addition to this, Party 1 was to map the geology of the upper Utukok-Kokolik Rivers area, south of the Driftwood anticline. Emphasis was to be placed upon the measurement of rock units older than those exposed in the Driftwood anticline in order to gain a reasonable idea of stratigraphic depth to the Lisburne limestone, and also to examine the outcrops of this formation to determine its possibilities as a reservoir rock 1/.

From June 2 to 7 Party 1, consisting of six men, was flown to the present site of the Driftwood airstrip which is approximately 2 miles north of the Driftwood anticline. Three weasels had been cached here for the party's use during the summer. Mapping of the structure was immediately begun and was continued until June 27, at which time the group moved southward for stratigraphic studies. In mid-August the party returned for a few days investigation of streamcuts which had been covered with snow in late June. At the end of the field season, September 3, weasels were cached at the Driftwood airstrip.

The exposed area of the Driftwood anticline comprises about 38 square miles between latitudes 68°50'N. and 68°53'N. and longitudes 160°35'W. and 161°25'W. It is approximately 200 miles from Point Barrow, 230 miles from Umiat, and 80 miles from Point Lay on the northwest Alaska coast. Overland routes of travel from these points are difficult and are necessarily circuitous because of the uneven topography. No lakes near the anticline are suitable for landing other than the smaller types of aircraft. However, a gravel airstrip about 3,200 feet long was constructed by Arctic Contractors personnel along the Utukok River during the summer of 1950. Weasel travel in the vicinity of the Driftwood anticline is relatively easy. Except when at flood crest, both the Utukok River and Driftwood Creek can be crossed at selected shallow spots.

1/ Sable, E. G., and Mangus, M. D., Stratigraphy and structure of the upper Utukok-Kokolik Rivers area: U. S. Geological Survey Navy Oil Unit Preliminary Report No. 29, 1950.

In 1947, a few traverses of a reconnaissance nature were made on the anticline in the area east of the Utukok River, and on rivercuts along the Utukok 2/. Photographic studies of the Driftwood anticline were made from trimetrogon and vertical photos in 1949 3/. A west plunge was proved, but possible east plunge was obscure in covered areas. These studies showed indications of possible tear faults and thrust faults, and a strong asymmetry near the western end of the anticline.

Topography and methods.—The Driftwood anticline trends roughly east, crosses the Utukok River at latitude 68°52'N. and longitude 161°08'W., and lies immediately north of Driftwood Creek. Its exposed axial area measures about 19 miles in length and 1½ to 2 miles in width. It is long and narrow, and asymmetric.

The Driftwood anticline occurs along the boundary between the Northern and Southern Foothills sections of the Arctic Foothills province. It is surrounded on the north, east, and south by wide, almost featureless flats underlain by shales of the Torok formation, zone A. A huge, mostly tundra-covered gravel terrace 600 feet above Driftwood Creek covers the eastern part of the anticline and probably extends almost to the Colville River, 8 miles east. Thickness of the gravels in this terrace is 15 to 20 feet.

East of the Utukok River, the anticline is topographically expressed as a long, essentially level ridge 1 to 1½ miles north of Driftwood Creek. The ridge extends from the Utukok River to within 1 mile of the large gravel terrace, where its character becomes lost in an area dissected by minor north-flowing drainages. The ridge crest has a maximum relief of 70 feet. It is believed to be coextensive with the axis of the Driftwood anticline east of the Utukok River. The sides of the ridge slope gradually, and are broken by few traces of resistant units, mud heavings, and minor drainages. The height of the ridge above Driftwood Creek is 380 to 520 feet. Outcrops and traces are extremely scarce east of the Utukok. A few good outcrops occur along Driftwood Creek; in the dissected area on the north flank of the structure; and in the hills adjacent to the Utukok. With the above exceptions, exposures are limited to wide bands and hillocks of mud boils and heavings that contain comminuted rock fragments and showing no indication of bedding other than a general strike.

Along the Utukok River fairly good but sporadic exposures of rocks occur in a few cut banks. The maximum thickness measured in a single outcrop was 595 feet. Other cutbanks expose from 5 to 300 feet of section.

2/ Thompson, R. M., and Barksdale, W. L., Stratigraphy and structure of the area of the Utukok River with notes on the Corwin-Cape Beaufort region, Alaska: U. S. Geological Survey Navy Oil Unit Report No. 18, 1948.

3/ Fischer, William A., The Driftwood anticline: U. S. Geological Survey Navy Oil Unit Special Report No. 9, 1949; and Photogeologic map, Quadrangle L-20.

West of the Utukok River, traces and bedrock are somewhat better exposed than in areas on the east side. Nevertheless, all bedding traces are exposed only for short distances, and most are too poor to show more than a strike line. Mud flows and heavings bearing no apparent relation to the structure are common, and most of these show no linear trend. A few outcrops occur in small cut banks of Plunge Creek.

In contrast to the regular east-west ridge east of the Utukok River, the exposed "core" of the anticline on the west side is dissected by structurally controlled tundra drainages and by one transverse stream, Plunge Creek. The topography at the extreme west plunge of the anticline is typical of a "breached" structure. The highest altitude on the western extension of the anticline is 2,250 feet, and maximum relief is approximately 750 feet.

The method of structural mapping was as follows:

1. Two triangulation nets of fourth-order accuracy were established, one on the north flank and one on the south flank of the anticline. Stations were located insofar as possible on points of geologic interest, and were plotted on vertical aerial photographs. Considerable difficulty was encountered in properly spotting stations on featureless wide traces and heavings common in the area of the anticline. All altitudes were based on the relative altitude of 2,000 feet established by Thompson and Barksdale in 1947 4/.

2. Plane-table traverses from selected stations, and vertical aerial photo computations were used to map traces and measure thicknesses of resistant units.

3. Topographic contours of 50-foot intervals were established by altimeter traverse and the above-mentioned surveying methods.

4. Direct readings by Brunton compass were taken wherever possible, three-point solution of dip and strike problems was used on the few suitably exposed traces.

The extremely poor and discontinuous exposures in the axial area necessitates a generalized interpretation of the Driftwood anticline. Because of anomalies due to minor folding, reversal of dip along the flanks, possible major faulting in the western part of the structure, and the lack of any "key horizon", structure contours cannot be delineated. A geologic map (pl. 1) showing altitudes and trends of resistant units and individual traces, and approximate geologic contacts accompanies this report. Only two fairly reliable cross sections could be drawn, one on the east side of Plunge Creek, and one along the Utukok River (pl. 2).

4/ Thompson, R. M., and Barksdale, W. L., Op. cit.

STRATIGRAPHY

The exposed core of the Driftwood anticline consists of a lithologic unit designated in this report and in the report on the upper Utukok-Kokolik Rivers area 5/ as Torok formation, upper siltstone-shale unit. The anticline is surrounded by less resistant younger rocks of the Torok formation zone A shale unit in all areas where exposures occur. The contact between these two units is placed at the uppermost heavy-bedded traces of the upper siltstone-shale unit. Because of rapid shaling out of the heavy-bedded sequences, this contact is a lithologic one and is not to be considered as a time-line.

The upper siltstone-shale unit in the Driftwood anticline is similar in lithology to its exposures 3 to 6 miles south of the structure, but appears to be less resistant than the southern sequences. Approximately 30 percent to 50 percent siltstone, fine-grained sandstone, and conglomeratic sandstone lenses constitute this unit, and vary in thickness from 6 inches to 10 feet. They are medium-gray to olive-gray, moderately micaceous, highly calcareous, well-indurated, and weather to an olive color. Prominent fucoidal markings, mud-flow phenomena, worm trails, carbonaceous material and shale pebbles are common. A very finely cross bedded to laminated appearance is characteristic of the siltstones. Most sequences are monotonously similar, and resistant units "shale out" laterally within short distances. A few thin, discontinuous lenses of green-gray conglomeratic sandstone as much as 5 feet thick occur on the south flank of the anticline, east of the Utukok River, and appear to lie in the upper 1,000 feet of the unit. This sandstone was not seen west of the river.

On the north flank of the anticline near the gravel terrace, a distinctive sandy zone forms the only prominent trace in the locality. This consists of approximately 25 feet of very fine to fine-grained, medium-gray to yellow-brown, platy to blocky sandstone that weathers a dark-yellow orange. The trace disappears under the gravel terrace to the east and is covered by tundra to the west. It constitutes the uppermost heavy-bedded layer of the unit in this vicinity. Dark-gray, nodular to blocky silt shale and clay shale make up the remainder of the unit. These are indistinguishable from the overlying zone A shales of the Torok formation.

One sample for porosity-permeability determination, Sa8, was collected from the south flank of the Driftwood anticline. Porosity of this sample is 5.74 percent and permeability less than 1 millidarcy. Two samples collected in 1947, Ba6 and Ba8, show porosities of 10.6 percent and 12.8 percent respectively. No permeability data was recorded. The rocks appear muddy, and their calcareous nature probably makes them unsuitable as reservoir rocks.

5/ Sable, E. G., and Mangus, M. D., Op. cit.

An approximate thickness of 4,000 feet of this unit appears to be present in the Driftwood anticline along the Utukok River. This measurement was arrived at by computations based on readings from sporadic outcrops on both limbs of the anticline. Because of poor exposures, "shaling-out" of resistant rock units, and the absence of key beds, totally reliable stratigraphic sections of rocks exposed in the anticline could not be measured.

STRUCTURE AND INTERPRETATION

Where determinations of axial trend could be made, the Driftwood anticline is tightly folded, overturned, and asymmetric; its axial plane dips south. The position and attitude of the major axis of the anticline could be determined with reasonable accuracy in only two places: on the east bank of the Utukok River, and immediately east of Plunge Creek. In the former locality the axial plane dips south at an angle of about 67° from the horizontal, in the latter location the axial plane dips about 84°. West of Plunge Creek the axis is fairly well located, and swings southward from a general N. 70° E. trend to N. 55° E. at the nose of the fold, where it plunges 20° W. Eastward from the Plunge Creek exposures, the position of the axis is fairly well located for a distance of about 2 miles. From this point to the Utukok River, axial position is questionable until it is located once more on the east side of the river by correlation of exposures believed to be equivalent. Farther east the position of the axis is uncertain. It is believed to coincide with the long, nearly level ridge that extends almost to the gravel terrace. The belief that the axis is in or near this ridge is based upon projections of averaged dips from either flank of the anticline, and from the persistent character of the broad ridge top. This topographic feature is interrupted and apparently displaced in one locality 3½ miles east of the Utukok. No definitive field evidence for faulting is present; however, the displacement may be due to a tear faulting. East of the Utukok, dips far out on the flanks suggest a slight overturn to the north. The position of the anticlinal axis near the gravel terrace is extremely questionable. No exposures occur on the south flank in this vicinity.

Only one mappable minor structure is exposed on the anticline. This is a 20° W.-plunging anticlinal fold located at triangulation station 26, 1½ miles west of the Utukok River. The fold can be traced for only a short distance, and no field evidence in the nearby area gave true indications of relationships between this and the major axis. However, from the general east-northeast trend of rubble traces, it might be interpreted as a bifurcating part of the major axis.

On the north side of the anticline at triangulation station 26A, drag folds are expressed as sinuous traces that show no good bedding attitudes.

At triangulation station 22 a thin-bedded siltstone and sandstone outcrop has an anomalous strike of N. 25°-20° E. and dips of 10°-15° E. One 10-foot outcrop of north-dipping clay shale on the south flank of the anticline 3/4 mile southwest of triangulation station 13 has an anomalous dip of 10°-20° N. The attitudes of beds in both these outcrops are believed due to local drag folding.

The above-described folds occur in the upper siltstone-shale unit of the Torok formation. The relatively incompetent zone A shale unit on the flanks of the anticline contains numerous complex drag folds and small faults, but in general reflects the larger structure. It is probable that a considerable amount of drag folding is present throughout the anticline, and that this might affect shallow drilling or geophysical work in the area.

Cross section A-A' (pl. 2) drawn along the Utukok River shows a computed thickness of approximately 4,000 feet of the upper siltstone-shale unit of the Torok formation on the south and north limbs of the anticline. Cross section B-B' (pl. 2) drawn east of Plunge Creek (pl. 1) shows an anomolous relationship between the comparative thickness of the upper siltstone-shale unit exposed in the north and south limbs of the anticline. Structural computations show a thickness of 1,600 ± feet exposed on the north limb and 3,000 ± feet on the south limb. The base of these sections was believed to be approximately correlative. There is no field evidence to suggest repetition of beds on the south flank owing to folding or faulting, but folds or faults duplicating some of the beds could be present in the covered areas on the south flank. If present, this repetition would probably be due to isoclinal folds or thrust faults.

Possible tear faults occur in three local areas of the Driftwood anticline: east of triangulation station 32, west of triangulation station 16, and on the extreme northeast flank of the anticline. These possible tear faults were inferred from apparent displacement of resistant units, and are believed to be of relatively small size. However, the fault in the vicinity of triangulation station 32 may have a maximum displacement of 900 stratigraphic feet. No evidence for a tear fault formerly thought to occur along the Utukok River was recognized.

On the northeast side of the anticline, a resistant, easily identifiable trace has a general east to N. 80° E. trend to a point north of triangulation station 3A, where it curves southward to a N. 75° W. trend, and disappears below the gravel terrace. West of triangulation station 3A, readings taken on outcrops exposed on the trace show a 42°-52° N. dip and a strike approximately paralleling the trend of the trace to station 3A. East of station 3A, strike readings of N. 60°-75° E. cross the trace. Some small displacements are apparent on aerial photographs, and it is thought that a series of minor transverse faults is present, producing an apparent southward swing of the trace. The trace rises in altitude as it curves southward; where it disappears under the gravel terrace a small sharp southward bend of the trace is due to topography.

North of the anticline, rocks of the zone Z shale unit exposed in cutbanks of Seismo Creek and its tributaries maintain a fairly regular east-northeast strike and show no indications of east plunge of the structure.

No positive field evidence for an eastward plunge of the Driftwood anticline is present. However, several traces on the south flank trend N. 65° E., and the inferred contact between the upper siltstone-shale unit and zone A shale unit swings northward as it approaches the gravel terrace. Both of these suggest east plunge.

A traverse was made 8 miles east of the gravel terrace to the Colville River, where scattered outcrops reveal complexly folded rocks of the zone A shale unit 6/. No evidence for east plunge was seen, but all exposures now believed pertinent to mapping of the axial trend of the anticline were not visited. Further field work in this region will be done in 1951, along the upper Colville River between latitude 68°50' N. and 68°56' N. to study the rocks along the eastward projection of the Driftwood anticlinal axis. This area is thought to be underlain by the zone A shale unit.

In making stratigraphic and structural studies 15 to 25 miles south of the Driftwood anticline, Party 1 was able to gain an idea of thicknesses of rocks between the top of the Lisburne limestone and the rocks exposed in the core of the Driftwood anticline. This rock sequence is believed to be between 5,400 feet and 6,500 feet thick.

Locations of measured sections are shown on the geologic map of Preliminary Report No. 29 7/. Because of facies changes and because of the presence of at least one probable erosional unconformity between Cretaceous and older rocks, it is not known whether the sequence underlying the anticline is similar in lithology or in thickness to the measured sequence to the south.

Rock units and their approximate thicknesses as interpreted from studies in the upper Utukok-Kokolik Rivers are given below:

4,400 (± 600?)	feet	Torok formation, upper siltstone-shale unit.
1,300 (± 400?)	"	Torok formation, conglomerate unit (may be in part correlative with upper siltstone-shale unit).
900 ±	"	Torok formation, Lower shale-siltstone unit.
1,600	"	Okpikruak formation.
1,200 ±	"	Penn.-Permian?, Triassic, Jurassic? rocks
9,400 ±	"	(10,500 feet maximum thickness)

6/ Relationships between the Driftwood anticline and these exposures are shown in plate 1 of Preliminary Report No. 29.
7/ Sable, E. G., and Mangus, M. D., Op. cit.

Surface occurrence of 4,000 feet or more of the upper siltstone-shale unit is believed to be present in the Driftwood anticline along the Utukok River, as shown by cross section A-A' (pl. 2). The position of the anticlinal axis here is fairly well defined, and the axial plane was computed to dip about 67° S. The attitude of the axial plane in the subsurface, as shown in cross section A-A', is purely theoretical. However, in areas south of the Driftwood anticline the rocks have a regional south dip owing to deformation that originated in the Brooks Range. This implies that the axial plane would continue its southward inclination in the subsurface.

If the axial plane in cross section A-A' were projected downward at this degree of inclination, and if a normal sequence of sediments and parallel folding are inferred, then the Lisburne limestone would occur along the axial plane south of the exposed axis. If the stratigraphic thickness to the Lisburne were 5,400 feet here, then a hole drilled 2,600 feet south of the exposed axis would penetrate the Lisburne at a depth of 6,000 feet. This is shown in cross section A-A'. For progressively greater stratigraphic thicknesses, correspondingly greater distances south of the axis would be necessary to reach Lisburne limestone at a minimum depth.

If these assumptions are correct, the Lisburne limestone on the north limb of the anticline would lie at greater depth beneath the surface probably not less than 10,000 feet.

In 1950 results from refraction shooting on the north flank of the Driftwood anticline by the United Geophysical Co. indicated that high-velocity beds, such as the Lisburne limestone, were almost certainly not within 9,000 feet of the surface where the shooting was done, and probably not within 11,500 feet of the surface 8/. Further refraction shooting on the south flank about 3,000 feet south of the axis may, however, show high-velocity beds at shallower depths.

SUMMARY

The Driftwood anticline is long, narrow, asymmetrical, and tightly folded. The upper siltstone-shale unit of the Torok formation comprises the exposed "core" of the anticline. Torok zone A shale unit occurs on the flanks. No positive proof for closure of the structure could be ascertained by surface geologic studies during 1950. A west plunge of 20° was proved. Certain trends on the south flank of the structure indicate possible closure, but evidence on the north flank is negative. Rocks believed to be younger in age than those in the exposed core of the structure occur east of the gravel terrace beneath which the anticline disappears. However, these rocks were examined very briefly and will be studied further before they are accepted as evidence indicating possible closure.

8/ Allen, Samuel, Completion Report for Driftwood area: United Geophysical Co. Report, Party No. 148, 1950.

Exposures of rock along the anticline are poor, and structure contours could not be drawn. Some evidence of small-scale tear faulting is present, and a possible duplication of section caused by folding or thrust faulting occurs in the western part of the anticline. Drag folding occurs on the flanks of the anticline at various localities.

Using thickness data gained from field studies south of the anticline, and assuming that similar units occur in the Driftwood vicinity, a stratigraphic thickness from 5,400 feet to 6,500 feet of beds would necessarily be penetrated to reach the Lisburne along the axis of the anticline. In subsurface, the Lisburne would probably lie nearer the surface south of the exposed axis of the anticline than it would to the north. This may account for inconclusive results obtained from refraction shooting on the north flank of the anticline.