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FINAL

GEOLOGICAL REPORT

on

THE RIBBY BANK AND ISLANDS OF THE MACKENZIE RIVER

NORMAN WELLS TO CARCAJOU ROCK

N.W.T. (Canada).

IMPERIAL OIL LTD., CANOL PROJECT

Assignment No. 39.

By: W. P. Hancock — Party Chief
D. C. Wetterberg — Assistant.
W. T. Worthington — Helper.

Date submitted: February 9, 1944.

Read and accepted by: Mer. A. Link

Date: Feb. 10th '44

CONFIDENTIAL

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N.W.T. (Canada)

A B S T R A C T

Strata of Lower Cretaceous and Bosworth (Devonian) ages are exposed along the right bank and islands of the Mackenzie River from Norman Wells to Carcajou Ridge.

The Norman Wells oil field lies at the eastern end of the report area. The reservoir rock in this field is Reef limestone in the Fort Creek shales, and this reef is thought to underlie all or most of the report area. Two structures, the Morrow Creek Anticline and the Perry Anticline, were examined. It is suggested that these structures may be separate structures not connected with the Hoosier Ridge Anticline, and if this is true, they may provide oil traps in the Reef limestone, and/or the Beavertail limestone.

It is recommended that further reflection seismograph work be done on these structures to establish their relationships to the Hoosier Ridge. Seismograph surveys should also be carried inland as far as possible, on both sides of the river, to locate other potential oil structures and stratigraphic traps of Reef limestone.

Chapter I.

I N T R O D U C T I O N

The area covered in this report extends along the north bank of the Mackenzie River from Norman Wells to approximately one quarter mile east of P.M. 61 N near the foot of Carcajou Ridge. All islands below (downstream from) Goose Island were examined (Plate 1).

The purpose of the work was to locate and study low shelving outcrops along the river bank and islands, in hopes of finding low dipping structures which, in this area, presumably underlain by reef limestone, would provide ideal locations for testing.

D. C. Wetterberg and W. T. Worthington assisted the writer in this survey. The party left Norman Wells in two canoes on September 3rd, and returned September 27th, 1943. A plane table survey was made from the Discovery No. 1 well to the Morrow Creek Anticline. Haider, Ogilvie, "Judith" and "Perry" Islands were also plane-tabled. The remainder of the islands and river bank were mapped with the aid of aerial photographs. Tributaries of the Mackenzie river along the north bank, with the exception of Bosworth and Morrow Creeks, were also traversed. At the request of Dr. H. T. U. Smith the traverse of "Elliot" Creek was made in the upper formations exposed along the flank of Thomas Mount-

ain. Part of the north bank of the Mackenzie river from Norman Wells to Carcajou rock were mapped by Dr. T. A. Link in 1919 (5) and by Mr. [illegible] in 1920 (8). Except for Haider Island, called "Big" Island [illegible], the islands in this portion of the river were not [illegible]

The writer wishes to acknowledge the co-operation of his assistants [illegible]. Discussions with F. A. McKinnon (7) and J. M. Parker

(9), who worked adjoining areas, and general discussions with all of the geologists have been of great help in the preparation of this report. Mr. C. R. Stelck made the fossil identifications. A preliminary report was submitted on this area (Assignment No. 39, Report No. 41).

Chapter II.

T O P O G R A P H Y

Discovery Range is the dominant topographic feature of the area. This is a mountainous range, composed mainly of Devonian and Silurian limestones and dolomites. It was formed by a major uplift affecting the greater part of the Mackenzie River Valley. The range trends southwesterly along the northern portion of the area, then it makes an abrupt swing to the south forming the east boundary of the area. In the western part of the report area, this range has a relief of approximately 1200 feet. The relief however, decreases progressing southwestwardly, and is only 500 to 600 feet where cut by Vermillion Creek.

Vermillion Ridge is a topographic feature of much smaller magnitude bordering most of the southern boundary of the area. It is in direct alignment with the Discovery Range west of the report area. Between this ridge and the Discovery Range is a wedge-shaped relatively flat, basin area. This basin has its greatest width where crossed by Vermillion Creek, coincident with the change in trend of the Discovery Range.

Glacial action has modified the topography of both the basin area and the Discovery Range, by scouring parallel to the major structural trends. Glacial morainic ridges and eskers have been deposited in the wedge-shaped basin area, and in the deeper glacial scours in the Discovery Range, particularly where underlain by the Ramparts shaley member.

Chapter III.

STRATIGRAPHY

General

The stratigraphic sequence in this area is very poorly exposed and consists approximately of 700 feet of Bosworth (Devonian) and 100 feet of Lower Cretaceous. Except for the high Cretaceous shale banks downstream from P.M. 59 N, the majority of the exposures are low and shelving, and may be observed only during the low water stage of the river. In several instances bedrock was found only by digging below the beach deposits. The nature of the outcrops makes compilation of a columnar section impossible without a great deal of inference, therefore no columnar section has been drawn, but the sections submitted by Parker (9) and McKinnon (7) are regarded as applicable.

Beds of Bosworth sandstone and shales (uppermost Devonian of the Norman Wells area) and of Lower Cretaceous shales and sandstones are exposed in the area examined. The Lower Cretaceous rests unconformably upon the Bosworth. Lithologically the two formations are rather similar and unless paleontological evidence is found, their distinction in certain areas is difficult.

SURFACE GEOLOGY

Bosworth Formation

The Bosworth sandstones and shales comprising the uppermost Devonian, is the only formation of Devonian age exposed in the area. The base of the formation is not exposed, but is known elsewhere to grade into the underlying Port Creek formation. The top of the Bosworth is marked by an unconformable contact with the overlying basal Cretaceous sediments.

Intermittent outcrops of Bosworth are exposed from Norman Wells to the north flank of Morrow Creek Anticline (see Plate 2). On Ogilvie

Island four feet of Bosworth sandstone is exposed, underlying the basal Cretaceous conglomerate. The same beds are exposed again at the end of the traverse near Carcajou Rock. Dr. Link (5) believes that the sandstone outcrops along the north bank of Raider Island belong to the Bosworth formation. The writer was unable to substantiate this, and believes these sandstones may be of Cretaceous age. The problem is considered further under the description of the Lower Cretaceous.

The sketchy nature of evidence obtainable from the outcrops of Bosworth gives little information on the detailed lithology of the formation. Sandstone predominates in those sections exposed. The sandstone is fine grained, silty, light grey and greenish grey, weathering grey to buff and rusty. It is generally soft but in places is hard because of a calcareous cement. Outcrops 9, 10, 11 and 12 are composed of dark grey sandy shale (Plate 2). At Outcrop 9, eight feet of dark grey sandy shale, with thin ironstone bands, is exposed. The remainder of the shale outcrops occur in small rivulet channels (12 to 18 inches deep) along the river bank. On the basis of the lithology of the exposures at outcrops 10, 11, and 12, and an assumed thickness of 700 to 800 feet for the Bosworth formation at Norrow Creek anticline, these shales could be of Cretaceous age. An abundance of ironstone concretions along the river bank above Outcrop 10 supports this possibility. A shale sample was taken at Outcrop 10, and when studied for microfauna, may give evidence regarding this.

No accurate estimate of the thickness of the Bosworth can be made from the information obtained. Because of the unconformity at the top of the formation its thickness will undoubtedly vary. The formation varies from about 400 feet in the Goose and Bear Island wells to 820 feet in the

Mac No. 1 wells. These wells are at the eastern edge of the report area. Parker (9) estimates the thickness at Carcajou Rock to be 650 feet.

Fossils were observed only in outcrops 1 and 13, as listed below:

Spirifer

Productella

Atrypa devoniana

These are not index fossils of any particular zone in the Bosworth, but merely help distinguish the sediments as being Devonian in age. Shale samples were taken at outcrops 9 and 10. No faunal or lithological zones which could be correlated with established Bosworth zones were found.

Bitumen and oil stains were observed in the sandstone at outcrop 1. Oil seeps were also reported by Bosworth and Kindle (1) in this formation near Carcajou Rock. These rocks are a possible reservoir for oil, but their widespread silty character and their poor showings in the Norman Wells oil field, suggests that they are not likely to provide any quantity of oil.

Lower Cretaceous

The complete section of Lower Cretaceous is not exposed in the area. These rocks overlie the Bosworth formation unconformably. The base of the Cretaceous is marked by a basal sandstone and conglomerate zone.

Where the Cretaceous-Bosworth contact is not definitely known the distinction between these formations is difficult to determine on a lithological basis alone. Following are some observations the writer has made in studying these formations in the field, and in well cuttings from the

Norman Wells oil field:

Sandstones and shales are present in the lower 300 feet of the Cretaceous, but sandstones predominate in the Bosworth.

Glauconite is characteristic of Cretaceous sandstones, but has not been observed in the Bosworth.

Bentonite seams occur in the Cretaceous, but were not seen in the Bosworth.

Ironstone concretions occur in both formations, but are larger and more abundant in the Cretaceous.

Lower Cretaceous sediments presumably underlie all the north shore downstream from the Morrow Creek structure. The first exposures appear one and one half miles below P.M. 56 N. These are thin shelving sandstone outcrops with digital vertebrate remains. Large slumped shale exposures occur below P.M. 59 N and the base of the formation is exposed near Carcajou Rock at the west end of the map area. Basal Cretaceous beds overlie Bosworth sediments on the south side of Ogilvie Island. Cretaceous sediments occur on the east and west ends and the south side of Raider Island. Sandstone exposures on the north bank of this island were previously mapped as Bosworth. These sandstones are fine grained, clean, light greenish grey, with locally abundant glauconite. Lithologically they are typical of Cretaceous sandstones. The basal Cretaceous sandstone and conglomerate zone exposed at Carcajou Rock and Ogilvie Island extends to the Goose Island and Bear Island wells where it is 30 feet thick. It is presumably consistent over the intervening area but it does not outcrop on Raider Island. The writer therefore believes that these exposures on the north bank of Raider Island are Cretaceous. The other islands are underlain by Cretaceous sediments.

The Cretaceous, like the Bosworth, is poorly exposed and lithologic details are lacking. Uncertainty regarding some of the dip and strike readings adds to correlation difficulties. The base of the

formation is best exposed on Ogilvie Island at outcrop 17; it consists from top to bottom of:

Top

4' Sandstone, fine to medium grained, light grey, quartzose, glauconitic.

6½' Sandstone as above, with scattered conglomerate beds; the pebbles are quartzite and chert; the conglomeratic beds weather rusty; carbonized plant remains occur in lower 2½ feet.

4' Covered.

8' Sandstone, medium grained, porous, quartzose, some glauconite, plant remains; pebbles of chert and greenish sandstone occur at top.

Bottom

It is estimated that 300 feet of sandstones and shales lie above this. These are exposed on Judith, Perry and Patricia Islands. It is probable that the outcrops on the mainland opposite Willard Island belong in this 300 feet. These exposures are of the same horizon and their dip to the north is probably caused by displacement due to water and ice action. This sandy series is well developed in the Goose Island, Bear Island and Mac No. 1 wells.

Above this sandy series at Outcrop 33 are badly slumped soft, dark grey shales from which bentonite has apparently flowed and collected at the base of the cliff. These beds are probably equivalent to the bentonitic shales above the sandy series in the Mac No. 1 well and on Loon Creek (4) and to the bentonitic shales exposed on Slater River (3). The thickness of this series is not known.

Grey shale with thin sandy beds, weathering yellowish to rusty, is exposed at and downstream from Outcrop 42. These beds presumably overlie the bentonitic series. Insufficient information was obtainable

to indicate their thickness.

Specimens of Beudanticeras were found throughout the Cretaceous section. Vertebrate remains occur in outcrops 36, 37, 38 and 41. Some shale samples were taken, but they have not yet been studied for microfauna.

SUBSURFACE GEOLOGY

The unexposed formations underlying the area are known from the tests at Norman Wells and Hoosier Ridge, and from exposures of these beds in the mountain area to the north.

Following is a table giving a brief description of these subsurface formations:

Formation	Thickness	Description and Importance
Upper Fort Creek	800' ±	Shale, dark grey to black, platy; lower 100' ± bituminous; source rock of oil.
Reef Limestone	0-480'	Coral reef limestone, varying porosity, in part bedded; reservoir rock at Norman Wells; contains fresh water at Hoosier Ridge; reservoir rock.
Lower Fort Creek	0-550'	Shale, dark grey, platy; free oil observed in fractures at Hoosier Ridge No. 2 well; possible source rock.
Beavertail Ramparts	400-500'	Limestone, massive and bedded, in places coralline and porous at top, lower 300-400' with shaley beds; small amount of oil recovered from this formation at Hoosier Ridge No. 2; possible reservoir rock where there is reef development near the top.
Bear Rock	?	Brecciated dolomitic limestone, both porous and non-porous, bituminous; contains salt water at Norman Wells and at Hoosier Ridge; possible reservoir rock.

Chapter IV

S T R U C T U R A L G E O L O G Y

General

The area lies on the north flank of the Long Reach - Carcajou synclinal basin, one to five miles from the uplifted Discovery Range and related mountains. The regional dip is to the south, and dips range from two to six degrees. Many of the exposures are covered by water and ice for part of the year and have undoubtedly been broken and moved by ice gouging. The present attitude of such beds therefore, does not represent the true structural conditions.

Structures related to the major uplifts have previously been mapped in the Long Reach - Carcajou basin. Two such structures were studied in the report area. They are: the Morrow Creek Anticline, which was first mapped by Miller in 1921 (8), and the Perry Anticline which is indicated by the data obtained by McKinnon (7) combined with that of the writer. Hoosier Ridge, Rainbow Arch and Loon Creek Anticline are examples of other structures within the basin.

Plate III shows the trends of these basin folds and of the bordering major uplifts. There are two general trends, an east-west trend including Carcajou Rock, Rainbow Arch, Hoosier Ridge and Morrow Creek Anticline, and a northwest trend including Perry Anticline, Paige, Thomas, Cleaver and Morrow Mountains, and the Discovery Range. There are variations in these trends but these are to be expected especially where different trends approach each other.

Morrow Creek Anticline

The Morrow Creek anticline is upstream from Hoosier Ridge and on the opposite bank of the river. The axis of the anticline appears

to strike parallel or en echelon to that of Hoosier Ridge and lies approximately one mile south of it (see Plate II).

Bosworth sandstones are the only beds exposed. Three exposures dipping 16 to 21 degrees south were found near river level on the south flank of the structure. Only one exposure occurs on the north flank, this dips 11 degrees north. The subsurface geology as shown on Plate IV was taken from information obtained at the Hoosier Ridge tests.

Reflection seismograph studies were made along the river bank. The seismic map indicates a sharp rise of the Reef limestone and of the Beavertail-Ramparts formation approaching the surface anticlinal axis from the south. Due to poor reflections north of the axis, the structure was not confirmed.

It is not known whether or not the structure is closed to the east and west. A north-south structural relief of 200 to 300 feet is suggested by the dip values obtained from the outcrops.

Miller (3) suggests that this structure is a continuation of the Hoosier Ridge anticline. Dresser (2) illustrates a southward warping of the east end of the Hoosier Ridge anticlinal axis and also intimates connection of these structures. Fresh water was encountered in the Reef limestone at the Hoosier Ridge tests, and salt water in the Bear Rock formation at the No. 2 well, therefore the Morrow Creek anticline is already condemned if it is a continuation of Hoosier Ridge. The writer offers an alternative suggestion of an en-echelon arrangement of these folds (see Plates II, III, and IV), a common pattern displayed in the structures of adjoining areas.

Assuming that the Morrow Creek anticline is not connected with Hoosier Ridge, and that the structure is closed, it offers an excellent opportunity to test the reef limestone at shallow depth.

Perry Anticline

Dips along the left bank of the Mackenzie River opposite Perry Island (7) and those obtained on Perry Island indicate a long, low anticline trending northwest, referred to here as the "Perry Anticline".

Cretaceous sediments are exposed on both limbs of the structure. The exact position and extent of the structural axis is uncertain. No geophysical work has been conducted in its vicinity. The probable relationship of this structure to Hoosier Ridge and Morrow Creek anticlines is illustrated in Plates II, III, and IV. The stratigraphic section illustrated in Plate IV is taken from information obtained in the Hoosier Ridge tests.

From available evidence, the Perry anticline appears to be a distinct structure separate from Hoosier Ridge. Because of this it is more promising than the Morrow Creek anticline. Seismograph reflection surveys should be carried out to confirm the structure at depth.

...eastern end of the map ...type oil field and the trap is formed ...development within the Fort Creek formation. Bitumin-
ous zones within the Fort Creek formation are considered to be the source rock of the oil.

From a stratigraphic point of view the entire area is favorable for oil prospecting. Bituminous Fort Creek shales are known to extend beneath the Long Reach - Carcajou basin. Reef limestone, within the Fort Creek, is exposed in adjoining areas as shown on Plate II. The Beavertail - Ramparts formation is in places composed of reef limestone at its top (Parker, No.9). A small amount of oil was recovered from the Beavertail in the Hoosier Ridge No. 2 test. Two stratigraphic horizons favorable for the accumulation of oil are thus indicated to be present under much or all of the area. Both horizons are covered by suitable cap rocks and are adjacent to the source rock. Stratigraphic traps of reef limestone, as in the Norman Wells field, are not well expressed in the surface exposures. Their presence is better detected by geophysical exploration or best by systematic wildcatting.

The regional structural setting is very favorable for anticlinal oil traps. Anticlinal flexures with potential reservoir rocks at depth and covered by impermeable cap-rock offer opportunities of obtaining commercial oil production. The Perry anticline and Morrow Creek anticline are believed to be in this class and the Perry anticline is the more favorable of the two. Other structures in areas having no exposures may be revealed by seismograph reflection studies.

Chapter VI

CONCLUSIONS AND RECOMMENDATIONS

Source beds, reservoir rocks and cap rocks with positive indications of oil are known to exist in the area.

Oil may be expected to be found in stratigraphic traps of reef limestone, or in structural traps involving the reservoir rocks. The search for stratigraphic traps will require reflection seismograph studies and wildcat drilling. Two potential structural traps, the Morrow Creek Anticline and the Perry Anticline are known to exist. These structures are considered to be separate folds not connected with the Hoosier Ridge Anticline, and if this is true they ofier possibilities as potential structural traps. The Perry Anticline is the more favorable of these structures.

It is recommended that detailed seismograph studies be carried out on these two structures to verify their extent and their relationship to Hoosier Ridge. The seismograph survey should be carried on down the river, and as far inland on both sides as possible, to check for the presence of stratigraphic traps of reef limestone, and for anticlinal structures.

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APPENDIX

January 4, 1944

MEMORANDUM:

TO: Dr. T. A. Link.

RE: Fossil Identification.

Attached is a tentative identification of fossils collected by Mr. W. P. Hancock on Assignment No. 39 - Islands & Right Bank of Mackenzie River from Norman Wells to Carcajou Rock.

C. R. Stelck

[illegible]/ng

FOSSIL IDENTIFICATION - - ISLANDS & RIGHT BANK OF MACKENZIE RIVER FROM NORMAN WELLS TO CARCAJOU ROCK - W.P.Rhoades

Suite No.	Location	Date	Fossil	Accession No.	Age
85121	Perry Island	Sept. 13	Beudanticeras	43830	Cretaceous
85128	Outcrop 42 Mackenzie River	Sept. 20	Beudanticeras	43831	Cretaceous
85114	Morrow Creek Structure	Sept. 8	Atrypa devoniana	43832	Beaverth
85125	Outcrop 37 Mackenzie River	Sept. 19	Vertebrate remains	43833	Cretaceous
85111	Outcrop 1 Mackenzie River	Sept. 4	Spirifer with Productella	43836	Beaverth

PLATE 2

GEOLOGICAL MAP

RIGHT BANK and ISLANDS of MACKENZIE RIVER
NORMAN WELLS to CARCAJOU ROCK

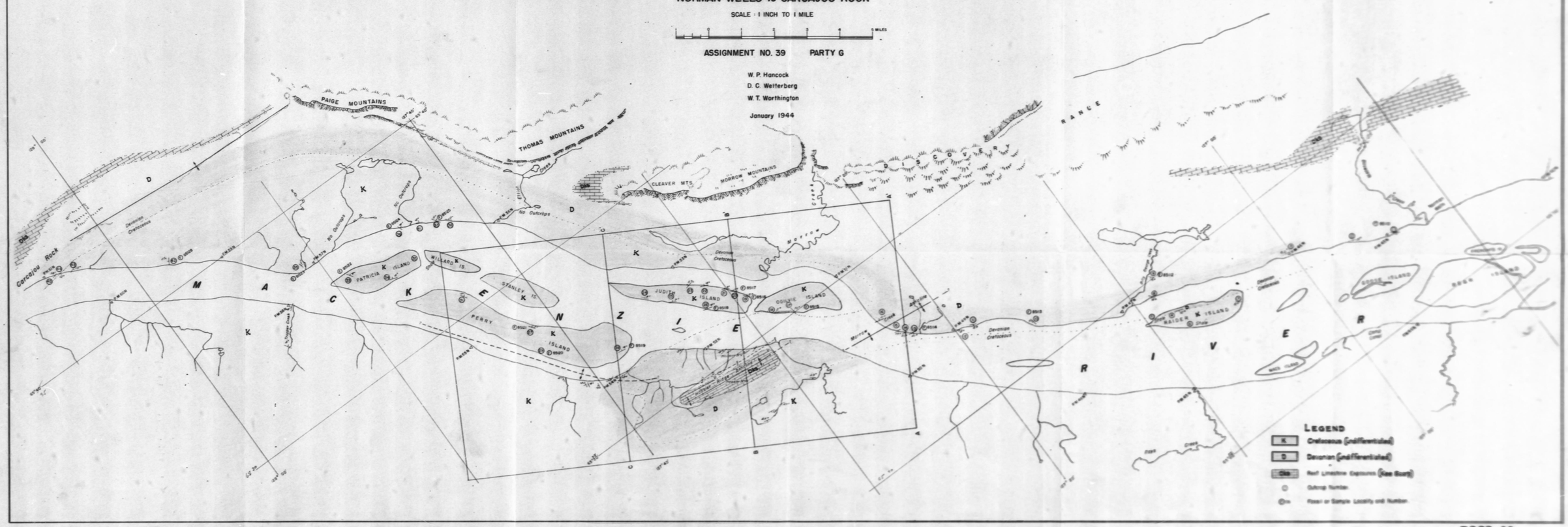
SCALE - 1 INCH TO 1 MILE

5 MILES

ASSIGNMENT NO. 39 PARTY G

W. P. Hancock
D. C. Welterberg
W. T. Worthington

January 1944



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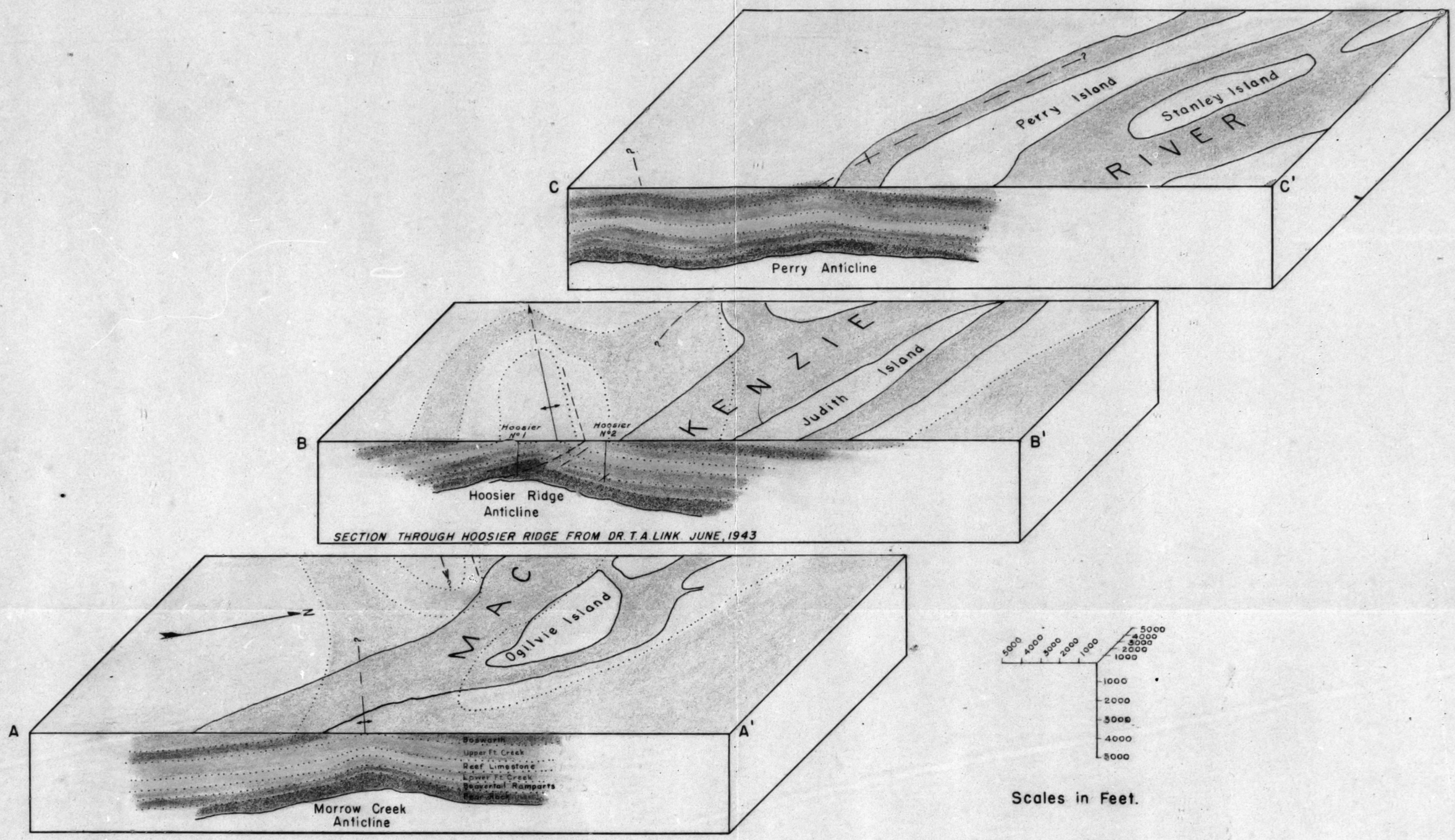

Scales in Feet.

BLOCK DIAGRAM
showing possible relationship of

MORROW CREEK, HOOSIER RIDGE & PERRY STRUCTURES

Datum River Level at Hoosier Ridge