STRATIGRAPHY AND PALEONTOLOGY OF A PART OF GARFIELD COUNTY MONTANA WITH NOTES ON AN UNCONFORMITY AT THE BASE OF THE LANCE FORMATION

By

LESLIE EDWIN WILSON

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INTRODUCTION

The information presented in this paper is the result of three months' field work done in the area by the writer while he was chief of a field party for the Midwest Refining Company.

The paper describes the geology of a considerable area in east central Montana. The principal part of the report relates to the area covered by field detail mapping of Tps. 15 and 16 N., Rs. 38 and 39 E. of the Principal meridian, Montana, the area now being known as Freedom Anticline.

It is an area which had received no previous detailed geologic work nor is mention of this anticline made in either state or federal reports, although the country which lies at some distance from it had had the interest of the United States Geological Survey for many years. The Survey has recorded the geology and coal and oil possibilities of adjoining areas in some recent reports among which are the following:

U.S. Geological Survey Bulletin 621 pages 61-70 has a brief discussion by C.F. Bowen entitled "Possibilities of Oil in the Porcupine Dome, Rosebud County, Montana (1914) ", a report of

field work partly detail and partly reconnaissance, on a dome which lies twenty-five miles due south of the area which is the subject of this report. The same writer presented information in an advance sheet of the U.S. Geological Survey on the Alice Dome area, which is situated 35 miles southwest of Freedom Anticline. About fifty miles southeast of the area the coal-bearing strata of the Fort Union beds were mapped and the geology discussed in U.S. Geological Survey Bulletin 341-A. Considerable work has been done on the coal beds north of this area, on the northern side of the Missouri River about 100 miles distant.

It is seen from these remarks that an area covering practically all of Garfield and parts of adjoining counties has had no detailed geological work. In the following pages it is proposed to describe the stratigraphy and geology of the region with especial reference to the unconformity discovered at the base of the Lance formation. The key map on the following page shows the general location of the area described in this report. It is more carefully described as being in the four townships 15 and 16 north, ranges 38 and 39 east, Principal meridian, Montana.

The principal trading point for the region is Miles City, ninety-three miles distant. The area is probably one of the most isolated in Montana, at least in regard to lines of communication. The nearest railroad station is Ingomar 72 miles distant on the Chicago, Milwaukee, and St. Paul Railway.

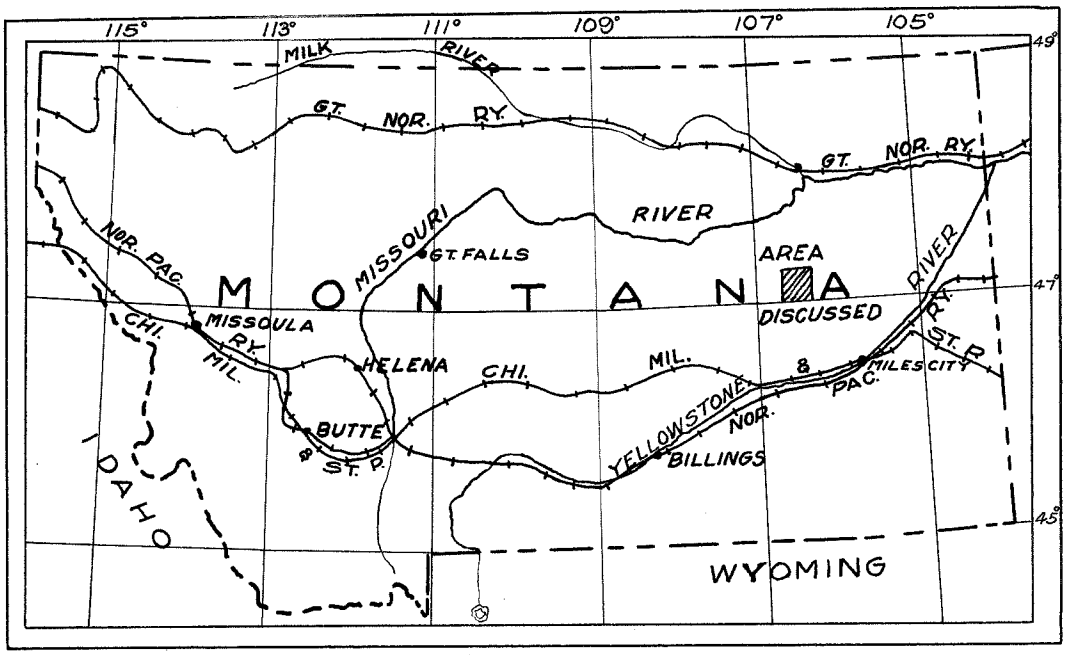

Plate I Key map of Montana .

There is a stage road from Ingomar to Jordan, a town 20 miles north of the anticline, but the condition of the road is such that the longer route to Miles City is preferable.

ACKNOWLEDGMENTS

The writer is happy to acknowledge the assistance and criticisms of the Dean of the College of Science under whose direction this thesis was written, and of the Professors of the department of Geology, University of Washington. Appreciation is also expressed to the Geologists of the Midwest Refining Company for suggestions during the course of the field work, and to the company for permission to use the material for a thesis. To the Assistant Geologist of the party and to the Instrument Man, thanks are due for work in the field. Mr. Darwin Harbicht collected from Garfield County and adjoining areas and sent the writer the fossils listed in this report, which are presented to the University of Washington.

PREVIOUS WORK

In 1921 the Mid-Northern Oil Company of Montana detailed Mr. J.M. Sickler, one of the company geologists, to make a reconnaissance report on the area. Mr. Sickler spent two or three days on the area and made a sketch map by means of hand compass readings which showed the chief structural feature. He reported to the company that the area was worthy of care-

ful geologic work. In the same year the Absaroka Development Company of Montana sent a party into this area. No doubt a report (unpublished) was made, although this writer did not see it, and a map was made showing what was believed to be the most favorable surface holdings. In about 1923 ? a reconnaissance party of the United States Geological Survey made a trip through Garfield County and mentioned both the anticline now known as Freedom Anticline, and the Blood Creek Syncline eight miles north, as prominent structural features. The information was sent out in an advance sheet of the U.S. Geological Survey. It is doubtful if it has yet been published.

When the Midwest Refining Company decided to map the area carefully, Mr. Norton was sent to the region and spent about a month's time establishing base lines and setting the triangulation net over the four townships above mentioned, before the writer's arrival in the last part of August 1924.

LAND SURVEYS

Practically all of the section and quarter-section corners of the original subdivision survey were found and tied to the triangulation net. The corners were found in good condition and consisted, on the area mapped, of set rocks with evidences of pits, or mounds of stone, or buffalo bones, a characteristic of old United States Land Office corners in

eastern Montana, at places where no rocks for mounds were available when the corners were set. When a more extensive triangulation net was set for the purpose of carrying a sea level elevation to the area, it was learned that considerable recent subdivision had been done, the newer corners being marked with the regulation cement-filled iron posts with brass cap. The distances and bearings of township and section lines corresponded very closely with our triangulation and are shown as a base map on the accompanying structure map.

TOPOGRAPHY

The Freedom Anticline lies in the open plains region of east central Montana. The general topographic expression of the area may be described as long rolling and gently sloping plains wherever the surface is sandy in character. The topography becomes more steep where shale is the predominating surface constituent. In the vicinity of the anticline the topography may be called hilly. The plains are treeless except along creek bottoms where an occasional cottonwood is found. In the valleys of some of the largest creeks the cottonwoods attain a size of probably 20" in diameter, but for the most part are smaller. In a few instances straggling groups of willows occur. The aggregate, however, makes only a scattering of growth in the valleys, and shows effects of the occasional floods which rush down the ravines and gulleys after a rain.

The general sea level altitude of the country is about 2800 feet with approximately 400 feet of relief on the anti-

cline. The chief topographic feature is the structure on which the work was done. The largest stream connected with the area is Sand Creek eight miles north and flowing northeast along which there are extensive dissected tracts of Lance and Fort Union shale reaching from this creek a distance of a mile or more on both sides. This stream is small and sluggish in dry weather but attains the proportions of a minor river during times of rain. The rapid erosion of the Fort Union shale results in many steep and narrow gulleys which represent the beginnings of bad lands. This creek is bordered by frequent abrupt walls fifty feet in height, a large part of each being torn down by undercutting after a rise of the water. Extensive bogs border the stream wherever its gradient is gentle, and quicksand has been reported in its bed in a number of places.

Except where hard sandstones form the surface, erosion is rapid both by water the chief means and by the prevailing high winds. Large isolated buttes characterize this part of the country and at the top of each is usually found a hard sandstone capping underlain by fifty feet or more of soft shale. The position of hard and soft layers of material is well marked in these buttes by the shelf-like outcroppings of the more resistant members. The buttes themselves were found to be convenient for use as triangulation bases for monuments in the net established for the purpose of bringing in a sea level elevation to the anticline.

The chief topographic feature of the area detailed is a steep escarpment of lower Lance sandstone forming the northern edge of the anticline and extending in a northeasterly direction for about ten miles. This escarpment is well defined on the northwest, north, northeast, and southeast edges of the area, with dips as steep as 16 degrees on the northern side. The change to a gentle slope of about 1 degree at the southern extremity is regular. The greater part of the central and western parts of the anticline are rugged and badly broken, exhibiting no reliable slope dips. In this location the surface consists of a succession of steep buttes, their sides strewn with large blocks of lower Lance sandstone. Farther west the buttes become smaller in size and more widely scattered until after passing the Bearpaw contact they are only isolated knobs.

Along the valley of Santo Arroya Creek and that of its largest southern tributary, the surface which lies in the Bearpaw shale has been eroded to large flats which are full of small steep-walled, ditch-like streams. Passing to the extreme northwestern edge, the steep escarpment is again encountered although it is not easily discerned because of the overlying Lance and Fort Union Beds. The change in elevation from the valley to the top of the escarpment is abrupt. On the western edge a high ridge with many sandstone members roughly parallels Santo Arroya Creek about two miles from it.

At the extreme southwestern end of the structure, steep wall-like ridges of Lance are met. On the southern and south-

eastern sides the topography becomes more rolling because of the sandy surface overlying harder members of the Lance. Phillips Creek on the southeast and East Long Branch Creek on the east are the only streams of sufficient strength in their respective localities to cause ruggedness in a topographic sense and their valleys are small.

The topographic high points form a divide between Santo Arroya Creek on the west and East Long Branch and Phillips Creeks on the east and southeast, which extends from the northern edge of the escarpment in section 25 T. 16 N., R. 39 E. to the southern part of section 14, T. 15 N., R. 39 E. bearing slightly southwestward.

DRAINAGE

The area under discussion is drained by Santo Arroya Creek and tributaries on the northeast and by Phillips and East Long Branch Creeks and several smaller ones on the east. Santo Arroya Creek flows northwest from the anticline thru a gap in the escarpment, and turns eastward to empty into Sand Creek which is a tributary of Big Dry Creek. The Big Dry flows northeast and empties into the Missouri River. Phillips Creek flows southeast and thence east to join the Little Dry which in turn flows north to unite with the Big Dry.

During the heavy spring rains all these streams carry a considerable quantity of water, especially the Big Dry and Sand Creek which then warrant the name of rivers. At other

seasons, after a single heavy rain or couldburst, they become temporarily bold and torrential, but for the greater part of the year they are all feeble streams. This type of topography allows a rapid run-off especially when the surface is shale, and as a result the tendency is toward steep-sided gulleys of the semi-badland type. At only a few places in the locality are there any water seeps and many of the smaller streams have been dammed to provide water for range cattle during the months of drought.

The best damsite found is in the southwest quarter of section 30, T. 16 N., R. 39 E. At this place a dam 180 feet long has been built at the junction of two large coulees. An additional four feet to the height of the present dam will back the water up the larger coulee a distance of approximately 600 feet. This site is about one and a quarter miles from the high point of the structure and vertically 134 feet below it.

CLIMATE, CULTURE, AND TRANSPORTATION

Twenty years ago this region was used only as a cattle range and is still so used although less extensively. The sandy slopes and rolling prairie lands support a growth of grass which is abundant in spots. With the rapid settlement of eastern Montana this region too was tried for its agricultural possibilities in spite of its great distance from a railroad. That the dryland er was for the most part unsuccessful is attested by the large number of abandoned

shacks and broken barbed wire fences that are seen when traveling any considerable distance about the country. The few homesteaders who were successful are located along the valleys of the larger streams and run cattle and sheep in this locality during the greater part of the year. The chief product of the farms is wheat.

The country is infested with prairie dogs, and coyotes were seen almost daily in the vicinity of the anticline where the abundant caves in the Lance and Bearpaw formations afford well hidden dens for them. The only poisonous reptile here is the rattlesnake, which in certain spots becomes troublesome. Antelope were frequently seen investigating the sight flags and the triangulation monuments.

There is no traffic northward to the Great Northern Railway from this region because of the distance to towns, at least 150 miles, and because of the lack of bridges across the Missouri River. The principal town encountered near the area is Jordan, twenty miles north. It has, as was previously mentioned, no rail connections, and of the two stage roads to railroad points the one leading to Miles City is the better. This road leads from Miles City up North Sunday Creek and is known as the Mordan stage road. The entire distance of 93 miles is graded but only a few miles are graveled and since the roadbed contains much gumbo it is barely passable for cars after a rain and often impassable for several days at a time during the winter months. Freight rates are high, particularly in winter and the prices of all commodities are correspond-

STRUCTURE

The two dominant structural features of this region are the Freedom Anticline and the Blood Creek Syncline. The location of the anticline has been previously given and the low points of the syncline lie about eight miles north. The syncline consists of a broad and deep trough bearing roughly northeasterly and contains the entire Lance formation as it is present here, with most of the overlying Fort Union formation. Adjacent to the anticline the strata dip steeply toward the trough, but within a mile or two thereafter, the change toward gentle dips of one or two degrees is effected within a comparatively short distance. Evidence of the depth of the trough is had by observing that the topmost beds of the syncline lie in a topographic depression which in itself is several hundred feet deep. This depression is the valley drained by Sand Creek. It is characteristic of the region that the topography coincides quite closely with the structure.

There is a small syncline lying along the western edge of the anticline which separates it from a fold of minor importance called locally the Jordan Dome, which lies some six miles farther southwest. The direction of this syncline is N. 20° W., and the beds rise slowly to the west continuing to the top of the so-called Jordan Dome. The presence of the Lance and Fort Union ? beds in its northward extension give no clue as to its persistence, but its shallowness makes it

unimportant except at the locality where it serves as a structural depression between the two folds.

The Freedom Anticline, the most prominent structural feature of the region, has the shape of an asymetrical dome with the steep side on the northeast. It covers the greater part of Tps. 15 and 16 N., R 38 E., and parts of the two adjoining townships in R. 39 E. Except for the small uplift called Jordan Dome, there is no other anticlinal feature in this region, the nearest being the Porcupine Dome, the northern extension of which is some thirty miles south. The folding took place at a time after the Fox Hills and Lance had been deposited and probably after Fort Union time, although the latter formation is not present on the flanks of the fold to give the relative age of the folding. The formation does occur in the adjoining area in the trough of the Blood Creek Syncline which was probably folded concurrently with the uplifting of the anticline.

The attitude of the beds on the northern side exhibits steep dips, being as high as 16° in the steepest parts, although they are not continued for a distance greater than a quarter to a half mile. Moreover these dips are read on the hard sandstone members of the lower Lance, and therefore cannot be taken as entirely correct in view of the apparent unconformity which exists at its base and which will be later described. However the Bearpaw shale was sufficiently exposed on this northern flank to allow the computation of its

dip over a distance of six miles and to record it as varying from 13° to 4° which closely approximates the attitude of the Lance rocks. Within a distance of about a mile from this steep escarpment, the beds become more flat as they approach the trough of the syncline. The northern edge is cut by deep gullies into the Bearpaw shale which allows a progressive series of contacts to be mapped over the entire distance from the crest of the fold to the western extremity. Contacts on the northeast side are not so easily had because the Lance and Fox Hills beds have not been sufficiently eroded to expose the Bearpaw except along the head of East Long Branch Creek. On the southeast side fine contacts were obtained for a distance of about five miles along Phillips Creek and tributaries. The dip on this side is much less than on the northern edge, being about 1° at the edge of the structure. Contacts on the Bearpaw can be had here only as long as the stream gradient is sufficient to cause erosion through the Lance and Fox Hills. The composition of these formations is so changeable that contacts by means of correlation with them is out of the question. By way of illustration, in one place, what appeared to be four separate sandstone beds, each more than four feet in thickness and separated by several feet of shale, were followed a distance of 300 yards where they were found to become one sandstone bed eight feet thick.

Contacts were mapped in all the gullies through the

central part of the fold and down to the southwest corner where the final dip computed gave but 0° 45' which brings out the relative amounts of opposed dips at the two extremities of the anticline. On the southern side few contacts were to be had because of the presence of the beds younger than Bearpaw. However a regular bed of rocks containing Unio was mapped for several miles and its position computed by measurements at places where the interval could be taken from a fossil bed containing Corbicula which marked the top of the Fox Hills on the southern side of the area.

The general bearing of the major axis is northeast, with a slight curve to the east after passing section 25 where the high point of the fold is found. Since the beds dip gently southward from the crest for several miles, at the same time spreading out in a fan-like shape, the gathering area controlled by this dome is large. The critical side was found to be on the southwest where the closure in that direction was found to be 230 feet. The structure contour map of plate II shows the position of the beds as contoured on the Bearpaw-Fox Hills contact. This contact will be described under the heading of stratigraphy.

Three faults were encountered in this area, but one of them lying far out on the eastern side and up in the Lance rocks was of too little extent and importance to map. The most significant fault, the surface trace of which is shown in plate II, is located near the crest of the dome, and is a normal fault with downthrow on the north side.

The throw measured in the dip plane of the fault is about 75 feet, and its direction is S. 65°. Its hade is 45° , and being to the downthrow will therefore not affect the size of the gathering area of the fold, combined as it is with the steep dip of the strata about a half mile northeast of the fault and parallel to it. The third fault is located on the west side of the dome more than two miles from the top, and extending in a direction a little south of east. It is not so well exposed as that at the top of the dome, disappearing under the Lance beds at both ends and for a distance of a half mile in section 33. It was first observed in the bank of one of the tributaries of Santo Arroya Creek where it was recognized by the filling of the old shear plane with calcite and aragonite which on weathering has mixed with the shale to form large yellow patches along the fault plane. In both of these faults the shear has apparently been regular and the absence of any quantity of gouge indicates the depth of the faults. However the nature of the material is a consideration which would overcome this assumption since it is a characteristic of a fault in soft shale to disclose no jagged lines marking the surface trace. Frequently faults in this type of country may be located by a break in the kind of vegetation, but here it is not observed because enough of the sand from the overlying beds blows down on the Bearpaw to make the vegetation entirely uniform. The throw of this fault is about 25 feet as shown on the structure map. It will not affect the fold as a reservoir for oil.

STRATIGRAPHY

FORT UNION (TERTIARY)

The youngest with which we are concerned in this region are those belonging to the Fort Union formation, which covers practically all of that part of Montana east of this area to the state line. The Fort Union is one of the many formations named by Meed and Hayden in the days of the Territorial Surveys. In 1862 (1) these gentlemen measured a type section of the beds near old Fort Union, a former military post on the Missouri River in North Dakota, about three miles from the Montana boundary, and described the formation.

Hayden collected plants at Fort Union and gave the collection to Newberry for determination, who called them Tertiary and placed them in the Miocene because he identified in the collection many species of plants collected at various European localities described by Professor Oswald Herr in "Flora Fossilis Arctica" and called there Miocene, but they were later shown to be Eocene. Many of its forms have been found along the Pacific Coast in the Tertiary deposits there. The flora are now well correlated with American, European and Greenland forms and the formation is definitely established as of Eocene age.

(1) Meek, F.B., and Hayden, F.W., Description of - - - - and Tertiary fossils collected in Nebraska by the exploring expedition - - -; Acad. Nat. Sci. Phila. Proc. vol. 13, p. 433, 1862.

The Fort Union has been eroded from the uplift of Freedom anticline but appears on the eastern edge and northeast along Sand Creek, and practically over all the area traversed by the road from the anticline to Miles City. It is usually subdivided into an upper member, in which the most valuable lignite deposits are found, and a lower member called the Lebo shale. The upper thick member consists of sandstones and shales but as it is not represented near the anticline, its description will be omitted. The Lebo shale member as the name implies consists principally of shale with clay and sandstones comprising only a minor part. The lignite seams which occur in this member are thin and do not compare in importance with those of the upper beds. Along the road to Miles City are seen the characteristic layers of dark carbonaceous material sometimes becomming nearly red in color, and frequently adjacent to a small seam of lignite. The formation weathers into high buttes with a hard sandstone member forming the crown and the softer material forming steep and often perpendicular sides. The harder layers stand out plainly along the sides where the various colors and thin intercalations can be noted even at a considerable distance. The bedding in the shale members is generally regular. Where the erosion of the hard sandstone has left the shale exposed the typical "badland" appearance results.

The lower member is about 300 feet thick and can be distinguished from the upper member with difficulty. The entire

formation varies in thickness from 1000 feet at Plentywood, in the northeast corner of the state (2) to 3000 feet in the Crazy Mountains area. No section of the lower member was measured on the anticline because the formation does not occur in a place where it would have to be penetrated by the drill in testing the anticline. The underlying Lance formation is so nearly like the Fort Union that they are frequently hard to distinguish, although local unconformities have been reported in a few places.

LANCE (TERTIARY ?)

In 1889 Professor O.C. Marsh gave the name "Ceratops Beds" to certain (upper Cretaceous ?) beds situated in Wyoming, Montana, Colorado, and the Dakotas. The name was significant of the reptilian and mammalian fauna, the horned dinosaurs, or Ceratopsidae which were excavated in abundance in a part of Converse County, Wyoming. The best sections of this formation were then found along Lance Creek, Converse County, and were at a later time designated "Lance Creek Beds." Eventually the name was shortened to Lance which is the present accepted name. The formation has had also a variety of other names, among which we find "Laramie", when it was temporarily thought to be a part of or equal to the Laramie formation.

(2) Bauer, C.M. Lignite in the vicinity of Plentywood and Scobey, Montana. U.S. Geol. Surv. Bull. 541, p. 299.

"Lower Fort Union", when the evidence from the flora seemed to indicate that the Lance and Fort Union were the same formation, and "Somber Beds", a name still in local use, derived from the appearance of the upper shale beds of the formation. As an unit, this formation includes all the sediments lying above the Fox Hills and below the definitely known Fort Union. Its stratigraphic position has been one of the subjects which has caused considerable discussion and argument by paleobotanists, paleontologists, and stratigraphers for the past thirty years, and no conclusion has yet been reached which can reconcile all the branches of evidence.

The Lance continues south from Freedom anticline about twenty miles, nearly to the Porcupine Dome, and then extends west to the Musselshell River, a distance accepted as about 50 miles. It borders the Musselshell River to its junction with the Missouri, in a belt 20 to 60 miles wide, and continues along the Missouri for a distance of about 150 miles in a belt varying in width from a few miles at the eastern end to 60 miles at the western extremity. There are many other places in eastern Montana where it occurs, although this expanse of the formation constitutes one of its largest exposures in Montana.

The Lance has been subdivided in places into three members, the lowest including the massive sandstones, sand logs and beds of sand, a middle member composed of clays and shales and crossbedded sands, and the top member of shales and

some lignite seams. Other divisions have been made to depend on various horizons of vertebrate fossils. Also, during the summer of 1912, E.R. Lloyd of the U.S. Geological Survey, discovered a strictly marine member of the Lance, situated in the uppermost 250-300 feet of its beds. (3) On the Fort Peck Indian Reservation there were reported several thin layers of limestone. (4) The character of this formation is not fixed, but changes from place to place in a most surprising fashion, showing that variation in conditions of elevation, subsidence, and of deposition were going on continuously from the close of the Fox Hills time until the more stable conditions of Fort Union time were reached.

As found on the Freedom anticline, the Lance was represented by two members. The base of the lower one was a marked fluviatile deposit separating the Lance from the Fox Hills by what appeared to be an unconformity. Above this was found a dark brown coarse sandy bed with some shale and frequently containing bands of limonite. These bands are often as much as a foot in thickness and are made of rounded concretionary masses which erode to round balls and various similar shapes. In other places the bands are composed of a layer of red brown

(3) Lloyd E.R. The Cannonball River lignite field, U.S. Geol. Surv. Bull. 541, p. 243. 1912

(4) Smith, C.D. The Fort Peck Indian Reservation lignite field, Montana. U.S. Geol. Surv. Bull. 381-A p. 43. 1910.

limonite massive in appearance and very brittle, which character permits it to become scattered over many of the shale and sand layers to which it does not belong. These bands are not persistent for any considerable distance, nor are they constant in number. Like many of the other layers in the Lance, they come in and go out either singly or several at a time. The bands are usually separated by shale or clay which varies in amount from one to ten feet.

The evidence is indicative of swamps and bogs at the time these sediments were deposited. Forther confirmatory evidence is had from the presence of stems of plants. Apparently dinosaurs were present at this time, for the bones of one of them were found near the central part of the area. The skeleton was but partly preserved, and those bones which were recognizable were not sufficiently well silicified to permit their removal. On the western edge of the area, at this horizon, or perhaps a little above it, were found some very good specimens of fossil bones of dinosaurs. It was at this period that the Triceratops flourished, and the American Museum of Natural History has procured several specimens of it from Garfield County. In one place on the western edge of the anticline preserved bones of these monsters were excavated by the writer and some of them saved. At this locality fossil bones could be obtained at nearly all places where the horizon of a shale bed was exposed. It is safe to conjecture that the place had been a watering hole for the creatures and that they

had become mired while wading about in the muds and shales. It has been generally supposed that the last of the Cretaceous marked the highest development of the reptiles and at the close of the period both sea and land possessed a large reptilian fauna. The beds containing their remains had early been correlated with the Danian or Maestrichtian, both of which are characterized by reptilian fauna. It has been generally supposed further, that the fauna, being sensitive to changes of temperature, were extinguished by a general lowering of the temperature. The evidence as exhibited in the Freedom area, however, is not in accord, for in the rocks immediately overlying the horizon of Ceratops, are found preservations of the same flora which were in existence at the time the animals were entombed. The lithology of the sediments suggests that the region became more arid for a time, which explains too the popularity of the swamps.

Among the good specimens found were several that appeared to be leg bones. Fragments of bone could be found in great abundance, and probably had one the time some interesting discoveries might be made in this locality .

The clays and shales of this horizon are drab in color weathering almost white partly because of the alkali content. In a few places buttes of dark shale occur, which upon first glance may be mistaken for the Bearpaw so closely does it resemble the older formation. It may be distinguished by the bedding of the hard and soft layers, a character lacking in the Bearpaw shale.

Above the first sandstone is a thick light-colored sandstone, measured in the southern part of the area as 60 feet. This is a persistent part of the lower Lance, and has been described in several reports as the real base of the formation. In this area it lies above the Ceratops horizon, and is therefore not the base of the Lance, which must be made to include the vertebrates called Ceratops. It changes color slightly from place to place, and at its lightest resembles the Mesa Verde sandstone of the southwestern United States, while in places where the iron content is greater its color is more brown than white. It erodes into steep-walled canyons, many of which on the southern side of the area give nearly complete sections of the bed. It is cross bedded in many directions and within as short a distance as ten feet, one can find bedding planes are changing 90^{0}, while some are actually curved. The material is coarse grained quartzitic sand tightly cemented and resistant. The appearance suggests that during the time of deposition this part of the formation was the shore line of a large and stormy lake, large because the sand extends for hundreds of miles, and wild because of the vigorous cross bedding. At the top of the sandstone is a more hard and resistant cap layer consisting of about ten feet of brown sandstone massive in appearance. The two parts seem discrete both in lithologic character and in the manner of deposition. The cap rock exhibits no cross bedding and its thickness is fairly regular indicating that at the time of its deposition quiet water prevailed.

The log-like sandstones appear in these parts of the formation and resemble in appearance large trees lying about on the ground. A frequent form of erosion is the breaking of the log into blocks or a lateral break part way through, both of which give added resemblance to trees. The size varies from one or two feet in diameter to ten, and the manner of their formation has not been explained. Among the suggestions advanced to explain their making is that they represent the filling of underground tunnels cut by running water. The logs themselves are all sand and not replacement products of metasomatism. Hypotheses are multiple but it is believed that the explanation has not yet been properly ascribed.

Above this regular sandstone layer is found about ten or twenty feet of shale of somber gray color and no special characteristics. It is overlain by a sandstone bed about six feet or more in thickness which contains a very abundant fauna identified by Mr. Norton and Mr. Bauer as Unio. The preservation has been excellent and the size is very large. Moreover this member of Naiadacea lived in still muddy water, which is another proof of the quietness of the waters succeeding the storms in which the heavy sand members were deposited. The fossil bed was mapped for a distance of several miles along the southern edge of the area, and measurements from it to a fossil bed which marked the top of the Fox Hills showed 125 feet of the Lance between the two.

Above the Unio bed the Lance passes into the gray shales

with widely separated sandstone members which appear to decrease in size as the younger parts of the deposit are reached. There is more than two hundred feet of the formation on the southern side of the area but only fifty feet near the top of the dome. Just at the crest it is all eroded, exposing both the Fox Hills and the Bearpaw.

FOX HILLS (CRETACEOUS)

Below the hiatus at the base of the Lance formation is a stratigraphic unit made of sands and shales and limestone beds which represents stratigraphically the Fox Hills of the western South Dakota region. This formation received its name from Meek and Hayden in 1861 (5) at Fox Hills between Cheyenne and Moreau Rivers above old Fort Pierre. At the type section the top of the Fox Hills is marked by a thin brackish water bed with Ostrea, Anomia, Corbicula, Melania and other forms. The similarity of the beds at the base of the Lance at Freedom, and those of the Fox Hills in South Dakota was recognized, although so far as known, the Fox Hills had not been mapped as an unit this far west. The sequence and general appearance of the beds is striking although there have been some lithologic changes which would be natural in sections so far apart.

In the Freedom area this formation is represented near the top of the structure by a light colored sand varying in thickness from seven to thirteen feet, lying just below the Lance. This bed can be correlated with the harder and more

(5) Proc. Acad. Nat. Sci. Phila. vol. xiii pp. 419, 427.

resistant brown sandstone at the top of the Fox Hills in the type section. This sand overlies alternating bands of light gray shale and sand of about a foot each, in thickness. Several sections of these top layers were taken about the area, especially near the top of the anticline where the best exposures were obtained, and while some variations were noted in the thickness of individual bands of the shales and sand, the total thickness was as constant as could be expected for any regularly deposited sediments of this kind. These top layers had been trenched and channeled by erosion prior to the time at which the Lance was deposited on it. This is evidenced by the fact that the Lance sands fill several "V" shaped gullies cut into the clays. These irregularities show no evidences of slumping, but give the appearance of having been caused by stream erosion.

Below these upper layers is a persistent bed of buff limestone in which the subgenera Corbicula was particularly abundant. It may be correlated with the Ostrea-Corbicula bed in the position corresponding to it in the Fox Hills region. This bed is about four or five feet in thickness and marked a time when brackish waters had returned in greater depth than for the shale interval which preceded it.

Below the Corbicula bed is a succession of gray shales attaining in their best development a thickness of about 12 feet. Below them is found another buff limestone fossil-

iferous bed similar in appearance to the one above described but not so thick as the younger. It too contains abundant Corbicula and several other forms not identified. Between this limestone bed and the Bearpaw shale is a bed varying in thickness from one to five feet, persistent throughout the area and consisting of a series of highly colored bright yellow, red, and magenta bands each a few inches thick and alternating with dark shale. In the largest of these bands at the bottom, is a thin seam of fine gray powdered sand whose occurrence is limited to the lowest band only. This seam of sand was taken as the contact between the Bearpaw and the Fox Hills for the following reasons: It is the lowest sand seam of the overlying beds. It lies just above the dark marine shale with characteristic concretions and Bearpaw marine fossils. It can be readily distinguished from all the other colored bands and is thin and persistent and readily recognized wherever weathering has exposed it. This band was mapped and its elevation computed for all parts of the field for the structure contour map of the anticline shown in plate II. At places it appears as a thin hard gray sandstone, forming a shelf above the less resistant Bearpaw shale. In it are found many round nodules of pyrite and along it occur star-shaped or hexagonal deposits of gypsum. This shape of the gypsum gave rise to the opinion that it is here occurring as a secondary mineral from the original pyrite nodules. The gypsum is probably formed by the action of ferrous sulphate

on calcium carbonate, the ferrous sulphate being an oxidation product of the pyrite. This suggests the following chemical synthesis of the gypsum:

$H_2O + SO_2(gas) + O = H_2SO_4$

FeS_2 (pyrite) + $H_2SO_4 = FeSO_4 + H_2S + S$

$FeSO_4 + CaCO_3 + xH_2O = CaSO_4.2H_2O$ (gypsum) + $FeCO_3$

The total thickness of the formation varies from 35 to 66 feet, the apparent irregularity being explained by channeling.

BEARPAW (CRETACEOUS)

The Bearpaw formation was named by Stanton and Hatcher in 1903, from the Bearpaw Mountains around whose north, south, and east sides it is well developed. In this region it is usually designated as the upper member of the Montana Group, and is limited to dark or black marine shales lying below the Lance (or Fox Hills where present) and above the Judith River sandstones. It probably represents but a part of the Pierre farther east, with which it is correlated stratigraphically and paleontologically. Its thickness has been estimated in various places in eastern Montana at from 750 to 1000 feet. It contains a rich invertebrate fauna referred to deep and quiet waters. The fossils are found in limestone concretionary beds which extend with more or less regularity at intervals throughout the formation. The thickness of these beds is seldom more than a few feet and the yellow to buff colored

limestones lie as an aggregate of large concretions within which the fossils are found. They have been filled with calcite and aragonite at the seams which extend in net-like shapes throughout the beds.

Because of the high content of gypsum and other alkaline salts all water found in the formation is not fit for domestic use. Sage brush and greasewood grow sparingly on the shale and grass appears only where sand has been mixed from surrounding formations. In the Yellowstone valley a sandy phase of the formation is known but in the region of Freedom, sand is practically absent. These shales weather readily into broad flats and depressions several miles across with fairly level but rough surface surrounded by escarpments of sandstone of other formations. In the region of Porcupine Dome the formation outcrops in a belt which surrounds the dome, and shows both upper and lower contacts.

These sediments represent the last depositions made in deep water in the Cretaceous sea. Some slight oscillations occurred allowing the sea to become deeper at the intervals of the limestone members, but quiet water was the usual thing. The retreat of this sea seems to have been slow for there are no sudden breaks in the type of sedimentary deposits other than the occasional advances of deeper water when the concretionary beds were formed. The high development of the invertebrate forms points to warm and pleasant conditions.

The Bearpaw is the oldest formation exposed on the area. It appears in but few places on the east side but is well

exposed from the top to the extreme west and southwest edges, where three miles due west of the top at least 100 feet have been eroded. Two of the chief forms identified from the concretionary beds are the Baculites compressus and the Scaphites nodosus which occur abundantly within fifty feet of the top. Above the uppermost limestone bed are found some yellow clay bands and about 20 feet of dark gray shale extending to the Fox Hills contact.

The probable thickness of the formation here is between 700 and 800 feet. A trip was made to the Porcupine Dome, the nearest exposure of a complete section of the shale, and a measurement of its thickness was made there of 764 feet. The section here was not very good, but had to be accepted because it is the only one near the area, and it lies more than twenty miles south. Because of the slight dip, the section covered a surface measurement of more than six miles in which distance the strike had changed considerably. The dip had changed from 3° at the lower contact to 1° at the top. On the western side of the Porcupine Dome the Bearpaw was measured as 1000 feet. The formation becomes thinner eastward and changes but little north and south which leads one to conclude that the measurement on the north edge of Porcupine Dome is practically the same thickness that will occur at Freedom.

At least fifty species of marine invertebrates have been identified from this formation and a few of these are discussed at the end of this report.

JUDITH RIVER (CRETACEOUS)

In 1871 F.V. Hayden, (6) working on the Geology of the Missouri Valley, named a formation which he found at the mouth of Judith River, after the stream. The formation consists chiefly of fresh and brackish water beds lying between two marine shales, the Bearpaw above and the Claggett below. It is a member of the Montana Group as determined by Stanton and Hatcher in 1903, and is the time equivalent of a part of the Pierre shale.

Although this formation is not exposed on the anticline, it is necessary to get information of it because it is a possible source of gas, and must be penetrated by the drill in testing the structure. Accordingly two trips were made to the nearest exposures for the purpose of studying and measuring the formation. One section was measured on the northeastern edge of Porcupine Dome where the thickness was found to be 136 feet. A second section was measured about twenty-five miles southwest of the anticline and there found to be 239 feet. These sections are about 30 miles apart, and since there is no exposure between them to give further information it must be concluded that the formation grows thinner toward the east.

There are two thick sandstones in this formation separ-

(6) Hayden, F.V. U.S. Geol. Surv. Terr. 4th Ann. Prel. Rept. p. 97, 1871.

ated by alternating layers of sandstone and shale with the shale predominating. In some areas coal beds are found and the beds are locally rich in remains of dinosaurs. The upper sandstone member is soft and erodes readily and covers the lower shales. In color it is nearly white and in texture coarse and granular. The lithology and color of the upper sandstone change from place to place sometimes being light yellow instead of white or gray and being more massive in some places than in others. Occasionally cross bedding is observed and some ripple marks can be detected. The upper surface of the sand is crossed by a network of cracks resembling the joints or columnar structure of basalts. The intermediate shales are somewhat sandy although clay predominates. In color the shales are much darker than the top sandstone and contain streaks of light gray material or brown sediment. Occasionally a thin seam of carbonaceous shale was found. Where the shale member is exposed it erodes into shapes resembling those of the Lance and confusion frequently arises from this similarity in regions where correlations are not easily made. This feature led to a difference of opinion as to the stratigraphic position of the Judith River beds, for many years.

Near the base of the formation limonite concretions and oblong blocks of sandstone occur. Bright colored bands appear in the darker portions which on examination prove to be stains from the limonite nodules. The sandstones at the top and bottom produce walls on weathering while the middle

member weathers to sharp ridges. The second section mentioned above was measured at a locality known as "Hole in the Rock" where once a large basin had been made by the erosion of the middle member, and this was later cut through one end exposing the lower sand as a cliff and leaving the middle part as a basin surrounded by cliffs of the upper sandstone.

The thickness taken from these two sections and compared with Freedom for geographical location, indicates that about 150 feet of Judith River would be present at the anticline.

CLAGGETT (CRETACEOUS)

The type section of this formation occurs in the vicinity of Judith (old Fort Claggett) on the Missouri River and it was here studied and named by Stanton and Hatcher. It is separable into two divisions, a lower shale and an upper sandy member, but Bowen (7) says that the upper one as there described belongs in the Judith River formation.

The lower part was found both at Porcupine Dome and at Hole in the Rock, although at neither place could the base be found. This part consists of dark marine shale similar in color to the Bearpaw, but more evenly bedded and probably harder. The harder layers usually break into cubes or similar shapes and show stains of various colors at the parting surfaces. The invertebrate life is similar to that of the Bear-

(7) Bowen, C.F. The stratigraphy of the Montana Group. U.S. Geol. Surv. Prof. Paper 90-I, 1915.

paw and contains Baculites ovatus, Baculites compressus, Inoceramus and other forms characteristic of the Bearpaw. Gypsum occurs throughout the dark shale making the water in it strongly alkaline.

A section measured at Musselshell by Bowen was found to be 750 feet in thickness. Musselshell is about 80 miles southwest in straight line distance, so that this measurement may not be representative of the thickness to expect at Freedom. In the log of a well drilled 50 miles south of Freedom 900 feet of Claggett was assigned to this formation. However it was believed that the general thickness of the formation, according to measurements in several localities, should be about 700 feet at Freedom anticline.

EAGLE (CRETACEOUS)

This formation, the lowest of the Montana Group, is very thin or absent at Freedom. It has not been recorded as a unit of sufficient size to map, east of the Musselshell river.

COLORADO (CRETACEOUS)

This formation which took its name from the state in which it was first mapped, underlies much of the Great Plains Region of the United States and Canada. It consists of a light colored upper member about 250 feet thick and composed of drab shales and a few concretions. Below that, as nearly as can be determined the shale continues for 2000 feet with no great change in lithology. It overlies the Dakota sandstone, which is the oil-bearing formation in central and eastern Montana.

A condensed section of the formations which must be drilled at the Freedom anticline is given below.

Formation	Description	Probable Thickness	Total
Bearpaw	Sand only in spots Shale and concretions	800	800
Judith River	Sand and shale	150	950
Claggett	Shale	700	1650
Eagle	Thin or absent		
Colorado	Blue and gray shales	2200	3850
Dakota	Sandstone	50	3900

In 1914 the Chicago, Milwaukee, and St. Paul Railway Company drilled a well at Vananda, 50 miles south of Freedom for water and penetrated the following sediments. (8)

Formation	Description	Thickness	Total
Judith River	Sand and shale	215	215
Claggett	Shale	685	900
Colorado	Shale	2290	3190
Kootenai ?	Sand, limestone, shale	167	3357

The hard sand found near the top of the Kootenai at a depth of 3200 is probably Dakota. Add to 3200 the thickness of the Bearpaw, 800, and the depth to be drilled at Freedom by this correlation would be 4000 feet.

(8) Bowen, C.F. U.S. Geol. Surv. Bull. 621, p. 61, 1914.

EVIDENCE OF AN UNCONFORMITY AT THE BASE OF THE LANCE FORMATION

In the Rocky Mountain region the horizon which separates the Mesozoic era from the Cenozoic has been in dispute since geological work was begun on those formations representing the time interval which closed the Cretaceous and opened the Tertiary periods. The correct determination of this horizon is a part of a large problem which is concerned with the correlation of formations along the eastern flank of practically the whole Rocky Mountain system.

To attempt to even summarize the literature that this argument has called forth would require the space of a small volume. It is proposed therefore, to mention here only what appears to be the chief contentions, to state the evidence by which the conclusions were reached and to interpret in connection with them the new evidence discovered in 1924 at the Freedom anticline.

The formations which are pertinent to the discussion are the Fox Hills, which is agreed by all to be late Cretaceous in age, the Lance, the Cannonball formation (a marine member of the Lance), the Laramie whose age is not definitely fixed, and the Fort Union which is accepted by practically all geologists as of Eocene age.

Since the eras represent the intervals between the dominant breaks in geologic records, and since the breaks themselves are recorded by means of diastrophism, marked erosion, culmination of a dominant organic type or rise of a

new type, the evidence which will determine such a rupture may be classed under the following heads:

Paleontological, of both vertebrate and invertebrate forms.

Paleobotanical.

Stratigraphic.

To correctly draw the line which is to separate the Cretaceous from the Tertiary requires careful study of all these kinds of evidence giving to each only its significance for this area, and reconciling views that appear, upon cursory examination, opposed. From the evidence accumulated since geological investigation of these beds was begun, it is probably safe to eliminate violent diastrophism as the criterion for determining the separation of these periods.

> "Investigations of the Rocky Mountain Provinces and adjacent lower country to the east and west, made within 30 years past, have surely proved that the older idea of the diastrophism which characterized the transition from the Cretaceous to the Eocene period was very faulty. The change was gradual, not abrupt, and while over a large area the great Cretaceous succession was ended, the uplift was epeirogenic for a long period during which erosion and prevailingly continental deposition proceeded, and there was no such abrupt environmental change affecting life upon the land as has been assumed. " (9)

In considering the evidence which may be classed as paleontological, let us first consider the information to be had from the vertebrates which lived during the time

(9) Cross, W. Science, N.S. 1921, p. 304.

that part of these beds were deposited. One of the older ideas was that the presence of dinosaurs decided the age of the containing rocks and that they represented Cretaceous. The remains of vertebrates are found both below (Belly River beds) and above the contact of the Fox Hills and the Lance. The rocks just above the contact are richest in remains of dinosaurs in the area covered by this report and this is the usual case throughout the Lance formation. If dinosaur remains alone constituted the safe criterion, then the age of the Lance is Cretaceous. However, since there is evidence tending to prove that the Cretaceous ended before the Lance was deposited, it is easier to believe that the reptiles continued on after Cretaceous time in this area because they have survived periods of great erosion in at least one other place, remains having been found in the Denver beds where an erosion period sufficient to remove perhaps 20,000 feet of sediments has been experienced. (10) That is to say that dinosaurs of the type found in the Lance survived during the period in which the entire Cretaceous section was removed from a large part of Colorado. (11) The evidence of the vertebrates cannot therefore, be taken as final.

(10) Veatch, A.C. Am. Jour. Sci. xxiv, (1907), p. 18.

(11) Cross, W. op. cit. (9).

The following chart (12) shows the correlations according to vertebrate remains.

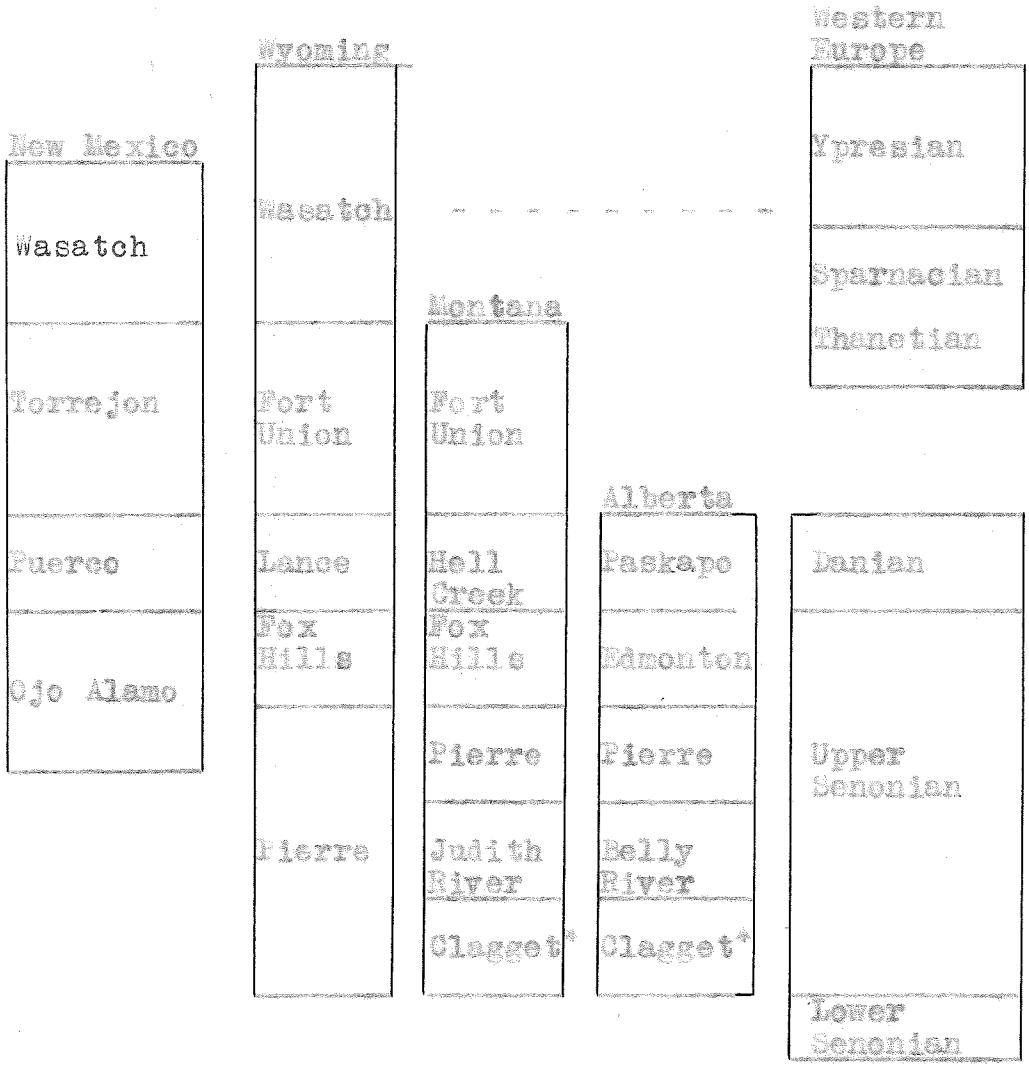

Chart 1. Approximate correlation of typical formations of the late Cretaceous and early Tertiary in Europe and western America based on their vertebrate faunas.

(12) Matthew, W.D. Evidence of the Paleocene Vertebrate Fauna on the Cretaceous-Tertiary Problem. Bull. Geol. Soc. Am. Vol. 25, pp. 381-402. *Given as Pierre.

A summary of the vertebrate evidence, then, shows that the line between Tertiary and Cretaceous should not be drawn between the Belly River and the Lance since the same faunal species exist in both formations. This view is not supported by the paleobotanical and stratigraphic evidence.

To evaluate the evidence presented by the invertebrate fauna would be a comparatively easy task if it were not for the Cannonball formation, a marine member of the Lance. The fauna of the Fox Hills is a marine and brackish water type and that of the Lance just above it is of fresh water origin the latter type being of little value in fixing age of beds. The value of the Cannonball marine member has been discussed by the discoverers (13) and summarized by Knowlton (14). It is a narrow irregular strip extending along the Cannonball River in North Dakota for about 75 miles with a thickness of from 200 to 300 feet, and with a marine fauna. Knowlton enumerates three possible explanations that were advanced to account for the presence of the member.

1. That it is a lens in the Lance in which case it must have resulted from a temporary invasion of the sea after the inauguration of Eocene time.

(13) Lloyd, E.R. The Cannonball River lignite field, North Dakota. U.S. Geol. Surv. Bull. 541-G, 1914, pp. 1-51.

(14) Knowlton, F.H. Cretaceous-Tertiary Boundary in the Rocky Mountain Region. Geol. Soc. Am. Vol. 25, p. 325.

2. That it is an erosion remnant of Fox Hills, surrounded by and projecting through the Lance.

3. That Fox Hills time continued through Lance to the Cannonball time.

The first of these positions has been adopted by the United States Geological Survey for the following reasons: Its position is above the Lance; it is not known to be structurally connected with the Fox Hills; its fauna, though differing somewhat is apparently most closely related to that of the Fox Hills. It may be a recurrent fauna surviving from the Fox Hills faune, itself partially recurrent from the Claggett (lower Montana). But this explanation requires a connection with the sea, presumably after the inauguration of Eocene time.

The evidence of the invertebrate paleontology would of necessity place the Cretaceous-Tertiary boundary at the top of the Cannonball formation, which itself is the top of the Lance, making a separation between the Fort Union and the Lance, a position not tenable in the light of the stratigraphic and the paleobotanical evidence. It would seem best for the time being to pass by the paleontological evidence as of unequal weight when compared to that with which it conflicts. That is to say that a single marine member lying at the top of the Lance should not be considered conclusive, for it is hard to see why a member of such small extent should be given greater weight than an unconformity of equal or greater extent. On the basis of paleontology, it will be recalled, the Judith River formation (middle Montana), was for many

years placed at a horizon equal to or above the Fox Hills which was, as has since been proved, error. (15)

The paleobotanical evidence is more strong in helping to designate the division line as adopted by the Survey. In 1878 a study of the flora of the Laramie was begun by Mr. Leo Lesquereux employed by Dr. Hayden. The flora were designated as Eocene for the Laramie and Miocene for the Fort Union. Mr. J.S. Newberry (16) made extensive collections of Laramie flora and made two trips to Europe to study the principal collections there of Tertiary and Cretaceous plants. He concluded that the Laramie belonged in the Cretaceous and that the Fort Union belonged in the Tertiary. L.F. Ward who has studied the problem in the Dakotas says that the plants of the Laramie occupy an intermediate place between that of the upper Cretaceous and that of the Eocene. According to Knowlton (14) sedimentation was continuous from the beginning of Lance time through the Fort Union, according to the evidence of the plant forms. The Fort Union has a very large flora of about 500 species and its Eocene age is verified by its affiliation with many European Eocene deposits of definite acknowledged position, as Ardtun in Mull, Gelinden in Belgium

(15) Bowen, C.F. The Stratigraphy of the Montana Group. U.S. Geol. Surv. Prof. Paper 90-I. 1915.

(16) Newberry, J.S. The Laramie Group Geol. Soc. Am. Vol. I. p. 524.

and Sezanne in the Paris Basin. This affiliation amounts to many identical and closely related species as well as related and identical genera. The flora of the Lance is also a rich one, comprising about 125 forms, 87 of which are positively identified and all but 15 are found also in the Fort Union. It is unmistakably a Fort Union flora and occurs through the whole vertical range of the Lance some of the most characteristic plants being found within 4 feet of the base of the beds. Of the entire known Lance-Fort Union flora less than 15 species have been reported from Cretaceous beds anywhere and this number will be reduced instead of enlarged by revision of the floras involved. Moreover in the Gulf region the Midway contains a published flora of about 65 species of which 25 are found in the Raton formation of the southwest. This correlation ties the Rocky Mountain region with the gulf. The Raton contains a flora of 148 species only four of which are found immediately below. The Raton in turn is correlated with the Denver with which it has 98 species in common, and with the Arapahoe. The plant beds at North Park Colorado rest on old shales, the Laramie being absent, but the flora is the same as that of the upper Laramie in Wyoming, and half of the flora of the upper Laramie is common to the Lance.

The line of separation of the Cretaceous from the Tertiary according to this evidence must be put at the base of the Lance, which is in accord with the stratigraphic evidence.

Turning to the stratigraphic evidence, it will be recall-

ed that various local unconformities have been discovered at the top of the Fox Hills. The time interval which elapsed during the erosion is not easy to determine. The localities where this phenomenon has been recorded are on Grand River, South Dakota, where there is a vertical cut of at least 72 feet; at Worthless Creek Valley, South Dakota, where the unconformity is angular as well as erosional; on the Moreau River near Covert post-office, South Dakota, where the Lance is horizontal while the underlying beds dip at an angle of 10°; at Hell Creek, Montana, where the Lance rests on a distinctly eroded surface, and similar occurrences have been recorded at other places in eastern Montana.

In the Freedom anticline area Mr. C. Max Bauer, formerly of the United States Geological Survey, while visiting the field party engaged there, called the writer's attention to a bed of quartz pebbles lying at the top of the Fox Hills, and mentioned the significance it might have on the Cretaceous-Tertiary problem if it could be proved to be of any considerable extent. This bed consisted of a band of quartz pebbles about half a foot or a foot in thickness, well rounded and water-worn and appearing usually as a single band frequently with a heavy brown limonite band. The size of the pebbles varied from an inch to about four inches in diameter. As a general thing they lay loosely piled as one finds them along stream beds, although in one instance they were found securely imbedded in the matrix of hard sandstone which form-

ed the base of the Lance. As stated in the description of the Fox Hills that formation had undergone erosion prior to the time at which the Lance was deposited, the evidence for this being the presence of trenches and channels filled by the overlying Lance. This is a common occurrence throughout the northwestern area, and that it is widespread is recognised. It shows that at the end of Fox Hills time, a period of erosion occurred sufficient to remove by actual measurement in South Dakota 72 feet of sediments and in addition probably all the normal Fox Hills thickness that is there absent. The Lance rests on an eroded surface of Fox Hills of varying thickness in the Freedom area. One is led to enquire whether the Fox Hills has not at one time been as regular a stratum as the Pierre, and that its present condition is the result of a period of erosion of demonstrated wide extent, the vertical effect of which depended on the osoillations known to be then taking place.

There is also further evidence in the Freedom area to substantiate the holding of an unconformity. It is the discordance in dip between the Lance and the underlying beds. This discordance is not pronounced, but on one side of the area was measured as 3°, sufficient to be considered as supporting evidence to the above proposition. The evidence of an unconformity in this area supports the view adopted by the United States Geological Survey and is in accord with the holding of the paleobotanists. It strengthens the contention that

an unconformity of widespread occurrence lies at the base of the Lance since this area is situated several hundred miles from like evidence at the same horizon in the Dakotas. The view of the Survey that the Mesozoic era ended with the deposition of the Fox Hills has thus one more piece of evidence presented in this area, to support its holding.

Description of species.

Phylum MOLLUSCA

Class CEPHALOPODA

Order AMMONOIDEA zittel

Suborder ESTRASIPHONATA zittel

Family LYTOCERATIDAE

Subfamily MACROSCAPHITINAE

Genus BACULITES anceps Lamarck.

Plate VII, figure 1

Description in "North American Index Fossils, vol., 2, p. 180"

BACULITES ovatus Say

Plate VII, figures 2 and 3.

Description in "North American Index Fossils, vol. 2, p. 180"

BACULITES compressus Say

Plate VII, figures 4 and 5.

Description in "North American Index Fossils, vol. 2, p. 180"

BACULITES gracilis Shumard.

Plate IX, figures 1 and 2.

Description in "North American Index Fossils, vol. 2, p. 179"

Family COSMOCERATIDAE zittel

Subfamily SCAPHITINAE Meek

Genus CAPHITES nodosus M & H

Plate VII, figure 7

See U.S. Geol. Surv. Terr. 1876 Hayden.

Subfamily PLACENTICERATINAE

Genus PLACENTICERAS Meek.

Plate VII, figure 6.

Description Zittel vol, 1, p. 671

Location: All the above fossils were found in T. 10 N., R. 33 E., Sec. 30, Principal meridian, Montana.

Order AMMONOIDEA

Genus AMMONITES graysonensis

Plate IX, figures 11, 12, 13.

Description in Trans. St. Louis Acad. Sci. vol. i, p. 593.

Location: T. 10 N., R. 33 E., Sec. 29, Montana.

Class PELECYPODA

Order PRIONODESMACEA

Genus INOCERAMUS labiatus Schlotheim.

Plate VIII, figures 1 to 5.

Description by T.W. Stanton, U.S. Geol. Bull. 106.

Superfamily NUCULACEA

Family NUCULIDAE Adams

Genus NUCULA Lamarck

Species undetermined.

Plate VIII, figures 11, 12, 13.

Undetermined (same) figures, 6,7,8.

Genus CUCULLAEA Lamarck

Species new.

Plate VIII, figure 10.

Genus CUCULLAEA Lemarck.

Species undetermined.

Plate IX, figures 14, and 15.

Genus YOLDIA scitula Meek and Hayden

Plate IX, figure 16.

Description: "North American Index Fossils" vol. 1, p. 403.

Genus LEDA pandoriformis Stevens

Plate IX, figure 17.

Description: "North American Index Fossils" vol.,1, p. 401.

Location: T. 10 N., R. 33 E., Sec. 30, Montana.

Class GASTEROPODA

Suborder BASSOMMATOPHARA A. Schmidt

Family AURICULIDAE Blainville

Genus MELAMPUS ? antiquus

Plate IX, figure 3.

Description in U.S. Geol. & Geog. Surv. of Terr. of Wyo. and Idaho for 1878, Pt. I, p. 23.

Family TURRITIDAE Adams ?

Genus TURRIS Bolton (Pleurotoma Lam.) ?

Species not determined.

Plate IX, figure 4.

Undetermined: Several species belonging in NATICIDAE, AMAUROPSIS Morch, Genus AMAUROPSIS bulbiformis ?

Plate IX, figures 5,6,7,8,9,10.

Plate IV Vertebra of dinosaur undetermined, by ½.

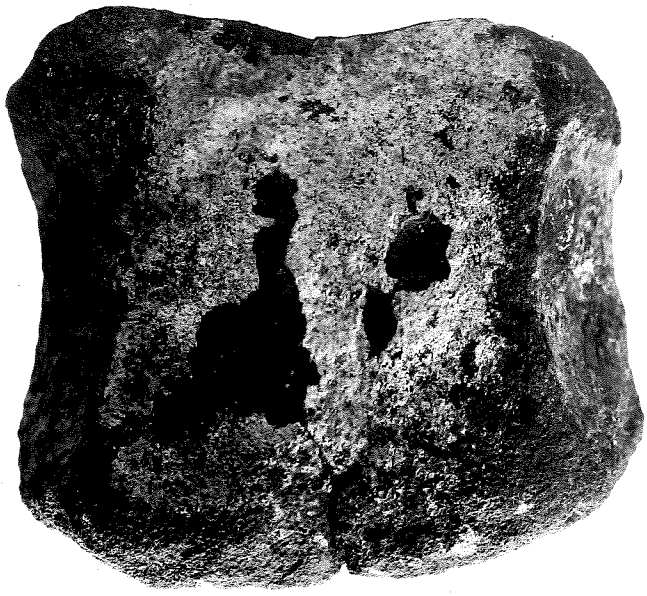

Plate V Top view of vertebra of Plate IV, by ½.

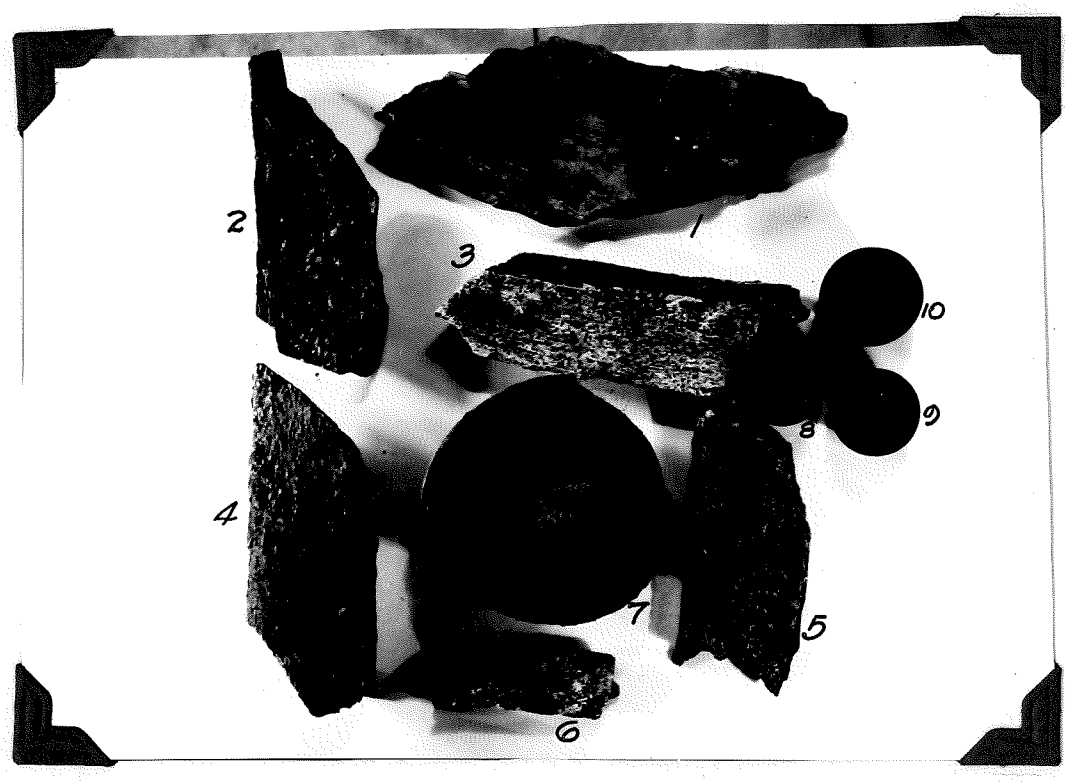

Plate VI Dinosaur bone fragments (unidentified) by $2\frac{1}{2}$

1, 2, 3, 4, 5, 6.

Typical concretions found with bones.

7, 8, 9, 10.

Plate VII CEPHALOPODA

BACULITES anceps Lamarck Figure 1, page 64

BACULITES ovatus Say Figures 2,3. 64

BACULITES compressus Say Figures 4,5. 64

PLACENTICERAS Meek Figure 6 65

SCAPHITES nodosus M & H Figure 7 64

All x ½

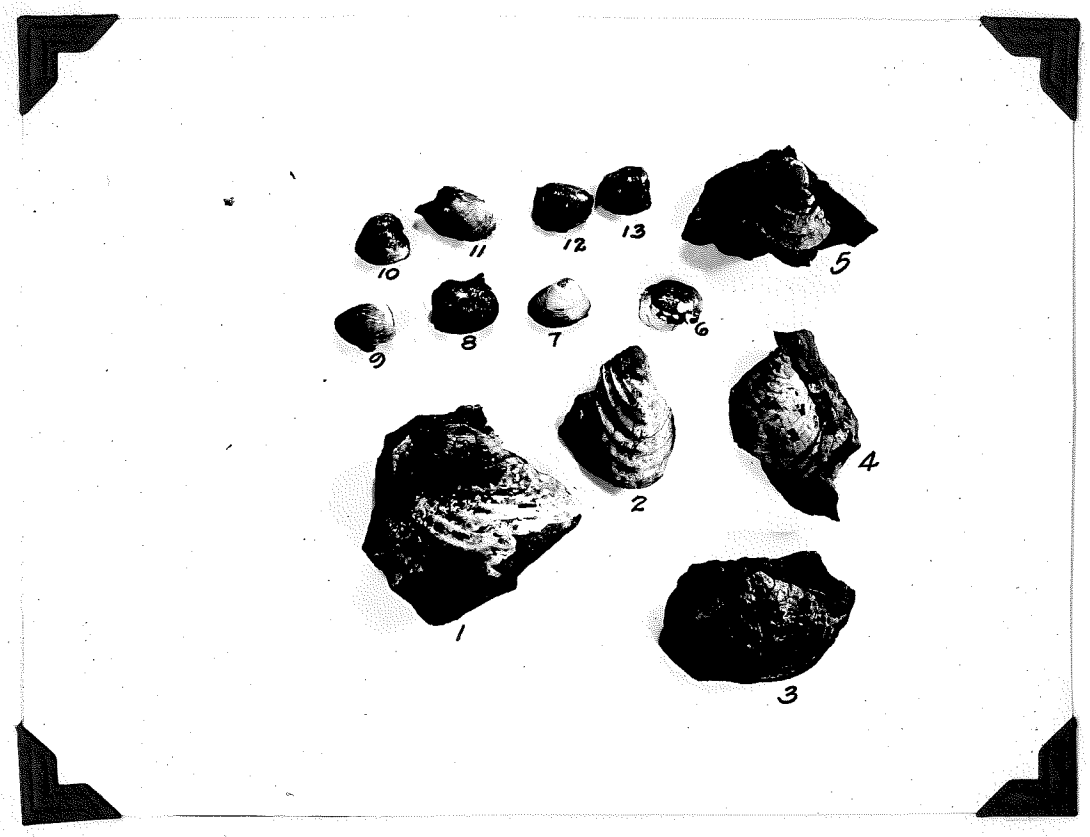

Plate VIII PELECYPODA

INOCERAMUS labiatus Schlotheim. Figures 1 to 5 Page 65

NUCULA undetermined 6,7, 8.

Lamarck 11, 12, 13 Figures 6,7,8,11, 12, 13. 65

CUCULLAEA Lamarck n. sp. Figure 10 65

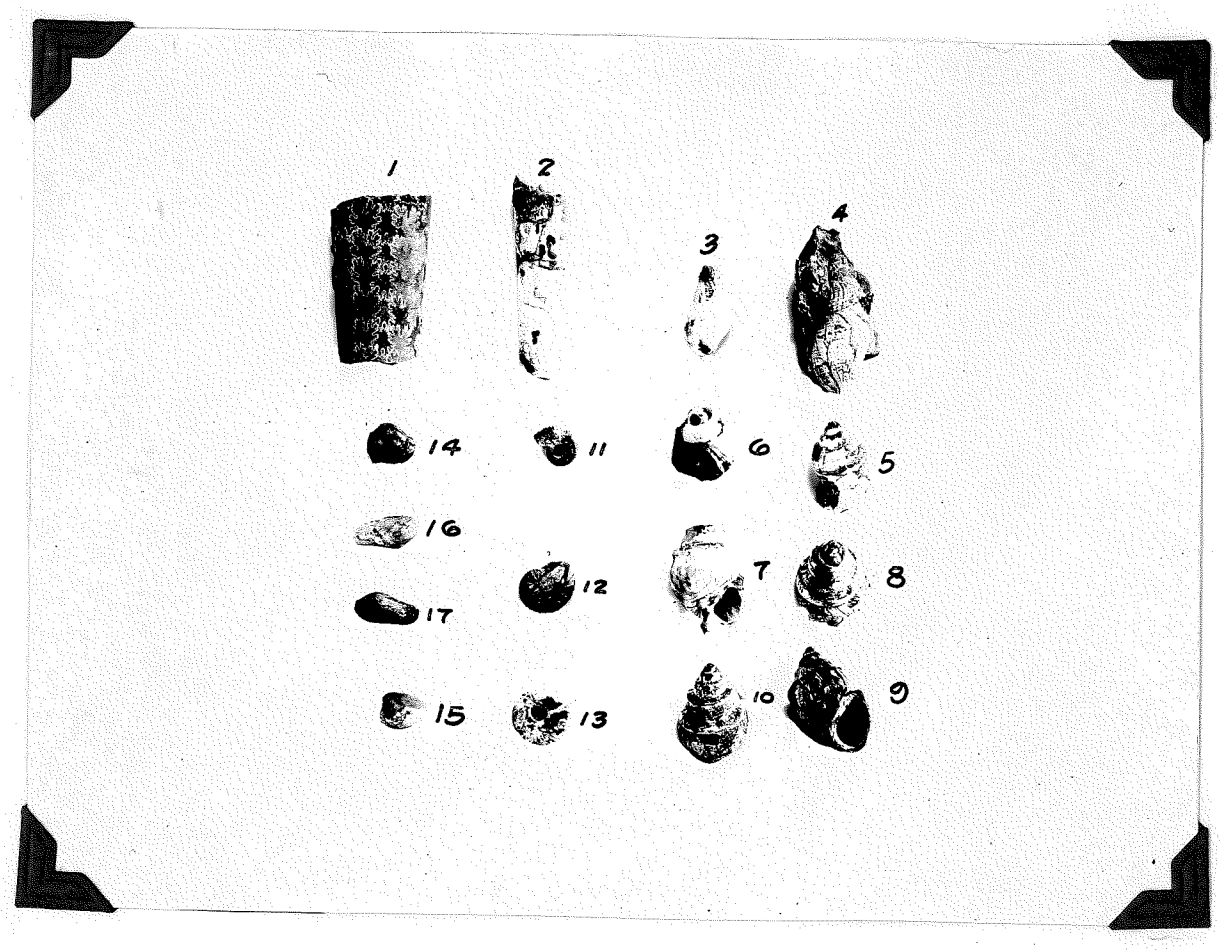

Plate IX

BACULITES gracilis Shumard	Figures 1, 2.	page 64
MELAMPUS ? antiquus	Figure 3.	66
TURRIS ? Bolton	Figure 4.	66
AMAUROPSIS bulbiformis ?	Figures 5 to 10.	66
AMMONITES gransonensis	Figures 11, 12, 13.	65
CUCULLAEA Lamarck (undetermined)	Figures 14, 15.	66
YOLDIA scitula Meek and Hayden	Figure 16.	66
LEDA pandoriformis Stevens	Figure 17.	66

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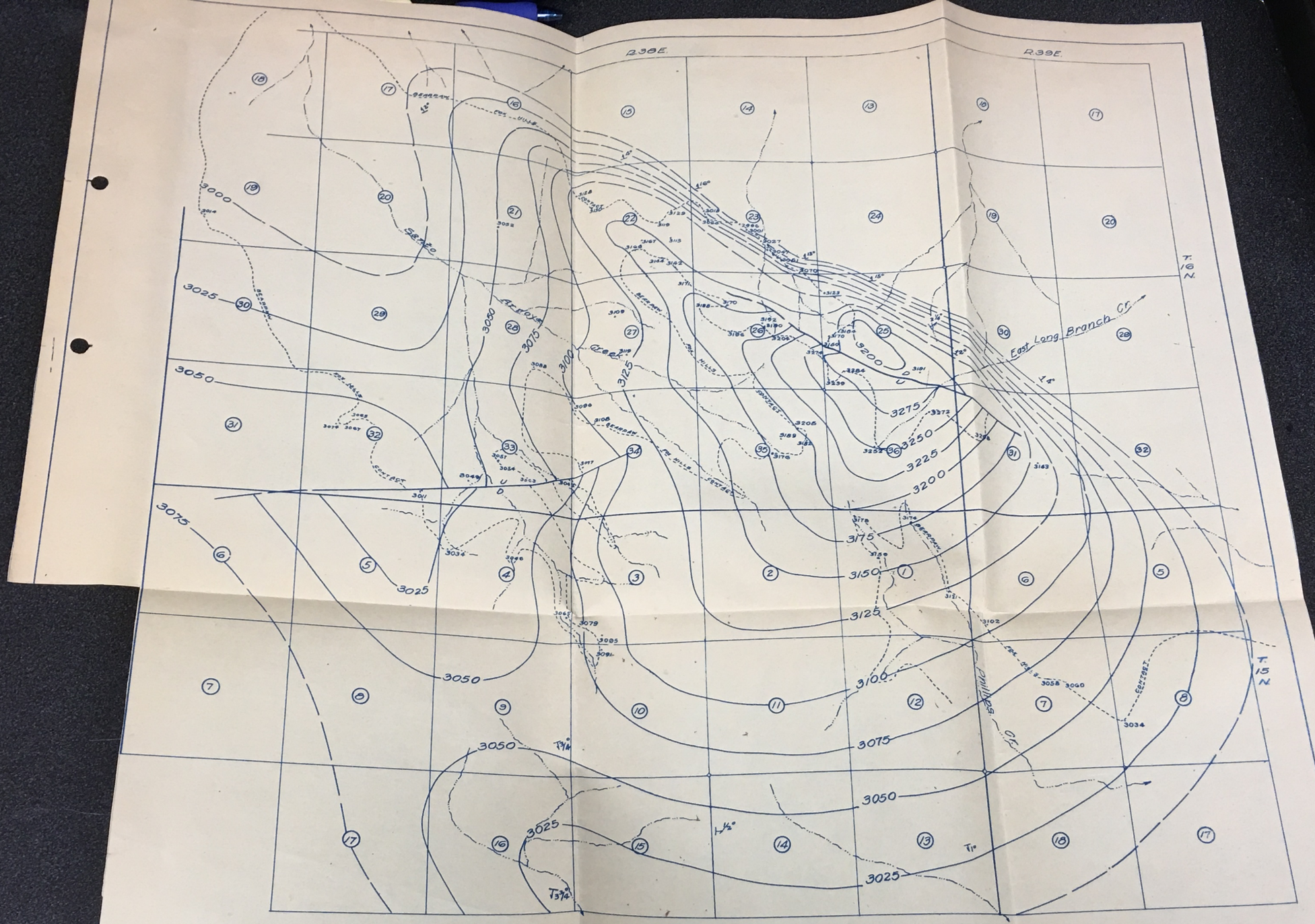

Structure Map

THE FREEDOM ANTICLINE

Garfield County, Montana.

PLATE II

By

L. E. Wilson and R. Norton.

Oct. 1924

Scale 2" = 1 mile

Contour Interval 25 Feet.

Contoured on Bearpaw-Fox Hills contact Datum Sea Level.

R38E

R39E

T. 19 N.

Lance

Fox Hills

Bearpaw

THE FREEDOM ANTICLINE

Garfield County, Mont.

PLATE III

By

L. E. Wilson and R. Norton.

Oct. 1924

Scale 2" = 1 mile

0 ½ 1 1½ 2

Datum Sea Level.