

THE WHITE BLUFFS FORMATION OF THE COLUMBIA

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A thesis submitted for the degree of

BACHELOR OF SCIENCE IN GEOLOGY.

UNIVERSITY OF WASHINGTON

1923.

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INTRODUCTION

During the summer of 1922, the writer was connected with the topographic branch of the United States Geological Survey during the mapping of the Hanford quadrangle on the Columbia, within which occur some of the best developments of the White Bluffs. Near the first of August, one of the topographers became sick, leaving two crews with only one man to work for. As a result, we alternated, one crew working one day in the field and remaining the next day in camp. The author spent much of the resulting spare time quite profitably in an examination of the geology of the White Bluffs.

That part of the bluff lying two miles to the North and four miles to the South of the town of White Bluffs is the only stretch that was examined carefully in detail during this time. The rest of it in the quadrangle was covered during the mapping, for the most part on a horse, but also in a buckboard wherever a road traversed the base of the bluff as between Hanford and Ringgold. Under such conditions, the type of work was such that little chance for systematic study of the outcrops was possible, so that only general observations were possible.

Later in the summer, the region along the east end of the Saddle Mountains was worked under conditions equally unfavorable to geological study. Mention of this region, and also of the region, and also of the region north of Saddle Mountain around Crab Creek, which was visited in the summer of 1921, is wholly on the basis of such reconnaissance observations.

PREVIOUS LITERATURE ON THE REGION

The White Bluffs have been long known in the geological literature, but have been comparatively little studied. I. C. Russell, in Bulletin 108 of the United States Geological Survey, 1893, described them, and considered them the equivalent of the Ellensburg Formation, itself the equivalent of the John Day Oligocene (then Miocene) of Oregon. Calkins (United States Geological Survey Water Supply and Irrigation Paper, No. 18, p. 35, 1905) discussed the White Bluffs beds, following the precedent in correlating them with the Ellensburg, but pointed out several points of contrast between the two formations. Two years earlier, George Otis Smith (Professional Paper No. 19) cited evidence to prove that whereas the Ellensburg Formation was fluviatile, the sediments of the White Bluffs were lacustrine. The final work done on the region was in 1916 by John C. Merriam and John P. Buwalda who published their conclusions in the University of California Publications in Geology, Vol. 10, No. 15. It was the purpose of these authors to try and correlate the two formations in question. Their contribution therefore was mainly paleontological. Mammal remains were collected at two localities between Hanford and Ringgold, and on the basis of these fossils, the age of the formation was placed as late as the Pleistocene. They gave it the name of the Ringgold Formation.

GENERAL DESCRIPTION OF THE WHITE BLUFFS

The Columbia River crosses the Hanford quadrangle in such a way as to include a maximum length within the boundaries of the sheet; it enters only about one mile south of the northwest corner, near Wahluke, where the stream bends from northeast to south, and leaves the quadrangle at Ringgold on the extreme southeast corner. Something over 20 miles of the course of the river are included.

The White Bluffs rise practically from the water's edge on the east side of the river to a height of between 300 and 500 feet. They extend for a distance of between 35 and 40 miles along the river, beginning about 12 miles above Pasco, and extending to Wahluke. Four miles below the town of White Bluffs, the surface above the bluffs, which to that point has extended comparatively level not only north and south, but also for at least 10 miles to the East, drops off perhaps 200 feet to a lower, more dissected area which can be correlated with the nearness of the Saddle Mountains on the North with its more pronounced drainage.

The bluff itself recedes from the river between the high level bluff on the South and the town of White Bluffs, but between the latter point and Wahluke, it again becomes prominent, except that it is about 200 feet lower than farther south. In fact, this northernmost extremity is more nearly deserving of the name "White Bluff" than any other stretch; the beds are whiter, and the slope steeper, and so closely undercut by the river that much of it is accessible only at the top, or by boat at the bottom.

EXTENT OF THE RINGGOLD FORMATION TO THE EAST AND NORTHEAST

The strata of the Ringgold Formation, outcropping typically in the White Bluffs, are nevertheless exposed widely thruout the region to the East and North of the Saddle Mountain Range. Southeast of the town of Othello, and facing the highly dissected eastward extension of the range across a wide dry valley, the typical cream colored sandy shales of the White Bluffs outcrop in a 50 to 75 foot bench facing the South and Southwest. This bench has been preserved by the five foot capping of travertine ^(Columbia type) which sedimentary type also occurs in the Hanford region. This is the only place where sediments of the Ringgold Formation were definitely observed in the region, but the same bench extends around west of Othello and several miles north of that town, where it is followed along the rim by the Chicago-Milwaukee and St. Paul Railway; the benchy topography around Crab Creek in the vicinity of Corfu north of the Saddle Mountains is also suggestive of the same formation.

Ten miles east of Hanford, the sediments occurring in the bluffs on the Columbia outcrop in a 300 to 350 foot escarpment facing the East. The intervening region is therefore a plateau. Below and to the east of the plateau, basalt "scab rock" is everywhere in evidence, both on the surface and in the form of rock knolls, showing that the base of the Ringgold Formation has here been reached. The rocks exposed along the road cut that descends this eastward escarpment are apparently the same as those exposed in the bluff overlooking the Columbia. These points were observed from a buckboard during a topographic reconnaissance, so that no more detailed observations could be made.

THE SURFACE OF THE RINGGOLD FORMATION

The surface extending several miles eastward from the rim of the high bluff at Hanford is in general a plane around 950 feet above sea, generally covered with different types of desert vegetation, but with considerable bench grass along the east edge. Merriam and Buwalda have concluded that it is a surface of aggradation rather than one of degradation. In a few places it is cut by dry coulees, but they are decidedly insignificant both in size and number as compared to ordinary drainage development of an area as large as that in question.

The dissection of the formation to its present extent apparently took place at a time previous to the present arid climate. The valley along the south side of the Saddle Mountains runs west with low gradient, and ends abruptly on the edge of the plateau at the top of the bluff. Thus the Columbia, which is slowly moving east, has moved far enough between the time that the coulee was formed and the present to have removed all of the lower course of the old channel.

The low region to the East of the White Bluff plateau swings southwest to enter the Columbia near Ringgold. It is perfectly dry at the present day, but at one time, an immense volume of water must have emptied thru here. North of the Saddle Mountains, a similar broad dry vally runs southeast from Crab Creek to the east end of the range. The two channels are connected across the dissected basalt of the extreme eastern end of uplift. Altho field work in this region was not extensive enough to theorize, I believe that further geological examination will bring out some interesting facts in regard to drainage of the Columbia thru here in one

of the stages of the Glacial Period or later.

The bench consisting of sediments of the Ringgold Formation already mentioned, which overlooks from the north the valley at the east end of the Saddle Mountains, has been dissected only on the face of the escarpment, very few of the resulting gulches go back more than 500 feet before they have risen to the tableland above. These gulches can be referred to erosion which has taken place under climatic conditions such as they are at present.

FORMER EXTENT TO THE WEST

The White Bluffs occur only on the east side of the river; the surface on the west side lying within the Hanford quadrangle is made up either of basalt hills or else of low sage covered sand hills. Merriam and Buwalda state that occasional outcrops of the same formation exposed in the White Bluffs are found west of the river, but none were observed by the writer. The Ringgold Formation formerly extended over this region probably to the Yakima Range, but have been removed by the Columbia River in its secular shift to the East. It is to this incessant encroachment on the bluff by the river that the White Bluffs owe their existence, for even in this arid climate, the soft sediments of the bluff tend to weather down into rounded escarpments wherever the river has interrupted its crowding for any length of time.

Besides the remnants of the Ringgold Formation noted by Merriam and Buwalda on the west side, which should be more common along the extreme west border of its former extent, there are two other lines of evidence confirming this view. In the southwest quarter of the Hanford quadrangle, stream cobbles of almost every type and typical of the rock beds along the present banks of the Columbia, are extensively developed over a considerable low area which has been swept free from sand hills. The well developed valley along the south side of Saddle Mountain is adjusted to either a much higher elevation of the Columbia in its present position, or more probably to the river nearer its present altitude but much farther west, for as it exists today, the valley is truncated by the plane of the bluff without forming even a gully in the face of the cliff.

STRATIGRAPHY AND STRUCTURE

The sediments of the White Bluffs are made up of soft very fine grained sandy shales, somewhat coarser sands, shales, travertine, volcanic ash, and coarse gravels. In general the lower part of the exposed sections are shale, while the upper part is more sandy; this I believe will hold for most of the region around Hanford and farther to the South, as well as for the White Bluffs region where studied in detail. In the latter region the distinction between the two variations is sharp, and the contact is easily followed for over five miles.

The underlying shale is massive in detail tho stratified in thick beds; it is fractured in all directions and of some shade of light gray. The sandy shales at the top however are generally well stratified horizontally, block-jointed, and in color ranging from creamy to yellow. The stratification does not usually show unless the outcrop is weathered, or unless the rock is broken. A number of thin beds of sand, up to two or three feet thick, occurring in this upper member exposed on the hill road at Hanford, show very fine ripple bedding. In general however, stratification is horizontal. Some of the beds are laminated, showing alteration of buffy and creamy bands. A number of pure shales occurring in the top within the upper sandy member are likewise laminated; one type, occurring in one place in a ten foot seam, is a pure white shale laminated with very light bluish gray shale, and with a waxy lustre and feel.

Three detailed sections were made, the first at a point one mile above White Bluffs, the second in the first bluff north of the White Bluffs ferry, and the third at the beginning of the

high Hanford bluff four miles below White Bluffs. The distinctions between the lower shale members, which naturally grade imperceptibly unto each other, were decidedly artificial, and consequently the sections did not check, but the distinction was everywhere pronounced between the yellow sandy formation at the top and the underlying gray clays, so pronounced in fact that the contact can be easily determined in a photograph. All three sections were also similar in that the top shale member was from four to seven feet of very hard, fractured, light bluish-gray shale, bluer than any of the underlying facies. Beyond a mile north of White Bluffs, the two separate formations lose their identity to a great extent, the sandy member, lighter colored than at White Bluffs, extending down into the shale realm. Farther south of where studied however, the distinction is apparently maintained for some distance at least.

The White Bluffs beds, wherever stratified and undisturbed, are horizontal. The elevation of the horizon marking the contact of the two members described is 587 feet at a point one mile north of White Bluffs, 583 feet at the first bluff north of the ferry, and 595 feet four miles below. These elevations are all good to within three feet, and show how remarkably level the strata lie. The point farthest down stream being the highest, it might at first seem that the strata had been tilted a little to the North, but when it is recalled that the horizon was at one time the bed of a river or lake, and that the present section does not necessarily correspond to the line of the old channel or axis, so that the point farthest down stream might well have been laid down closer to shore, the surprise is rather that the elevations should cor-

respond as well as they do.

The high bluff for several miles along the river above and below Hanford is capped by travertine, to whose superior resistance to erosion the sharp rim of the bluff is due. It lies generally at the top of a ledge, 10 to 25 feet high, the lower beds of which are the softer sandy shales, which are able to stand up as long as they are protected, but which, as soon as they are beyond the immediate protection of the caprock, weather down to a steep escarpment. The travertine bed is extremely level, so much so that during the traversing along the top of the bluff, the elevation of the rodman, 1000 feet away, could be estimated to within two or three feet by noting his position relative to the rim of the ledge. The rimrock itself is broken up into rough horizontal slabs generally just about big enough to make a good load for one man, and of just the right roughness to hold together well when built into monuments for control, of which several were built. This travertine extends for several miles to the East, and in one place, about half way between White Bluffs and Hanford but several miles to the East, it forms the rimrock of a sheep camp coulee.

Three to four narrow beds of volcanic tuff, around a foot in thickness, were noted, intercalated with the lower shales in the White Bluffs region, but nowhere were more than two ledges observed in a section.

Gravel beds were not observed interstratified in the Ringgold Formation proper, but they are quite common along the summit of the bluff, more abundantly in some places than in others. Peculiarly enough, no rock of any kind except here and there a few traces of travertine, was noticed on the plateau above the bluffs.

Almost every type of rock is represented in the cobble beds. A typical occurrence is at the top of the first bluff North of the White Bluffs ferry, where rounded and angular rocks up to six inches in diameter occur in what was at one time apparently a boulder bed, but much of the finer material has been swept away by the wind, leaving only the bare rocks. The rock types that were identified were biotite granite, hornblende granite, hornblende-biotite granite, graphic granite, syenite, diorite, gabbro, granite porphyry, dacite porphyry, syenite porphyry, basalt, conglomerate, quartzite, and mica schist, of which granite, basalt, and quartzite were most abundantly represented.

At another locality about half way between Hanford and Ringgold, a cobble bed, composed entirely of basalt, as near as could be told from a hasty survey while passing in a buckboard, is exposed at the top of the bluff on the road leading east to Mesa. This zone is overlain by sediments of some kind but they do not outcrop. Time was lacking for an examination of the relations here in detail to determine whether or not the overlying beds were part of the Ringgold Formation, but in all probability they were not, if deductions from conditions prevailing elsewhere can be applied here.

These cobbles, in the first locality at least, were deposited by the Columbia, for most of the rocks represented are foreign to the region. The fact that the Columbia once flowed over the surface of the Ringgold Formation is fairly good evidence for assuming that this formation was deposited by the Columbia. Furthermore, the occurrence of cobble beds shows that the river at the time of their formation, must have been very similar in the

speed of its current to the present day Columbia and that therefore, at this particular period at least, no lake was present.

A characteristic mineral of the lower shales and a marker of the arid conditions prevailing along the Columbia at present, is gypsum. It occurs as separate, flat, crystalline, rather thick plates, with pitted surfaces, ranging up to two inches across. If it is found in the undisintegrated face of the formation, it is only as an epigenetic growth, the crystals adhering to the sides of surface cracks, and disappearing as soon as this loose shattered shale on the exposed faces of the beds is removed. More commonly however, it is found loose in the surface soil derived from the weathering down of the shale. It could only have been formed by the slow evaporation of ground waters at the surface.

The summit of the high bluff for practically its entire length is followed by a low flat ridge, marginal to the plateau on the East, above which it extends at an average elevation of 25 feet. This ridge is generally between 300 and 500 feet wide. It is covered with sage brush and no outcrops are exposed.

This ridge is an eolian deposit. The prevailing winds along this part of the Columbia are from the West and Southwest. On striking the bluffs, the winds are deflected upward with considerable velocity; on a windy day a moderate gale may be blowing up the bluff, while 30 feet back from the summit of the eolian ridge, the atmosphere may, in comparison, be quiet. Sand and dust carried up the bluff are therefore dropped as soon as this calm belt is reached, forming a sand ridge, which is practically unbroken for several miles.

LANDSLIDES

The Ringgold Formation is everywhere jointed but the individual cracks do not usually extend over more than one or two homogeneous members. Faulting, except for local slides, was not observed. Landslides however, are everywhere in evidence, and some are very large. One just south of the first bluff north of Wiehl's ranch on the east side of the river at White Bluffs has so altered the beds around one of the fossil localities (locality 5) that it is hard to tell whether the latter is undisturbed, or has come down a piece from above.

The biggest slide observed lies just across the river from Hanford. The whole face of the bluff for a mile and a half has slidden down a considerable distance without breaking up, leaving a depression behind it which is one and one-half miles long, probably 400 feet wide, and between 75 and 100 feet deep. The old slide at the present time lies in the form of a high ridge in front of the main bluff, with its beds, as far as could be told from the relatively few exposures, practically horizontal. A secondary slide, similar in its relations to the primary, has slumped away from the first one, but it is neither so high, nor is the depression behind it so deep, being only around 15 or 20 feet.

These old slides occurred so long ago that there is at present no trace pointing to their origin except the physiographic form. The face of the new main bluff exposed is just as much carved by gullies as other regions along the bluff where no slide is evident. The fact that the depression is undrained is a point in evidence of the aridity of the region. Altho gullies on the face of the bluff show that considerable modification of the orig-

inal surface by water has taken place, yet all of such sediments derived have been washed into the ^{Sump}swamp below where they form a fairly level bottom. It may be possible that some of the water from off the bluff escapes along the old slide zone.

Slides, wherever the bluff is hugged too closely by the river, are continually occurring, tho they are not as a rule so large as this one.

FOSSILS

The White Bluffs beds were examined thoroughly for fossils between a point one mile above the town of White Bluffs and a point four miles below it. As a result, animal remains were found in at least eight localities, but with the exception of the fresh water shell bed examined, where the shells are perfectly preserved and entire, the rest of the localities yielded only fragments, which, to be sure, were well preserved, but the material represented was too meager to be of any great value. Observations made however are rather encouraging for future collectors in the region; the fossils are there, and the only problem is to find an animal whose members have not been too widely scattered before coming to their final resting place.

The commonest type of fossil found was the remains of fish, especially vertebrae, and fin and tail spines. These occurred at six out of the eight localities, only localities 5 and 8 being without fish. This collection was sent to Dr. David Starr Jordan of Stanford University, who very kindly examined and commented upon them. None of the fossils represented had ever been seen by him before, nor were any of them quite in shape for close determination, so that the best he could infer as to the age represented was that they were from the Tertiary.

The vertebrae found range in size up to close to an inch in diameter. The commonest type of spine is the pointed dorsal spine of some large, probably Percoid fish. The other type of spine is serrated, non-tapering, and according to Dr. Jordan, more nearly resembles the spines in a sting ray's tail than any other fossil with which he is acquainted, altho at first he believed it to be

the fine spine of some type of catfish. Whereas the first type of spine is most abundant at locality 4, the second type is the sole representative at locality 3. The two occur together however, as at locality 4, and also at locality 1.

Locality 4 also contained the bony shield of the head of some catfish, and two or three broad teeth resembling those of the genus *Carcharhius*, a living genus of sharks found in the Miocene of California. Sharks are marine fishes, but some of them go up the larger fresh water streams.

Both localities 4 and 3 contained abundant scales and amber like plates forming some part of the skeleton of fishes, but these parts were all too delicate and brittle to be gotten out whole.

Locality 7, according to Dr. Jordan, contained the "broken jaws with some molar teeth of a large fish--not like any fossil I know--and probably new."

These fossils, together with the detailed letter from Dr. Jordan, will be placed in the care of the university museum.

Fragments of turtle shells occurred at localities 1, 2 and 4, and at a complete shell might have been taken out in fragments had a little more care been observed in saving the pieces. The fractured condition of the shale however precludes against the occurrence of unbroken shells of the size of that of a turtle.

As for the rest of the vertebrate remains, six of them were of mammals and one of a bird. Of this lot, only two are worthy of any extended comment.

The bird bone from locality 1 was examined by Mr. Loye Holmes Miller of Los Angeles. It is the left humerus of an anserine bird, closely related to the genus *Marila*, and most nearly approximating

in size the species *collaris* of the present day. In fact, so closely does it resemble this species that Mr. Miller suggests that the bone might have been carried up onto the bluff within the last decade by a duck hawk or horned owl, referring the matter to my field notes for final decision on this point. I believe however that such is not the case. The bone occurred imbedded in the hard shale in a low ledge which outcrops along with similar underlying and overlying ledges from an otherwise soil covered escarpment. These ledges break the general slope of the steep escarpment only as short distances of almost vertical descent, and are far below the rimrock zone inhabited by the birds of prey. The piece of shale in which the bone was imbedded was brought to Seattle with the fossil, and it was kept as a cast for sometime after the removal of the bone, but was finally thrown away.

Only the head half of the bone was left as found, and this was considerably broken during its trip to California. Mr. Miller did not wish to commit himself absolutely to the identity of even the genus, since the specimen is too fragmentary, but he gave the above suggestions for what they might be worth.

Marila collaris is at present a very rare or unknown bird east of the Cascades in Washington, but other species of the genus are common.

The other vertebrate of interest, from locality was sent to Mr. J. W. Gidley of the United States National Museum for determination, and proved to be a very interesting specimen. The fossil is a small fragment of a jaw containing the second lower left molar of a small mouse like form, which is not referable to any

known living or fossil species, and apparently represents a new genus. To quote Mr. Gidley, "it is evidently a Cricetine but with what sub-group it should be placed it is rather difficult to determine. The enamel pattern is in general Microtine, but its subhypodont condition suggests an evolutionary stage about equivalent to some of the Neotomie group, especially *Nelsonia*, which it also somewhat resembles in tooth pattern, but differs from it and all other species of this group in that the anterior pair of re-entrant angles are not opposite each other, but alternate and overlap as in the *Microtus* group.

As for the rest of the vertebrate remains, the only specimen from locality 8 (which differs from all the others in that it is at the top of the bluff in the sandy member) was a single fragment of a very large vertebrate bone; locality 4, besides its fresh water fauna, contained a small fairly perfect toe bone of some small mammal, and locality 5 contained, as the only fossil besides its molluscs, a half of the pelvic bone of a small mammal about the size of a rat.

Opposite the region of the town of White Bluffs, the first molluscan fauna known from the bluffs was obtained, altho Calkins noted the reported occurrence of molluscs in the bluffs near Pasco. Locality 4 contained, besides its copious fauna already mentioned, a large number of fresh water molluscs, but they were so poorly preserved that after spending most of one day carefully extracting the best ones that could be found, they were still too poor to be determined more than generacally by Dr. G. Dallas Hanna of the California Academy of Sciences, to whom all the molluscan remains were sent either for complete determinations or for confirmation of

identities made by the writer. The genera represented were Goniobasis, Anodonta, Fluminicola, Lymnaea, Pisidium, and a large Planorbis.

Locality 5 on the other hand contained a fauna of 13 species, 3 pelecypods and 10 gasteropods, all wonderfully preserved. The pelecypods have not yet been determined. The gasteropods are

Lymnaea palustris

Lymnaea parva

Physa heterostropha

Physa ampullacea columbiana

Planorbis parvus

Planorbis exacuus

Planorbis opercularis (single ^{specimen} going specimen)

Succinea nuttalliana

Succinea avora (one specimen, 10 M. M. long)

Vallonia gracilicosta (one specimen)

All of these are living species. *Planorbis exacuus* has never been reported before west of Montana.

This fauna may throw some light on the mode of origin of the Ringgold Formation. The genus *Succinea* is subaquatic, living on the vegetation usually growing in the edge of water, but it is not aquatic. *Vallonia* is a land genus, but members of this genus often occur in stratified deposits even in the sea, to where they have been carried on pieces of driftwood. The rest of the genera are fresh water river and lake genera, but I do not believe that any of the species listed can be taken as characteristic of either type of water, tho a person more nearly familiar with them might be able to tell more exactly. This evidence on the whole rather points to

a river origin for the beds. On the other hand, the wide spread occurrence of travertine in the Hanford region is rather more suggestive of deposition in a lake.

Locality 5 is about one-fourth mile north of Wiehl's ranch on the east side of the river at White Bluffs, and 75 feet above the river. It is in an area disturbed by a slide, about 100 feet south of the first bluff north of the ferry. The bed in which the shells are enclosed is a clean quartz-biotite sand, which is not represented in the bluff section 100 feet to the north. The contact between the two points is covered by talus. Russell mentioned the fact that beds much later than the Ringgold Formation often occur against the base of the bluff in such a position that care has to be exercised in identifying any beds that might contain fossils as belonging to the White Bluffs beds. At the time that the writer was in the region, he was aware of this fact, but assumed, possibly too quickly, that locality 5 was too high to fall under this suspicion. It has since occurred to him that he might possibly have been mistaken, tho it is not very likely, since it would mean that the river had cut down 75 feet without moving out of its present position. I believe that a visit to the locality at some time in the future with the question particularly in mind will soon settle the matter.

An interesting side-light in regard to this fossil bed is the inscription that it bears, M. J. H., 1901. The ledge is so insignificant as compared with the other higher ledges above and the high bluff just to the North, that the idea was immediately suggested that the owner of the initials was aware of the significance of the shells, and might possibly have collected some of them.

AGE

None of the fossils mentioned in this report are of the type on which an age determination can be based. The shells and the bird wing however, by their close similarity or identity with present forms, tend to lower the age to a comparatively recent time geologically. This tendency agrees quite well with the determination as Pleistocene by Merriam and Buwalda.

Locality 1. In talus bluff $\frac{1}{2}$ mi. N. of cottonwood tree which is 4 mi. below White Bluffs. Only more resistant members of shale outcrop in 3-4 ft ledges--zone is at base of massive obscurely bedded slightly pinkish or yellowish tinged gray shale above a less massive, more cracked gray member, and 10 ft above a 2 ft very hard white shale, outcrops 800 ft along side hill. Elev. at least 100 ft above river.

Locality 2. In similar talus bluff $\frac{1}{4}$ mi. N. of preceding. Zone is a thin (4in.) buffy band in gray shale, below a 10 ft ledge butte at No. end of slope, and from there 100 ft No. to edge of outcrop. Elev. at least 100 ft above river.

Locality 3. At base of bluff where it occurs 300 ft downstream from where trail crowded down next to river, 1 mi. below Wiehl's ranch. There are 6 distinct ledges below this one, each succeeding lower one appearing as one goes N. W. to river--zone is in 3 in. buffy or brown band at contact of massive very obscurely bedded light gray shale, with very slight yellowish tinge--large (1 ft av.) joint cracks, with underlying gray shale more cracked up and closer jointed without trace of bedding. Horizontal extent of fossil bed only 10 ft.

Locality 4. In shale at top of talus, in face of bluff exposed

by large slide 1 mi. N. of Wiehls.

Locality 5. $\frac{1}{2}$ mi. N. Wiehls--75' above water is in deformed (slide) area about 100 ft S. of lower end of first bluff above ferry. Ledge is low and inconspicuous.

Locality 6. Continuation of same horizon as 4, but 300-400 ft farther S.

Locality 7. About half way between 4 and 5, at break in shale ledge which is basal ledge, but somewhat above Loc. 4.

Locality 8. In yellow sandy shale at top of section, 1000 ft upstream from Loc. 2.