

# Article V.—NOTES ON THE TERTIARY DEPOSITS OF THE BIGHORN BASIN.

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## PLATES V AND VI.

	Page
Introduction . . . . .	57
New Facts Regarding the Tertiary Stratigraphy of the Basin . . . . .	58
A Vertebrate Faunal Horizon near the Top of the Fort Union (?) . . . . .	58
The Buffalo Basin Section	
1. Distribution of the Knight Formation (Wasatch) . . . . .	60
2. Distribution of the Lysite and Lost Cabin Formations (Wind River) . . . . .	60
3. The Tatman Formation . . . . .	62
New Facts Regarding the Lithology of the Tertiary Sediments . . . . .	62
Gravel Beds . . . . .	63
Date of the Eocene Deformation in the Bighorn Basin . . . . .	63
Date of Dissection of the Basin Deposits . . . . .	64
Résumé . . . . .	64

## INTRODUCTION.

In continuing, during the summer of 1911, investigations begun the preceding year on the Tertiary deposits of the Bighorn basin in northwestern Wyoming, a number of new facts have come to light which it is deemed advisable to publish. The presentation of these data may, however, be prefaced to advantage by a brief statement of the stratigraphy, structure and lithology of the basin deposits, and of the special problems relating thereto which we have attempted to solve.

The drainage area of the Bighorn River is, structurally, a region of down-warp, inclosed more or less completely to the east, south and west by mountains of upwarp. The basin so formed is underlain by all the members of the Rocky Mountain section from the Archæan to the Fort Union and has been filled by a conformable series of clay, sand and gravel beds subdivided on palæontological evidence into the Knight formation (Wasatch), the Lysite and Lost Cabin formations (Wind River), all three known from their fossils to be Lower Eocene in age, the Tatman formation, a name which we propose for certain lignitic shales and sandstones overlying the Lost Cabin

formation and of doubtful age, and, finally, various gravels capping the Tertiary section which it has not been deemed advisable to name. As announced in an earlier publication,<sup>1</sup> microscopic examination of these sediments undertaken with the object of determining the origin of the materials composing them has shown that they have all been derived from the older rocks of the mountains and have been transported into the intermontane basin by streams. They represent, therefore, the waste of the mountains accumulated since the deformation of the Fort Union, on the uptilted edges of which the Knight formation rests unconformably. The Eocene clays are brilliantly colored and exhibit a more or less regular alternation of red and pale blue (yellow-weathering) bands of variable thickness and, frequently, of great horizontal extent. The colors seem to depend on the amount of iron present in the clays, the red variety carrying, in the two analyses which have been made, one and one-half percent more iron than the blue. We have suggested that the accumulation and oxidation to hematite of the excess of iron salts in the red clays may have occurred during dry climatic cycles and that the blue clays were deposited under moister conditions less favorable to the concentration and oxidation of the iron. That the deformative stresses which flexed the older rocks into their basin structure continued to act after the deposition of the Tertiary sediments filling the basin is shown by the presence of marginal anticlines and synclines and the general centripetal dip of the entire Lower Eocene series. The field work of the season just past shows that flexing of the basin deposits occurred after the deposition of the Tatman formation, which is post-Wind River in age.

The following report is merely a supplement to the already published, fuller presentation of the subject.

## NEW FACTS REGARDING THE TERTIARY STRATIGRAPHY OF THE BASIN.

### A VERTEBRATE FAUNAL HORIZON NEAR THE TOP OF THE FORT UNION (?).

McCulloch Peak (Map, Fig. 1) is a residual butte with three summits, approximately 6200 feet high, and composed entirely of Eocene clays and sandstones. Structurally, it is synclinal, the beds dipping, with minor irregularities, toward the central peaks. This syncline probably owes its existence to the same causes which produced the Elk Creek anticline dis-

<sup>1</sup> Eocene and Oligocene of the Wind River and Bighorn Basins. *Bulletin American Museum of Natural History*, Vol. XXX, pp. 83-117, 1911.

covered last year, namely mountain uplift accompanied by compression and flexing of the marginal portion of the intermontane trough. Banded clays are found to the very summit. The lowest beds rising above the broad bench on the south side of the Shoshone opposite Ralston and Powell contain *Systemodon* and are, therefore, referable to the Knight formation. At higher levels the Wind River may occur, but fossils are scarce and the region is so rough and inaccessible that we have not yet been able to verify this assumption. It is known, however, that the lignitic beds which we propose to call the Tatman formation overlying the Wind River on Tatman Mountain, are not present on McCulloch Peak. Due east from the lower end of the Irma ditch, on the southwest slopes of the peak, the red-banded Knight beds with *Eohippus* and other characteristic fossils rest on a series of bluish shales or clays, with one or two pink bands, overlain by a heavy yellow-brown sandstone (Plate V). These beds dip at a steeper angle ( $21^{\circ}$ - $23^{\circ}$ ) than the banded clays above, although in the same general northwesterly direction, and are slightly discordant with them in strike. Apparently the two series are unconformable. Fisher's map<sup>1</sup> includes the bluish beds below the banded series in his "Laramie and associated" formations, now known to be in large part Fort Union. At a locality on the southwest slopes of McCulloch Peak shown in the accompanying photograph (Plate V), about a mile due east of the point where the Wasatch-Fort Union contact line crosses the Shoshone River (see map), 245 feet stratigraphically below the contact with the red-banded beds, the following vertebrates, determined by Dr. W. D. Matthew, were found in the so-called "Laramie and associated," probably the top of the Fort Union:

*Phenacodus* sp., cf. *primævus*, one specimen.

Phenacodont, small form, two specimens.

Miacid, cf. *Vassacyon*, one specimen.

?Plagiaulacid or Insectivore, one specimen.

?Coryphodon, one specimen.

Creodont, indet.

Bird, indet.

What is believed to be the same faunal horizon occurs on the north side of the Shoshone River in the bluffs opposite Ralston station on the Burlington railroad where the beds seem to dip below the *Systemodon* horizon on the south side of the river. From these bluffs a partial skeleton of a new species of *Limnocyon* was obtained and also some teeth and limb bones of a medium-sized *Phenacodus*. The *Limnocyon*, although a new species, does not seem to be primitive, as compared with forms already known from the Bridger.

<sup>1</sup> Geology and Water Resources of the Bighorn Basin, Professional Paper No. 53, U. S. G. S., Plate III.

To the northwest of Ralston on Big and Little Sand Coulee (Map, Fig. 1), the following forms, determined by Dr. Matthew, were obtained from beds believed to be the same as those exposed below the Knight formation on the southwest slopes of McCulloch Peak:

*Phenacodus* sp.

*Phenacodus* sp., cf. *hemiconus*.

*Phenacodus* sp., cf. *primævus*.

*Didymictis* cf. *leptomylus*.

?*Palæonictis* sp.

*Esthonyx* sp. indesc.

?Small *Esthonychid*.

Edentate, gen. indesc. (probably *Metacheiromyidæ*).

Primate or Insectivore.

*Bathyopsis* sp.

No doubt is entertained regarding the stratigraphic position of the fauna from the southwest slopes of McCulloch Peak. At the other localities, the nearest *Systemodon*-bearing beds are several miles distant on the south side of the Shoshone, where they dip toward the peak. The beds north of Ralston and the exposures on Big and Little Sand Coulee seem to bear the same relation to the *Systemodon* beds on the north side of the McCulloch Peak syncline as do the "Laramie and associated" beds on the south side, namely to underly the Knight, but owing to the discovery in them of *Limnocyon* and *Bathyopsis*, neither of which has heretofore been found in beds as old as the Knight, we feel that further examination of the stratigraphy is desirable. Should the beds in question prove to be older than the Knight, and it be deemed advisable to give them a formation name, they may be referred to as the Ralston beds or Ralston formation.

#### THE BUFFALO BASIN SECTION.

1. *Distribution of the Knight Formation (Wasatch).*—Early workers in the Bighorn basin failed to recognize more than one formation affording vertebrate fossils, the so-called *Coryphodon* zone or Bighorn Wasatch, now known as the Knight formation. The discovery of *Lambdotherium* by the Amherst expedition of 1904 and its localization in the uppermost levels of the red-banded clays beneath the lignitic beds of Tatman Mountain by the American Museum party last year demonstrated the presence of the Wind River. The existence of the Lysite formation beneath the *Lambdotherium*-bearing levels was suspected but not definitely proved. At that time we assumed that the extensive Buffalo Basin exposures south of Tatman Mountain in the drainage area of Dry Cottonwood Creek, better

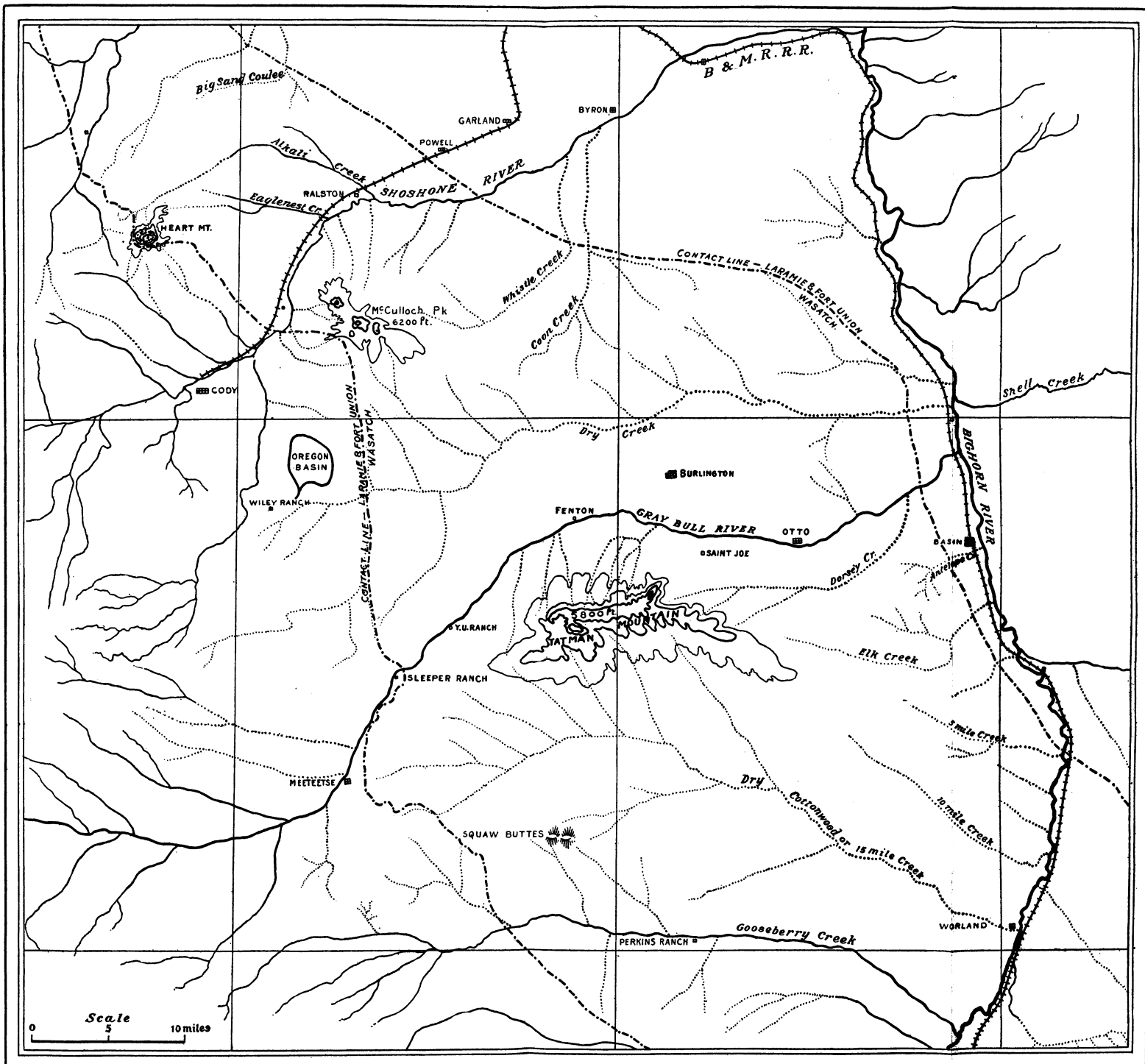


Fig. 1. Sketch-map of a part of the Bighorn basin studied by the American Museum Expedition of 1911. The Laramie-Ft. Union-Wasatch contact line from Sleepers Ranch to the southern margin of the map separates Wind River horizons from the Palæocene and older rocks. No Wasatch is there exposed (compare Fig. 2). Adapted from map of the Bighorn basin by C. O. Fisher.



known as Fifteen-mile, would prove to be Knight. Much to our surprise we have found sufficient palæontological evidence to show conclusively that they are referable to the Lysite and Lost Cabin formations.

The Knight formation is exposed in the valley of the Gray Bull from a point about five miles west of Fenton (see map, Fig. 1) to the contact with the Fort Union near Basin and on the west side of the Bighorn as far south as the mouth of Fifteen-mile and beyond. On going up Fifteen-mile successively younger formations are found to overlap the Knight, first the Lysite, characterized by the frequent occurrence of *Heptodon* and the entire absence of *Systemodon* or *Lambdotherium*, then the Lost Cabin with both *Lambdotherium* and *Eotitanops* and, finally, on the highest buttes in the basin, the lignitic beds of the Tatman formation. Where the contact between the Knight and the Lysite in Buffalo basin should be drawn on the map is somewhat doubtful as it depends on the presence or absence of certain none-too-abundant fossils in a conformable series of beds and not on stratigraphic or lithologic differences. It certainly lies well to the eastward

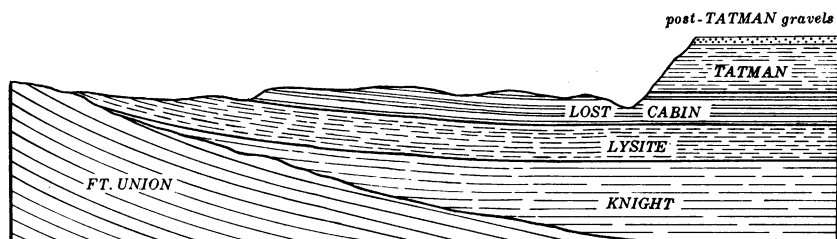


Fig. 2. Diagrammatic section trending in a general northeast-southwest direction from the top of Tatman Mountain toward Meeteetse, showing overlap of the Wind River horizons (Lysite and Lost Cabin) on the Knight formation (Wasatch). Not to scale.

of the intersection of the main branch of Fifteen-mile with the large dry-wash coming in from the eastern end of Tatman Mountain (see map, Fig. 1). Mapping on an adequate base and careful collecting must be done together before the boundaries of the various Tertiary formations in this area can be delineated.

Although the Eocene beds have been uptilted about the southwest margin of the basin, dipping in general, with the exception of minor flexures, toward Tatman Mountain, we have not been able to find any exposures of the Knight formation in this area, the Wind River horizons (Lysite and Lost Cabin) apparently overlapping unconformably on the Fort Union and entirely concealing the Knight as represented in the diagram (Fig. 2). It follows from this that Doctor Loomis's<sup>1</sup> section from near Meeteetse

<sup>1</sup> Am. Jour. Sci., 4th series, Vol. XXIII, p. 359, May, 1907.

to the top of Tatman Mountain does not show "the character of the Wasatch deposits" but combines four elements, the Fort Union, Lysite, Lost Cabin and Tatman formations.

2. *Distribution of the Lysite and Lost Cabin Formations* (Wind River).—On the north side of the Gray Bull-Fifteen-mile divide southwest of Tatman Mountain the deeper cutting of the former stream has incised its valley in the Knight formation while on the divide and to the south and southwest of it younger beds occur. The Lost Cabin formation is exposed on the Gray Bull-Fifteen-Mile divide and on all sides of Tatman Mountain where it may be readily located as the uppermost 325 feet, more or less, of red-banded beds immediately beneath the yellow lignitic shales of the Tatman formation. It extends across Buffalo Basin to the south of Tatman Mountain and may be found in a similar position beneath the Tatman formation both to the north, south and east of Squaw Buttes. The Lost Cabin formation, as at present defined, includes all the Wind River of earlier writers. The existence of the Lysite was not known previous to 1904 when the Amherst expedition made the first collection at the type locality on Lysite Creek and Cottonwood Draw in the Wind River basin.

With the deepening of the valley of Fifteen-mile down stream, toward the east, the Lysite formation is exposed and forms the great field of badlands to the south of Tatman Mountain. Its thickness, scaled from photographs, is probably not in excess of 600 feet and may be less. Like the Lost Cabin formation above it, it can be separated from the older Knight formation only by the fossils it affords. In the Gray Bull valley it may be found in any of the long draws south and southwest of the McGee ranch about five miles below the Y U ranch house where it is represented by brick-red and bluish shales interstratified with sandstone lenses, affording sections indistinguishable from those in the type locality on Lysite Creek and Cottonwood Draw north of Lost Cabin in the Wind River basin. On the north side of Tatman Mountain south of St. Joe post-office it undoubtedly is represented by all or part of the 600 feet of sparingly fossiliferous beds between the *Lambdotherium* zone and the top of the Knight formation with its abundant remains of *Eohippus* (see Plate IX, Fig. 2, Bulletin American Museum, Vol. XXX, 1911). It probably caps the high ridge south of Elk Creek also. At Fenton, the Gray Bull has cut below the base of the Lysite, exposing the Knight.

No Wind River fossils have yet been found on the north side of the Gray Bull, but it is highly probable that they will be found in the upper beds about the summit of McCulloch Peak.

3. *The Tatman Formation*.—We propose the name Tatman formation for a hitherto unnamed series of yellowish shales, yellow-brown and gray



sandstones and lignite beds overlying the red-banded Lost Cabin clays typically developed on Tatman mountain, but occurring also on Squaw Buttes and on the divide between Fifteen-mile and Gooseberry Creeks both to the north, south and west of the buttes. Wherever the contact is exposed, the Tatman formation appears to be conformable with the Lost Cabin beds below. It has not been found north of the Gray Bull River and seems to have been entirely eroded from this portion of the basin. Its thickness is estimated by Fisher<sup>1</sup> as about 600 feet.

Microscopic examination of the coarser Tatman sediments suggests that their source was the same as that of the underlying Eocene horizons, but that depositional conditions were different is shown by the scarcity of channel sandstones, the absence of color-banding and the abundance of impure, gypsiferous lignite at many horizons in the shales. Some of the thicker lignite beds have attracted attention among the local ranchmen as a source of blacksmith's coal.

With the exception of a few scraps of bone, no vertebrate fossils have been found in the Tatman formation. The invertebrates suggest that its age is probably Eocene and possibly Bridger.

The only change in our previously published diagrammatic section across the Bighorn basin<sup>2</sup> necessitated by the work of the past summer is the separation from the Wasatch of 400 to 600 feet of beds immediately beneath the *Lambdotherium* zone, which, it is now believed, belong to the Lysite.

## NEW FACTS REGARDING THE LITHOLOGY OF THE TERTIARY SEDIMENTS.

### GRAVEL BEDS.

The discovery of thick gravel lenses in the Knight, Lysite and Lost Cabin formations is one of the most important additions to our knowledge of the lithology of the Tertiary sediments of the Bighorn basin, for it demonstrates conclusively that their source is the older rocks of the surrounding mountains.

Gravel lenses interstratified with coarse yellow-brown sandstone occur in the Knight formation on the south side of Dry Creek, northwest of Fenton where they overly clays affording *Systemodon*. They have been seen at many localities in the Lysite and Lost Cabin formations throughout Buffalo Basin (Plate VI) where the pebbles seem to increase in size toward

<sup>1</sup> *Loc. cit.*, p. 34.

<sup>2</sup> *Bulletin American Museum*, Vol. XXX, Article VII, Fig. 2B.

the south and southwest, due, undoubtedly, to the fact that we are there approaching the source of supply of the material composing the gravels. Almost without exception, the pebbles are quartzite or chert, well rounded, but sometimes flattened with the flat surfaces lying parallel to the bedding planes of the lens (Plate VI). The matrix is coarse sand with calcareous or ferruginous cement. In one of the chert pebbles from a gravel lens in the Wind River near the Perkins ranch on the north side of Gooseberry Creek, a fragment of a coral resembling *Favosites* was found. Pieces of silicified wood were also noted in this conglomerate. These gravels are, unquestionably, channel deposits laid down by the streams which drained from the mountains during the Eocene and supplied the clays, sandstones and gravels to the intermontane trough. Gravels predominate in the southwestern portion of this trough simply because the Lysite and Lost Cabin formations, in which they occur most abundantly, have been removed by erosion farther east by the deep cutting of the Bighorn, but the absence of gravels from the easterly exposures of the Knight formation is rather remarkable.

#### DATE OF THE EOCENE DEFORMATION IN THE BIGHORN BASIN.

As Wind River fossils have not yet been found in either the Elk Creek anticline or the McCulloch Peak syncline, it cannot be determined whether these marginal flexures were produced during, before or after Wind River time. That they were probably later is suggested by the fact that the Tatman formation on the Gooseberry-Fifteen-mile Creek divide, overlying what is probably the Lost Cabin formation, has been tilted up with the latter, dipping toward the center of Buffalo Basin. It may well be that this accentuation of centripetal dips was contemporaneous with the development of the marginal flexures and that both were due to a common cause. Minor flexures have been noticed in the Lost Cabin formation on the divide between the Gray Bull and Fifteen-mile Creek north of Parker Spring.

#### DATE OF DISSECTION OF THE BASIN DEPOSITS.

Where the Shoshone River cuts through the Eocene clays west of McCulloch Peak, the lower terraces along the river are covered with water-worn pebbles and boulders of volcanic origin, mainly andesitic. When representatives of pre-Tertiary rocks occur they are always well-rounded.

At higher levels, the character of the terrace-mantle changes completely. Here nothing but highly angular rain-etched fragments of Palæozoic limestone are to be found varying in diameter from an inch or less to masses several feet across. Such fragments form a veneer on the tops of the higher terraces out in the badland clays, but they also occur far above the level of recognizable terraces on the tops of narrow ridges, 6000 feet above sea level, in the tremendously rough badland country to the west and southwest of the westerly summit of McCulloch Peak. That we are dealing with Palæozoic limestones and not the residual fragments of a Tertiary deposit is shown by the fossil corals and bryozoa which were repeatedly seen weathering out in relief on the solution-etched surfaces. Not a fragment of any rock other than limestone has been seen in these higher terraces and no water-worn material of any kind. High up on the west slope of McCulloch Peak an east-west-trending ridge of these angular blocks crosses the badlands. The ridge is six feet or more high and blocks, large and small, are piled up together in a symmetrical rampart. A similar mass is cut across by the river cliff east of Corbett station. The limestone blocks, falling over the cliff, have formed a talus high above the river, readily distinguishable from the rain-washed slopes of the surrounded clays. The nearest ledges of Palæozoic limestone are at least fifteen miles to the westward and yet blocks several cubic feet in volume have been carried out from the mountains, across the basin-filling of Eocene clays before the initiation of the erosion which has so deeply dissected it, and dropped without any attempt at assortment according to size, large and small together, and without any sign of water-wear. One block near Peter Miller spring measures approximately six by eight by three or four feet. In a cut bank at a level considerably above the lowest of the limestone-capped terraces highly angular fragments of the limestone were seen imbedded in soft, unstratified, yellowish silt, resembling boulder clay.

A brief statement of the facts observed was presented before the recent Washington meeting of the Geological Society of America and the transportation of the limestone blocks ascribed to glacial ice. Since then, correspondents have offered several alternative hypotheses, suggesting (1) that the fragments may represent a disintegrated remnant of an overthrust block of Madison limestone and (2) that they have been transported by water as claimed by Trowbridge<sup>1</sup> in explaining the transportation of the enormous blocks of granite found on the surfaces of the piedmont fans in Owens Valley. There is no evidence for such extensive overthrust of the Palæozoic series on the Eocene as the first of these suggestions necessitates

<sup>1</sup> Arthur C. Trowbridge. *The Terrestrial Deposits of Owens Valley, California, Journal of Geology*, Vol. XIX, pp. 706-747, 1911.

and, for the second, it seems difficult to assume aqueous transportation without postulating far steeper surface gradients than seem to have existed previous to the dissection of the Eocene basin filling.

The narrow-crested boulder ridges, high up in the badlands, suggest moraines. The terraces, capped only with angular fragments of limestone, suggest lacustrine conditions and the transportation of the fragments by floating ice. Unfortunately the problem must be left, for the present, in this most unsatisfactory condition, for lack of time and the palæontological objects of the expedition made it impossible to give it the attention which it deserves.

Since the limestone blocks were deposited over the floor of the Eocene basin, a tremendous amount of dissection has taken place, resulting in the maze of canons trenched in the McCulloch Peak mass and leaving isolated limestone blocks perched high up on narrow comb-ridges far above the present valleys. This dissection may possibly be an event of Pleistocene time.

That considerable erosion may have occurred in the Bighorn basin as a whole previous to the deposition of the limestone blocks is suggested by the absence of the Tatman formation and its overlying gravels in the McCulloch Peak area, where, as already stated, the limestone blocks rest directly on the red-banded pre-Tatman clays. This does not alter the situation, however, in regard to the cañon-cutting since these gorges have been cut in the clays beneath the limestone-block capping. That this is younger than the andesitic stream gravels on the top of Tatman mountain seems probable. These high-level andesitic gravels apparently antedate the dissection of the basin and are a remnant of a gravel sheet spread over the floor of the basin at the close of its depositional history. They must not be confused with the low-lying volcanic gravels found along the Shoshone River and elsewhere. These are much younger than the limestone-capped terraces. Such limestone fragments as occur in ~~them~~ are invariably water-worn.

## RÉSUMÉ.

1. The Lower Eocene sediments of the Bighorn basin represent the alluvial filling of an intermontane trough of downwarp.

2. They have been transported from the surrounding mountains as shown by the lithology of the gravels, sands and clays. No volcanic ash occurs.

3. They are stream transported and have been deposited in stream channels or spread over flood plains. No evidence in favor of wind transportation has been observed.

4. The Eocene clays are banded in more or less regular alternation, red and blue. This may be due to climatic causes leading to concentration of iron salts and their oxidation.

5. The beds are divisible into three formations, the Knight, Lysite and Lost Cabin, readily separable by their fossils, but not differing lithologically and conformable throughout. The Wind River (comprising the Lysite and Lost Cabin) is confined to the southwest portion of the basin (McCulloch Peak possibly excepted) and has been removed elsewhere by erosion.

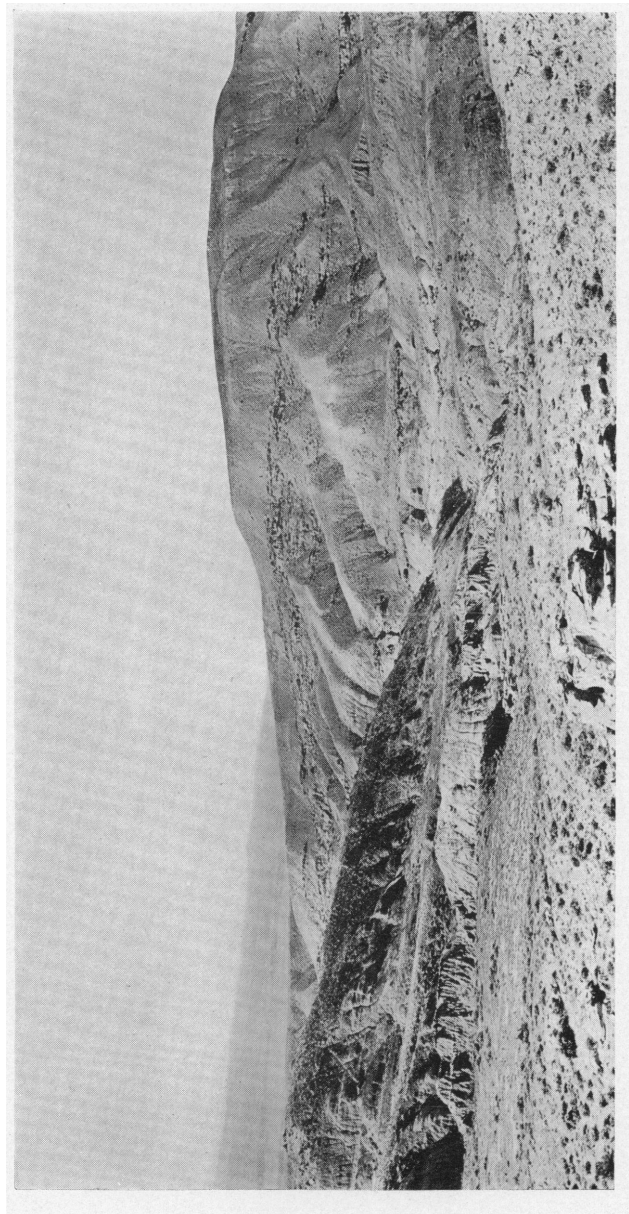
6. The Lower Eocene formations are overlain conformably by another set of beds, containing much lignite, the Tatman formation, in which determinable vertebrate fossils have not yet been found. Invertebrate fossils suggest that it may be of Eocene age, possibly Bridger.

7. The Tatman formation is overlain by andesitic gravels of doubtful age, of which but a remnant on the top of Tatman Mountain is preserved in place.

8. Deformative stresses have acted on the basin filling after the deposition of the Tatman formation, flexing it into marginal anticlines and synclines and increasing the centripetal dip of the beds.

9. The major dissection of the basin is, probably, a comparatively late event, geologically speaking, perhaps referable, in part, to the Pleistocene.





Contact of so-called Fort Union with Wasatch on the southwest slopes of McCulloch Peak. The fauna listed on p. 59 was collected on the two benches seen in the dipping beds at the left hand side of the picture. The star indicates the position of the banded Wasatch clays.







Gravel lenses in Wind River sandstones (probably Lost Cabin formation) about two miles east of Perkins's Ranch, on the south side of Gooseberry Creek.

