Article XII.—ON JURASSIC STRATIGRAPHY IN SOUTHEASTERN WYOMING.

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PLATES XXVI AND XXVII.

The purpose of this paper is to give some details in regard to the Jurassic strata of Wyoming, in which, for the last four years, the American Museum of Natural History has collected Dinosaur remains. Very little detail geological work has been done in the region. Prof. W. C. Knight published a map of southeastern Wyoming showing the Jurassic exposures [1]; and this is in part reproduced, with his consent, in Plate XXVI, Fig. 1, to show the location of the area in which the succeeding maps and sections are located. Prof. W. N. Logan [2] has also published a section made in the Freezeout Hills. The area studied, lying along the county line between Albany and Carbon Counties, includes all of the quarries worked for the American Museum; and, incidentally, a considerable number of Marsh's localities, where they were within the area mapped, are indicated.

Referring to Plate XXVI, Fig. 1, the axis of the Laramie Mountains is seen in the eastern part of Albany County, extending nearly north and south; but in Converse County it bends until it extends nearly west. In the angle thus formed are situated four short (8–20 miles in length), sharp folds, known as the Medicine, Como, Prager, and Miser anticlines. Their axes lie northeast and southwest, and each fold is thrust over beyond the vertical on its northern side. These folds are radial folds formed at the edge of the territory affected when the Freezeout Hills were thrown up. While the Laramie Mountains seem to be due to a thrust from the east, there must have been a force acting from the north in the neighborhood of the Freezeout Hills. This thrust from the north seems to have affected locally the axis of the Laramie Mountains, bending it to an east and west direction. The four short anticlines above named die out on the eastern boundary of the territory affected by the thrust from the north. How far west this thrust from the north, to which the Freezeout Hills are due, acted I cannot say.

It is along the southern exposures of Medicine and Como anti-

[1] Bull. Geol. Soc. America, Vol. XI, p. 377, 1900.
[2] Kan. Univ. Quart., Vol. IX, p. 109, 1900.

clines that the American Museum parties have worked, where the dip is 14–18°. The north sides of these folds stand too nearly vertical to be worked. Plate XXVI, Fig. 3, shows a section reconstructed to show the appearance of these folds had no erosion taken place. The position of this section is shown on Plate XXVI, Fig. 2, by a line from H to L running N. 25° W. The line starts on the Little Medicine River, about one and one half miles below the mouth of Sheep Creek. For ten rods on either side of the river all rocks are covered by river deposits. At the locality *c*, a collection of fossils[1] showed the presence of the Cretaceous (Fort Pierre); while within three rods to the south undoubted basal beds of the Jurassic[2] are found. A fault is thus indicated. While in the field I did not trace it out, so cannot speak in regard to its extent. The Jurassic is here inverted so that its basal member is uppermost. Between the Jurassic and the typical Triassic occurs a bed of creamy white sandstone, 40 feet thick, the same as is found in the Freezeout Hills, but this sandstone is lacking on the exposures situated further south. The Jurassic dips 60° S. (strike N. 53° E.), but proceeding south the dip quickly becomes vertical, changes to the north, and gradually diminishes till in the midst of the Triassic it becomes horizontal. The strata soon dip to the south increasing to about 14°, at which angle most of the rocks, as far as the Fort Pierre bed, dip.

At G the section changes its course to N. 5° W., crossing the Jurassic of the south side of the Medicine anticline. The Jurassic beds are here 274 feet in thickness and are overlaid by the coarse sandstones of the Dakota to the extent of 275 feet. Above these in turn lie the Fort Benton shales, the lower 80 feet of which consist of dense sandy limestone; while the upper 320 feet are thin bedded argillaceous shales, characterized by abundance of teleost fish scales. Above the Fort Benton are about 800 feet of slate-colored clay in which the stratification is obscure. On account of their soft texture these clays are easily eroded and the exposure is usually occupied by a long 'draw.' On weathering the clay turns black. As this clay overlies the Fort Benton

[1] The collection included *Inoceramus*, *Gryphæa*, *Lucina subundata* H. and M., *Tellina*, cf. *scitula* M. and H., *Anisomyon shumardi* W., *A. Patellaformis* W., and *Scaphites warreni* M. and H.

[2] The Jurassic layers carried *Belemnites densus* M. and *B. curtus L.*

and underlies the Fort Pierre, I consider it the representative of the Niobrara, although it is non-fossiliferous. A bed of gray sandstone comes next, making a prairie about three miles wide, so that to estimate its thickness is difficult, though there can scarcely be less than 300 feet. The sandstone furnished several badly preserved fossils among which were *Inoceramus*, *Gryphæ*, and *Scaphites warreni* M. & H. While the Ammonites are described as Fort Benton, inasmuch as I found the same at locality *c* mixed with the Fort Pierre Gasteropoda and Lamellibranchiata, and being strongly influenced by the stratigraphy, I am inclined to consider the sandstone bed Fort Pierre. Across the sandstone the Niobrara clay reappears, on its northern boundary nearly horizontal, but on the southern side overthrust, so that the Fort Benton lies inverted over the Niobrara. The Fort Benton dips 60° to the south (strike N. 48° E.). The change to the vertical occurs in the Dakota, which at this exposure (Carleton ridge) is only about one-half its usual thickness. The Jurassic dips 80° N. but as the Triassic is crossed the dip decreases to horizontal, changes to south, and gradually increases to about 17° S., at which angle most of the rocks, as far as the Prager anticline, dip. The section goes only to Como Bluff but the rocks at Prager anticline again show overthrust characteristics.

Three sections of the Jurassic are shown in Plate XXVII, Figs. 1, 2, and 3, giving the details of the series of rocks on the south side of Medicine anticline, and the north and south sides of the Como anticline. These sections are also tabulated on page 192 so that each layer can be traced in its variations across the two anticlines.

The base of the Jurassic I have located at the beginning of the series of clays. The Triassic is a great bed of sandstones, usually alternating red and gray. The first change from this to Jurassic is a layer of brown clay (No. 2), always of considerable thickness, and carrying *Belemnites densus* M. and *B. curtus* L. in such abundance that the ground is in many places so strewn with the shells that one can scarcely step without treading on one. The layer is widespread, occurring on Sheep Creek,[1] Medicine and Como anticlines, and is identical with Knight's No. 14,[2] and the lower part of Logan's No. 13.[3] It is usually designated as the Belemnite layer.

[1] The Sheep Creek exposures are 12 miles northeast of Bone Cabin Quarries.
[2] Bull. Geol. Soc. Amer., Vol. XI, p. 382.
[3] Kan. Univ. Quart., Vol. IX, p. 112.

PLATE XXVII, FIG. 3.			PLATE XXVII, FIG. 1.		PLATE XXVII, FIG. 2.	
Bed.	Section A–B.	Thickness.	Section C–D.	Thickness.	Section E–F.	Thickness.
		Feet.	*Dakota.*	Feet.		Feet.
No. 33	Yellowish sandstone.....	243	Straw yellow sandstone.....	120+	Sandstone.....	200+
" 32	Black sandstone	2	Black sandstone.	3	Black and red sandstone.....	4
" 31	Gray sandstone.	30	Yellow sandstone	12	Straw yellow sandstone.....	20
			Jurassic.			
" 30	Bluish green clay	21	Bluish green clay.	20	Maroon clay.....	10
					Bluish green clay.	15
" 29	Green clay.....	20	Green clay.....	40	Yellow green clay	13
					Bluish green clay.	15
" 28*a*	Flint.....	$\frac{1}{3}$	Flint.....	$\frac{1}{3}$		
" 28	Gray sandstone.	10			Sandy clay.....	5
" 27	Concretions....	2				
" 26	Green clay.....	3	Green clay.....	15	Green clay.....	2
" 25	Concretions....	$1\frac{1}{2}$	Concretions.....	2	Concretions.....	1
" 24*a*	Green clay.....	8	Green clay.....	9	Green clay.....	15
" 24*b*					Sandstone.....	4
" 24*c*					Green clay.....	10
" 23	Green clay with small concretions.....	10	Green clay with small concretions.....	9	Green clay with small concretions.....	25
" 22	Maroon clay with small concretions.....	10	Maroon clay with small concretions.....	28	Maroon clay with small concretions.....	20
" 21	Sandstone	3				
" 20	Green clay.....	8	Green clay.....	20	Green clay.....	9
" 19	Sandstone.....	1	Sandstone.....	2		
" 18	Red clay.....	5			Red clay.....	5
" 17	Sandstone.....	2				
" 16	Green clay.....	6	Green clay.....	9	Maroon clay.....	7
" 15	Sandstone.....	$1\frac{1}{2}$	Sandstone.....	2		
" 14	Red, green, maroon clay.....	12	Green, maroon, red clay.....	26	Red clay.....	8
" 13	Sandstone.....	2	Sandstone.....	$1\frac{1}{2}$	Gray sandstone..	28
" 12	Maroon, green, red clay.....	10	Green clay.....	20	Dark green clay.	10
" 11	Sandstone.....	2	Sandstone.....	2	Sandstone.....	$1\frac{1}{2}$
" 10	Green clay.....	22	Green clay.....	60	Red and green clay	10
" 9	Sandstone.....	1	Sandstone.....	$1\frac{1}{2}$	Sandstone.....	2
" 8	Green clay.....	20	Maroon clay. ...	20	Green clay.....	25
" 7	Reddish clay...	20				
" 6	Sandstone.....	$1\frac{1}{2}$	Sandstone.....	$1\frac{1}{2}$	Sandstone.....	12
" 5	Green sand shale	6				
" 4	Purple clay with limestones....	22	Purple clay with limestones	20	Purple clay with limestones	15
" 3	Nucula limestone	1				
" 2	Brown clay.....	43	Brown clay with limestone beds.	70	Gray brown clay.	55
	Total of Jurassic	$274\frac{5}{6}$	.....	$378\frac{5}{6}$	.....	$332\frac{1}{2}$
" 1	Triassic sandstones.		Triassic sandstones.		Triassic sandstones.	

On the surface of this, in Bone Cabin Draw, is found a one-foot bed of limestone (No. 3) made up mostly of *Nuculas*,[1] with occasionally a *Tancredia* and *Ostrea*. The band is not continuous, but similar layers at the same horizon occur both on Sheep Creek and in the Freezeout Hills.

No. 4 is a purplish clay with large limestone nodules scattered through it. It is in or on these nodules that the specimens of *Baptanodon* are found. That of the American Museum was found at locality *b*, at the foot of Bone Cabin Draw. It seems best to confine Marsh's[2] term, Baptanodon beds, to this layer instead of designating the whole lower Jurassic by that term. The bed is universally present in neighboring localities; and is Knight's 12 and the upper part of Logan's 13.

No. 5, green sand shale, is local.

No. 6, sandstone. This first sandstone bed seems to be widely distributed, and marks the beginning of a series of alternations between sandstone and clay. The clays are variously and brightly colored and often designated as the 'variegated clays.' The layers from 6 to 20 inclusive form a series of variegated beds in which there may be eight sandstone layers or only three. Very few of the clays seem to form wide horizons. Inside of a quarter of a mile I have seen three of the sandstone beds unite into one thick sandstone, the intervening clays being pinched out. These indicate a period of shallow water in which there were continually changing currents, so that deposits from any given source are laid down first in one place, later in another. In the Bone Cabin section there are 120 feet of these variegated clays, and it is somewhere in these layers that the change from marine to brackish (or freshwater) deposits occurs. In the Como section there is a 28 foot bed of sandstone, corresponding apparently with No. 13, in which a Dinosaur quarry (12) is located. This bed seems to represent the beginning of the freshwater (or brackish) series, and as such is the first member of the Como stage (Atlantosaurus beds). This sandstone (No. 13) is variable in

[1] At the foot of Bone Cabin Draw, locality *b*, were found in this layer *Nucula* nov. sp., *Tancredia inornata*, *Avicula mucronata*, and *Ostrea strigilecula*. A similar band near Sheep Creek furnished all of the above with also *Cardioceras cordiformis* M., and *Pseudomonotis curta*; see also Logan's No. 13, which furnished some of these and several other forms.

[2] Sixteenth Ann. Rep. U. S. Geol. Surv., 1896, p. 145.

thickness but there is no unconformity such as Logan seems to have found in the Freezeout Hills.

No. 22 is a bed of maroon colored clay with small limestone concretions scattered through it, and is a most excellent horizon indicator, for it is everywhere present, and its brilliant color makes it a conspicuous feature for miles. At Bone Cabin it is but 10 feet thick but increases to 30 feet in the Como Bluff. The considerable amount of concretionary limestone would seem to indicate brackish water.

The maroon clay graduates into a bed of green clay with similar small limestone concretions (No. 23). This layer like the maroon bed is widespread and thicker as one goes south.

The green clay with concretions is invariably covered with smooth green clay (No. 24). In the Como Bluff this layer has sandwiched into it a 4-foot bed of sandstone (24*b*). The sandstone is of interest as marking the horizon at which the few known Jurassic mammals were found. The mammal layer is the 6 inches of clay immediately underlying this sandstone. Most of the American Jurassic mammal remains thus far found have come from one quarry,[1] worked most successfully by Marsh and later by the American Museum. This pocket seems to be exhausted.

Above 24 is a constant layer of large nodular limestone concretions (No. 25). Single concretions may occur anywhere in the clay but this layer and No. 27 are definite layers of almost uninterrupted limestone nodules. The concretion layers are of considerable importance as, when weathered out, they make a prominent line on the bluffs just above which the most important bone bed occurs. In this limestone layer Logan found five species of fresh or brackish water mollusks.[2]

No. 27 is a green clay of varying thickness in which the most numerous quarries are located. On weathering, or having been dried out, this clay breaks into angular fragments and is therefore known as 'joint clay.' The 'Nine Mile Quarry,' the 'Aurora 1900 Quarry,' the 'Diplodocus 1897 Quarry,' and several of Marsh's quarries are in this layer. Most of the fossils are *Diplodocus* and *Brontosaurus* species.

[1] See Pl. XXVI, the S.E. corner of the map.

[2] *Unio knighti* L., *U. willistoni* L., *U. baileyi* L., *Valvata leei* L., and *Planorbis veternus* L.

In Bone Cabin Draw this green clay is overlaid by a second layer (No. 27) of concretions, so that the 'Nine Mile Quarry' is between two such layers.

No. 28 is a gray sandstone in which the rich Bone Cabin Quarry is situated, and also the Stegosaurus Quarry. The sandstone varies extremely in hardness, being, in the south part of Bone Cabin Quarry, soft and mixed with considerable clay so that it is workable with an awl. In the northern part of the quarry, however, there are bands of the firmest sort of sandstone. In Como Bluff the layer is clay with merely an admixture of sand. Bone Cabin Quarry has yielded a great variety of genera: *Diplodocus*, *Morosaurus*, *Brontosaurus*, *Allosaurus*, *Ceratosaurus*, *Camptosaurus*, *Stegosaurus*, as well as several genera of carnivorous Dinosaurs; also *Compsemys* and *Goniopholis*.

On the surface of this sandstone is usually a 4-inch layer of flint, No. 28*a*.

No. 29 is another green clay showing the 'joint' structure similar to No. 26. Several of Marsh's quarries are in this layer.

The series ends with a soft bluish green clay in which I have never seen fossils. This completes the Jura.

A cap of Dakota sandstone overlies the Jura, near the base of which is a narrow (2–6 feet) band of soft black, or occasionally red, sandstone. This band is colored by iron and of interest as having lately yielded a collection of bones probably crocodilian.

There is some difficulty in comparing the foregoing sections with those of Logan and Knight, as these authors give fewer beds. Marsh divided the Jura into three horizons, Hallopus, Baptanodon, and Atlantosaurus beds. The Hallopus beds do not occur in southeastern Wyoming. The Baptanodon beds, according to Marsh, included all of the lower Jurassic, which has since been subdivided, but the term Baptanodon is now applied to a single layer (No. 4) in which these reptiles occur. When this term is restricted to a single layer, the lower strata are without designation; so for these, Knight has proposed the term Shirley stage, which shall include all the marine Jura; that is, beds 2–12 inclusive. The exact boundary between marine and non-marine is difficult to locate, but bed 13 has furnished some Dinosaur remains and may therefore be associated with the beds in which Dinosaurs are abundant. Then beds 13–30, inclusive,

would form the non-marine upper Jura. There are no invertebrate forms of decisive character in these beds to determine between brackish and fresh water, but those found in bed 24 would incline toward fresh water. The change is clearly a gradual one. These upper beds Marsh calls Atlantosaurus beds, but as that genus has proved to be a synonym with *Camarosaurus*, a less misleading term is desirable; and Scott [1] has introduced the name Como stage for exactly these beds. He suggests that they belong to the Lower Cretaceous; and Logan also uses the term Atlantosaurus beds as distinct from Jurassic. There is no available invertebrate material in these upper beds for comparisons; but the strikingly close relationships between the British Purbeck mammalian fauna and the Wyoming mammals cannot be left out of consideration. The considerable number of British and Wyoming genera which are closely related will compel us to consider the Como stage of nearly if not just the same age [2] as the Purbeck and retain the Como in the Jurassic series. It is true there is no apparent unconformity between the Como and Dakota, as would be expected if this Como stage were dry land for a period as long as the Lower Cretaceous.

During the Shirley period, the deposits on the Medicine and Como anticlines were being laid down quite close to shore, as appears from the fact that within 30 miles to the south the Shirley is unrepresented, and all of the deposits are strictly shallow water sediments. However, during and especially at the beginning of the Como stage, a considerable transgression took place (see Knight's map) toward the south, removing the shore line to over 100 miles south. The deposits are also of shallow water.

The Dinosaur remains could, however, have travelled such considerable distances by floating. There could have been no currents in the Como lake strong enough to transport gigantic bones, for they were depositing clay. The bones are clearly floated out to sea by the presence of considerable meat on them. Most specimens must have started as complete carcasses, which with decay of the flesh (or its consumption by crocodiles and fish) have fallen apart, often making series of vertebræ, etc. Doubtless such quarries as the Bone Cabin Quarry mark an eddy, as there all sorts and sizes of animals are collected together.

[1] W. B. Scott, Introduction to Geology, p. 477.
[2] Osborn, Jour. Acad. Nat. Sci. Phila, (2) IX, p. 187, 1888.

In summary it may be said that the Dinosaur remains are mostly confined to beds from 26 to 29, although occasionally remains are found lower. The bones are usually nearly perfect, though in some localities pieces of the more delicate spines are broken away. The clay usually preserves bones much better than the sandstone.