

# AGE AND DEVELOPMENT OF RED BEDS AND TERRESTRIAL VERTEBRATES OF THE APPALACHIAN AND KANSAS-TEXAS SECTIONS <sup>1</sup>

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## INTRODUCTION

A study of the Upper Pennsylvanian and Lower Permian stratigraphy and fossils has been in progress by the writer for some time. This study has involved the correlation of the beds of these systems over North America and Eurasia, in so far as that is possible. It has particularly involved the correlation of the Appalachian and western sections, and in view of some novel suggestions that have been made to account for the peculiar distribution of the fossil air-breathing vertebrates, it is thought that the results of this work may be of interest.

## CORRELATIONS

### *SUCCESSION OF THE INVERTEBRATES AND CORRELATION OF THEIR HORIZONS*

The invertebrate fauna of the upper part of the American Pennsylvanian has certain characteristics. For instance, the fauna, as a whole,

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possesses unity of expression and is characterized by relatively little evolution when the great length of time involved is considered. The larger formations, or stages, are characterized by the introduction of a few distinctive species and the extinction or disappearance of others, together with the fact that certain persistent forms found throughout great thicknesses of strata become very abundant in certain horizons. A number of species run the gamut of the formations of the middle and upper parts of the Pennsylvanian.

The data on which these generalizations are based is shown in detail for the Kansas section in volume IX of the University of Kansas Geological Survey Reports.<sup>2</sup>

A glance at the Kansas faunal chart shows a continuous diminution of the number of species in the formations after the Oread limestone, the top of the Douglas stage, is passed. Many new forms are introduced in the higher formations shown on the chart. If still higher beds in the Kansas-Oklahoma succession had been included, the number of added species would have been considerably larger.

Subsequent to the publication of this work, data became available which made it advisable to consider the base of the Neva limestone as the base of Series IV, the base of the Permian, instead of the base of the Elmdale formation. This increases the number of species found in Series III by those that are first recorded in the Elmdale formation and diminishes the number found in Series IV, namely, a loss of ten species to Series IV and the addition of eight species to Series III. Since the chart was completed additional work in Oklahoma has added somewhat to the fauna that is accredited to Series IV, to a considerable extent by the addition of species not known from the formations below it. The numerical relationships of the species has been discussed elsewhere.<sup>3</sup>

Similar detailed charts were prepared by Miss Mark for the fauna of the Conemaugh formation of Ohio,<sup>4</sup> in which the Ohio faunas are compared and correlated with those of the Kansas section. The lower Conemaugh formation of Ohio is more typically marine in Ohio than in West Virginia and possesses a correspondingly richer fauna, Miss Mark's lists containing 168 species. This fauna is strictly Pennsylvanian in its characters; and Miss Mark correlates its highest horizon, the Ames limestone, approximately with the Oread limestone of the Kansas section, and its

<sup>2</sup> Beede and Rogers: Faunal studies of the Kansas Coal Measures. Univ. of Kans. Geol. Survey, vol. ix, 1908, pp. 318-385. See especially the chart facing page 328.

<sup>3</sup> Jour. Geol., vol. xvii, 1909, pp. 710-729.

<sup>4</sup> Clara G. Mark: Fossils of the Conemaugh formation in Ohio. Ohio Geol. Survey, 4th series, Bull. 17, 1912, pp. 261-326.

lowest member, the Brush Creek bed, with the middle of the Pottawatomie formation.

The first correlation, that of the Ames limestone with the Oread limestone, or possibly the base of the Shawnee formation, is in complete agreement with the writer's conclusion, based on the fauna as represented in West Virginia.

However, the writer made no attempt to correlate the lower Conemaugh with the Kansas section. Miss Mark places the lowest fossiliferous beds of the Conemaugh, the Brush Creek, approximately on a level with the middle of the Pottawatomie formation. That would probably be somewhere in the upper part of the Kansas City formation. However, the Brush Creek does not constitute the base of the Conemaugh, but is from 80 feet to a much greater height above it. Neither is the middle of the Pottawatomie the base of the Kansas beds supposed to rest on the top of the Allegheny, or Des Moines, of Kansas. This interval is larger in Kansas than it is in Ohio and West Virginia, but is insufficiently so to seriously influence the results attained in this paper; that is, *for our present purposes*, that difference is negligible.

The size and character of the Conemaugh fauna is such as to make its place in the Kansas succession fairly certain. It is quite certain that it does not belong much higher in the Kansas section than the place assigned to it, since the most of the fauna is characteristic of Series II, and possibly some of it the basal part of Series III, but none of it is characteristic of Series IV, the beds referred to the basal Permian.

Consequently the remainder of Series III is left for the non-marine Conemaugh and the Monongahela formations—that is, the upper part, or most of the Shawnee and the Wabaunsee stages, as limited elsewhere in this paper.

Leaving the Pennsylvanian part of the section, with its long-lived species and sluggish development of forms, and turning to the higher beds, we face a different set of conditions.

Thus, the Fusulinæ at the base of Series IV branched in two directions. One of these developed the true Schwagerinas in Kansas and Texas, and another into long, slender, complicated Fusulinas, found in other regions, quite different from the regular, tiny, fusiform species which characterize the Pennsylvanian, though a few of the latter persist into the basal Permian. Higher up, elsewhere in the Permian, these elongate forms attain gigantic proportions for Paleozoic Foraminifera, as one specimen, preserving hardly half its length, must have been over 50 millimeters long and 5 millimeters in central diameter.

Revised Table of Formations

West Virginia- Pennsylvania.	P E R M I A N. Series V.	Kansas.		Texas.
		Wellington.	Wellington.	
Dunkard.	Series IV.	Marion.	Pearl shale. Herrington limestone. Enterprise shale. Luta limestone.	Wichita.*
		Chase.	Winfield limestone. Doyle shale. Fort Riley limestone. Florence flint. Matfield shale. Wreford limestone.	
		Council Grove.	*Neosho form. } Garri- Florena shale. } son. Cottonwood limestone. Eskridge shale. Neva limestone.	
Monongahela.	Series III. Missourian.	Wabaunsee.	Elmdale formation. Americus limestone. Admire shale. *Emporia limestone. Willard shale. Burlingame limestone. Scranton shale.	Cisco.
		Prosser in 1895.		
		Shawnee.	Howard limestone. Severy shales. Topeka limestone. Calhoun shales. Deer Creek limestone. Tecumseh shales. Lecompton limestone. Kanwaka shale.	
		Douglas.	Oread limestone. Lawrence shale. Iatan (Kockapoo) lime- stone. Weston (Le Roy) shale.	
Conemaugh.	Series II. PENN- S- Y- L- V- A	Lansing.	Stanton limestone. Vilas shale. Plattsburg (Allen) limestone. Lane shale.	Canyon.
		Kansas City.	Iola limestone. Chanute shales. Drum limestone. Cherryvale shale. Winterset (Dennis) limestone. Galesburg shale. Bethany Falls lime- stone. Ladore shale. Hertha limestone.	
		Pleasanton. } Des Moines. } Henrietta. }	La Cygne shale. Lenapah (Coffeyville) limestone. Nowata (Walnut) shale. Altamont limestone. Bandera shale.	
Allegheny.	Series I. Des Moines.		Pawnee limestone. Labette shale. Fort Scott limestone.	Canyon.
		Cherokee.	Cherokee shale.	

\* = vertebrate fossils.

In the top of the Gaptank formation and in the Wolfcamp beds of West Texas, which lie in a part of the Permian geosynclinal basin, the Schwagerina fauna contains the beginnings of the typical Lower Permian fauna in such forms as *Fusulina* aff. *longissimoides*, *Schwagerina*, two species; *Enteleles oehlerti* Gemm. *Geyerella?* sp., *Productus guadalupensis comancheanus* Girty, *Euomphalus* aff. *ponderosus* M. and W., *Omphalotrochus*, two species. In the Wolfcamp are twelve species of Ammonoids, described by Böse, which possess Permian affinities, together with *Cladopora?*, *Leptodus*, and *Aulosteges*, aside from those already enumerated. As a rule, it is characteristic of a number of Permian invertebrate forms to show a marked increase in size over Pennsylvanian species. There is also a tendency for many of them to take on specialized and even bizarre forms. Some of these fossils have been mentioned above and others occur in higher beds, such as *Leptodus*, *Richtofenia*, *Aulosteges*, and other forms described by Girty,<sup>5</sup> together with such Ammonoids as *Waagenoceras*, *Perrinites*, *Adrianites*, *Medlicottia*, *Paraceltites*, *Stacheoceras*, etcetera, described by Böse.<sup>6</sup>

From these data it is apparent that the Schwagerinas occur at nearly the same horizon as the known beginning of the Permian ammonoids and in the same beds with other known Permian invertebrates. Based upon its invertebrate fauna, the Neva limestone of Kansas, with its Schwagerina fauna, may be regarded, in the light of our present knowledge, as forming the base of the Permian beds in Kansas, and the Schwagerina beds of the same age in West Texas may likewise be regarded as marking the base of the Lower Permian beds there.

The top of the Cisco in northern Texas reaches practically to the base of the Schwagerina beds, though species of this genus have not yet been found there. Evidences of unconformity have been observed at this level by at least three experienced geologists, though, so far, no publication to that effect has come to hand. Confirmatory to these observations is the fact that the usual *Fusulina* succession occurs to the upper Cisco where the more obese *Fusulinas*, precursors of the Schwagerina fauna, are found; but above these beds no Schwagerinas have been found, though they occur in the Hueco and Marathon regions to the southwest and in the Kansas-Oklahoma region to the north. It would thus seem that the region now occupied by the outcrop of the top of the Cisco and base of the Wichita beds that rocks of Schwagerina stage were not deposited or that they were removed by erosion after deposition. However, it is more

<sup>5</sup> Guadalupian fauna. U. S. Geol. Survey Prof. Paper 58.

<sup>6</sup> The Permo-Carboniferous ammonoids of the Glass Mountains. University of Texas Bulletin 1762, January, 1919.

likely that conditions were unfavorable to them. At the same time it is possible that this fauna exists there, but has not been collected, though it hardly seems probable.

In the light of the foregoing evidence it would seem that, so far as the evidence furnished by the invertebrate faunas of the Appalachian and western interior regions, the successions are not difficult to correlate. In the second place, that the evolution of the faunas was slow until the base of the Neva limestone or its equivalents elsewhere have been approached, when the evolutionary processes were remarkably quickened and new faunas were developed.

#### *SUCCESSION OF THE FLORAS AND CORRELATION OF THEIR HORIZONS*

On account of the widely distributed plant beds in the Pennsylvanian and the Permian systems, the record of the floras of these periods is of great value for purposes of correlation, and it will be interesting to compare correlations based on these floras with correlations based on the invertebrates.

In the Appalachian region above the Pottsville series, the flora is well known nearly to the top of the Conemaugh, and is the type section for comparison of upper Pennsylvanian floras of America. Without going into too great detail, it may be stated that the post-Pottsville plants fall into two groups, as found in the Allegheny and Conemaugh stages respectively. Skipping the uppermost Conemaugh and Monongahela series, the flora of the Dunkard series of the lower Permian has also been rather fully described.

Beginning with the Cherokee formation of Kansas and Missouri, the lowest Pennsylvanian formation occurring in the State of Kansas, we find a flora which was described by White<sup>7</sup> as Allegheny in age. This Allegheny flora extends upward to the unconformity in the upper part of the Pleasanton shales. In other words, it corresponds with the Des Moines stage of the western Mississippi Valley.

Concerning this flora, White remarks:

"The Lansing [Cherokee shales] horizon is certainly not lower than, and probably not so low as, the lower coal-bearing division of the Arkansas Coal Measures. . . . The flora seems to correspond to that of the Middle Coal Measures of Great Britain and to the uppermost portion of the latter or to the transition series above the Westphalian of the continent of Europe."<sup>8</sup>

Speaking of the flora of the Le Roy (Weston and Lawrence) shales of Series III of Kansas, he states:

<sup>7</sup> David White: U. S. Geol. Survey Monograph xxvii, 1899.

<sup>8</sup> U. S. Geol. Survey Bulletin 121, 1903, p. 111.

"From such material as I have examined from this horizon, I am disposed to regard its stage as more strongly marked by the large Pecopterids, including callipteridoid forms, by the broad Allethopterids and the dilated Neuropterids. The presence of *Allethopteris grandini*, *Annularia sphcnophylloides* var. *intermedia*, which is very closely related to *S. filiculme*, seems to point toward a level possibly as high as the Pittsburgh coal in the Monongahela formation. But the presence of the forms which, so far as known, appear to include a lower stage makes it seem improbable that the Lawrence plants are of quite so late a date as the Monongahela formation of the Appalachian trough."<sup>9</sup>

In short, they appear to belong to the upper part of the Conemaugh formation.

One of the critical floras to be compared with the plants of the Appalachian section is the flora from Onaga, Kansas, found in the Elmdale formation. Concerning these plants White states:

"Nearly all the species have been reported from the Permian of Europe or the Dunkard formation of the United States, though, with the possible exception of *Pecopteris newberriana*, none are distinctly characteristic of the Permian. It would seem that the Onaga flora should be of later date than the Pittsburgh coal. The evidence presented by this small Onaga flora may, therefore, be construed, so far as it represents the plants of its horizon, as indicating a stage probably within the Monongahela formation of the Appalachian region, or possibly as high as the lowest part of the Dunkard formation, although, with the exception of *Pecopteris newberriana*, the collection in hand does not contain any species characteristic of the Permian of the old world and does not signify the Permian age of the Onaga (Elmdale) beds."<sup>10</sup>

That is, plants typical of the Pennsylvanian formations are absent from this local flora, and its whole composition, aside from the one species quoted, is made up of the persistent or transition forms that pass over into the basal Permian.

The next formation above the Elmdale is the Neva limestone, which carries a *Schwagerina* fauna and forms the base of the *Schwagerina* zone of the western part of the Hydrographic basin of the Gulf of Mexico. The top of this zone is found in the Florence flint. Somewhat above the middle of this zone is the Wreford limestone, which is composed of two thick beds of cherty limestone separated by a parting of shale which contains fossil fish, land plants, and ostracods.

In this shale parting White made a collection of fossil plants, regarding the age of which he states:

"An inspection of the rather short list from the Wreford limestone reveals a flora most of whose species are characteristic of the Permian, a small per-

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<sup>9</sup> Ibid., p. 114.

<sup>10</sup> Ibid., p. 116.

centage only being common to the Coal Measures. It is, in fact, somewhat surprising to note so few pre-Permian forms in this flora."<sup>11</sup>

In the paragraph quoted, there is a discussion of a list of plants found north of Washington, Washington County, Kansas, with a considerable number of Pennsylvanian survivors, concerning which an explanation is necessary.

The apparent horizon of this locality, as belonging to the Winfield limestone, was given to White by the present writer. It is virtually an inlier in the Cretaceous rocks of the region and its position in the Permian section was inferred from its geographic position with respect to rocks outcropping farther east. Recently it has been found that one of the buried granite ridges of this part of the State is located in this region,<sup>12</sup> so it is likely that the apparent age of this exposure was underestimated on account of the presence of a large anticlinal fold the top of which had been eroded away. Its actual horizon is unknown.

From beds higher than the Neva limestone, in Kansas, we have 21 genera, represented by 50 species, concerning which White remarks:

"All the specially identified plants [eliminates five species] in the above list are found in beds referred to the Permian in their respective provinces, most of them being European. The species in bold types [33] are diagnostic of the Permian."<sup>13</sup>

In Oklahoma and Texas, in the beds which possibly are above a large part of the Kansas beds, from which the plants just referred to occur, we find a *Gigantopteris* flora introduced. This flora contains 18 genera and 46 species, practically all of which are either diagnostic of the Permian or occur in Permian beds of other parts of the world.<sup>14</sup>

From the foregoing data it is seen that in the case of the plants those characteristic of the Pennsylvanian continue nearly to the Neva limestone, when they disappear, except for certain persistent or transition elements which go over into the Lower Permian deposits, as is typified by the *Onaga* flora.

In this respect the whole history of the plants parallels that of the invertebrates, except that the species and genera of the latter are, on the whole, more persistent than are the species and genera of the plants.

In both cases the evolution of genera and species was relatively slow during the Pennsylvanian and was quickened with the initiation of the Permian conditions. They show apparently antochthonous genera and

<sup>11</sup> Proc. U. S. Nat. Mus., vol. xli, 1912, p. 509.

<sup>12</sup> Moore: Bulletin Amer. Assoc. Pet. Geol., vol. iv, 1920, map, p. 257.

<sup>13</sup> D. White: Proc. U. S. Nat. Mus., vol. xli, no. 1873, 1912, pp. 508, 509.

<sup>14</sup> D. White: Op. cit., pp. 505-507.



species, together with immigrants from other regions.<sup>15</sup> The conditions responsible for this rapid development accomplished the rapid elimination of the Pennsylvanian forms.

In the light of the evidence furnished by the fossil plants, namely, that all the typical Pennsylvanian species had been removed from the Onaga flora, leaving only those that persist into the Permian, and the presence of a well developed Permian flora in the Wreford limestone, it would seem that the Permian flora first appeared in an intermediate formation, more likely quite as near to the lower as to the upper horizon.

Similarly, faunal elements begin to appear in the Elmdale formation, which persists into the Permian, and Schwagerina and its accompanying fauna appear in the Neva limestone. Hence the line between the Pennsylvanian and Permian periods is placed at the base of the Neva limestone.

From the review of the fauna and the flora characterizing the Western and Eastern sections, it is found that the correlations based on the two types of evidence is not seriously discordant. Indeed, it is nearly as harmonious as one might expect for correlations based on marine invertebrates and on land plants, and there appears to be little reason to question these correlations, though the correlation based on the fossil plants would place the Conemaugh formation lower in the Kansas section than that based on the invertebrates. For present purposes, the difference is negligible.

#### *SUCCESSION OF THE VERTEBRATES AND CORRELATION OF THEIR HORIZONS*

With this history of the range and distribution of the invertebrates and plants of the latest Pennsylvanian and basal Permian beds in mind, it is interesting to turn to the analysis of the occurrence of the vertebrates which existed during the same periods of time. The following table shows the distribution of the vertebrates in the Appalachian and Western section:<sup>16</sup>

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<sup>15</sup> D. White: Jour. Geol., vol. xvii, 1909, p. 335.

<sup>16</sup> Case: Carnegie Institution of Washington, Publication No. 107, 1915.

Moodie: Carnegie Institution of Washington, Publication No. 238, 1916.

Genera and species of Amphibia.		Genera and species of Reptilia.		Locality and horizon.
Genera.	Species.	Genera.	Species.	
<i>Permian</i>				
16	26	27	41	Texas, Clear Fork.
11	15	23	35	Oklahoma-Texas, Wichita.
—	—	—	—	
Total.....	22	39	57	
<i>Pennsylvanian</i>				
1	1	1?	1?	Kansas, Louisville, base of Elmdale?
4	6	3	3	Illinois, Danville, Conemaugh?
1	1	2	2	West Virginia - Pennsylvania, Conemaugh.
23	51	1	1	Linton, Ohio, top of Allegheny.
10	17	0	0	Nova Scotia, top of Allegheny?
8	10	0	0	Mazon Creek, Illinois, base of Allegheny? or top of Pottsville.
—	—	—	—	
Total.....	47	7	7	

Of the genera of Pennsylvanian Amphibia, four continue into the Permian, as do three of the seven genera of Reptilia.

From this table it is apparent that the first known vertebrate fauna was a purely amphibian fauna, from the basal Allegheny or top of the Pottsville. The first known reptile, *Eosauravus*, occurs in the Linton coal of Ohio, in the top of the Allegheny series. Later two reptilian forms are known from the Conemaugh of Pennsylvania and West Virginia, and three are known from the Danville, Illinois, beds of uncertain age. It is at present impossible to ascertain with certainty the age of these last beds. However, the writer is of the opinion—largely unsubstantiated as yet—that the Danville material is of no later age than the Conemaugh, but fortunately it preserves a somewhat more complete picture of the air-breathing vertebrates of that time than do the Pennsylvania-West Virginia remains. There is also one amphibian and probably a reptile from the upper Pennsylvanian of Kansas. The wealth of material from Nova Scotia described by Dawson is probably very near the horizon of the Linton, Ohio, fauna.

In all these Pennsylvanian forms there are 47 genera and 86 species of Amphibia known from the Pennsylvanian and only 7 genera and ?

species of reptiles known from the same system of sediments. From this it is seen that the Pennsylvanian fauna is a distinctly amphibian fauna, 91 per cent of its genera being unknown in rocks higher than the Neva limestone; 50 per cent of the Reptiles go over into the beds higher than the Neva limestone.

In contrast with this condition we find in beds above the horizon of the Neva limestone (none of the beds within about 100 feet of it are known to contain air-breathing vertebrate remains) a very different relation of the two classes of animals. Thus there are only 22 genera and 39 species of Amphibia in these higher beds, while there is a total of 35 genera and 57 species of reptiles, which constitute a distinctly reptilian fauna in contradistinction to the amphibian fauna of the Pennsylvanian.

Taking the fauna in detail by formations, or stages, we find in the Wichita beds and their equivalent in Oklahoma 11 genera and 15 species of Amphibia, of which only four genera have come up from below, while there are 18 genera and 36 species of reptiles known from this stage, only three of the genera having persisted from the Pennsylvanian beds, leaving 15 out of the 18 genera introduced during the Wichita stage.

In the Clear Fork beds there are 16 genera of Amphibia, represented by 26 species—an increase in numbers over those known from the Wichita stage, but still below the Pennsylvanian numbers. The Clear Fork Reptilia are represented by 27 genera and 41 species, showing a marked and consistent increase over those from the Wichita beds.

This fact in itself is a very significant illustration of the faunal changes brought about during earliest Permian time. However, if we take into account the extensive specialization of many of the Permian reptiles, such as *Dimetrodon*, *Celpsydrops*, and others, the case comes to have far greater significance. To sum up the history of the air-breathing vertebrates of the Pennsylvanian and Permian, we start with a pure Amphibian fauna in the lower Allegheny, extending to the upper Allegheny, and a mixed Amphibian-Reptilian fauna above this horizon, with the Amphibia in overwhelming preponderance to the base of the Permian, when the Reptilian forms preponderate and are extremely specialized.

From the data at hand it is apparent that, so far as our knowledge goes, the air-breathing Vertebrata show very much the same history for the periods of time under consideration as do the invertebrates and the plants.

When measured in the terms of western sedimentary deposits, these fossils are distributed through some 5,000 or more feet of deposits nearly equally divided between the Pennsylvanian and Permian rocks, composed of shales, limestones, sandstones, and coals. The fauna clearly shows two distinct facies in the lower and upper part of these beds.

The fact that the earlier vertebrates are now known only from the eastern region and the highly specialized forms are confined to the western deposits demands consideration, as does tentative suggestions thrown out by Case,<sup>17</sup> to account for this distribution.

#### REVIEW OF CONDITIONS VERSUS TIME HYPOTHESIS

The main idea in Case's suggestion is that the Appalachian region began to emerge early in Pennsylvanian, or even Mississippian, time, and that the process was continuous until the whole of the eastern and central United States became a land area, at the close of the "Permo-Carboniferous." It is also postulated that a local climatic change occurred at the inception of this movement and continued to its consummation, finally migrating westward with the emerging land.

He distinctly states this hypothesis in an article entitled "Permo-Carboniferous Conditions *versus* Permo-Carboniferous Time."<sup>18</sup> In another place he described at length the supposed climatic and physical conditions, the faunas, and their vertical range and geographic distribution.<sup>19</sup>

Regarding the data on which the hypothesis is based, he states:<sup>20</sup>

"The lower limit of the fauna is confessedly vague and shadowy, passing far down into the Pennsylvanian. The Pennsylvanian amphibians described by Moodie in numerous papers are so close to those occurring in association with the Permo-Carboniferous forms from Texas that it is evidently a case of overlapping, and the only recognizable line is that where the first reptile occurs. It is, of course, probable that the reptiles occurred at lower horizons. In 1910 Moodie found a form near *Oricotus* in the Mazon Creek shales. These shales occur near the base of the Allegheny (or top of the Pottsville). David White regards them as the equivalent of coal No. 2 of Illinois (Morris and Braidwood coals of the Clarion). They are regarded by him as having close relationship with the Cherokee of Henrietta County, Missouri, at the base of the Allegheny."

"The Linton coal, from which comes *Eosaurus copci* Williston, . . . belongs to the Upper Freeport coal (coal No. 6.), and is referred by Prosser to a position near the top of the Allegheny. . . . Williston and Moodie have described the genus *Eosaurus*, giving figures, and demonstrated its reptilian nature.

"The earliest amphibians definitely comparable to the Texas fauna are from the Pittsburgh red shale. The Pittsburgh red shale lies 300 feet above the Freeport coal and 695 feet or more below the base of the Dunkard."

"The exact age of the beds in Illinois (Danville) and Prince Edward Island, in which similar forms occur, is not yet determined."

<sup>17</sup> E. C. Case: Permo-Carboniferous conditions *versus* Permo-Carboniferous time. Jour. Geol., vol. xxvi, 1918, pp. 500-506.

<sup>18</sup> Jour. Geol., vol. xxvi, 1918, pp. 500-506.

<sup>19</sup> Carnegie Institution of Washington, Publication 207, 1915.

<sup>20</sup> Op. cit., pp. 93-99.

"The limit recognized for the Permo-Carboniferous fauna is, then, from the Pittsburgh red shales to the top of the Clear Fork. The stratigraphic extent of the space delimited it is impossible to state, since there is no direct correlation of the eastern and western beds possible, but may be roughly stated as from the middle of the Conemaugh to the top of the Permo-Carboniferous. The limits of the fauna in America, however, are not those of Europe; the fauna there are continued into the Triassic."

In order to get a clear understanding of the whole subject, which can not be fully reviewed here, the two articles should be read in full.

After discussing the red beds and their fossil remains as local evidence of the gradual elevation of the Appalachians, he states:

"These local proofs of elevation are but contributory evidence of the whole eastern part of North America, probably as a continuation of the same movement which formed the Hercynian somewhat earlier in central Europe. The elevation of North America, which began on the eastern side, was gradually extended to the west, as is shown by the progressive disappearance of the Mississippian sea and the Pennsylvanian coal swamps in that direction.

"The elevation was attended by gradual change in climate; instead of gray and black shales and white sandstones the prevailing deposits were colored red by the oxidation of iron under the influence of a less equable climate, as seasons of relative drought and humidity succeeded each other.

"As the climatic change migrated toward the west only slowly, red sediments were formed at progressively higher and higher levels. In western Kentucky, Indiana, and Illinois the conditions necessary for the formation of red beds did not arrive until after the highest sediments now preserved had been formed, or only thin deposits were formed which have since been removed by erosion. That the surface of these regions was dry land by the time 'Permo-Carboniferous conditions' had reached them is suggested by the mode of occurrence of the vertebrates in Illinois and the Merom sandstone in Indiana." . . .

"Beyond the elevated region of Missouri, the upper Pennsylvanian and Permo-Carboniferous are limestones and gray to black shales, but farther south the Permo-Carboniferous beds of Oklahoma, Texas, and New Mexico are red. These beds lie above the Missourian of Missouri and Iowa which extend well up toward the top of the Pennsylvanian, as developed in Pennsylvania and West Virginia, certainly much higher than the first appearance of red beds in the Conemaugh of those States."

"As the uplift affected regions farther and farther to the west, the climate altered progressively in the same direction, and the resultant changes in physiography, hydrography, and vegetation compelled an alteration of the environment which permitted the migration of the Permo-Carboniferous amphibian-reptilian fauna with but little morphological change." . . .<sup>21</sup>

There are three phases of this postulate, the first two of which have been treated, to be discussed: First is the development of invertebrate, vertebrate, and plant life during the Pennsylvanian and early Permian;

<sup>21</sup> Carnegie Institution of Washington, Publication 207, 1915.

the second is the correlation of the Appalachian and the Kansas-Texas sections; the third is the evidence of climatic change during the time concerned, and possible migrations of vertebrates and plants.

#### AGE OF THE APPALACHIAN AND THE WESTERN RED BEDS

If the facts thus far presented warrant the correlations made between the Appalachians and the western interior regions, it will be a simple matter to determine the relative age of the red beds of the two regions.

In the Appalachian region the oldest Pennsylvanian red beds are found a short distance below the Ames limestone, in the Conemaugh formation of West Virginia, Ohio, and Pennsylvania, and are known as the "Pittsburgh red shales" in the West Virginia Survey Reports. Lately this name has been replaced by the term Round Knob formation, since the term Pittsburgh was preoccupied for another formation, the Pittsburgh coal. It is in this formation that the vertebrates were discovered by Raymond and I. C. White. Regarding its thickness and vertical extent in Ohio Condit writes:

"The beds vary from structureless, purplish red clay to deep red, even-bedded shale, which may alternate with bluish layers. The more sandy portions frequently show ripple-marks and sun cracks."

"In the southern part of the State, where the Ames limestone is generally thin or wanting, the Round Knob red beds are continuous, with similar strata above the Ames horizon for many feet, and locally even reach nearly to the Pittsburgh horizon" [top of the Conemaugh].<sup>22</sup>

From this it is plain that nearly the whole upper Conemaugh locally may be largely composed of red beds. The base of these beds is slightly below the middle of the formation, below which there are no true Pennsylvanian red beds.

In the various county reports of the West Virginia Geological Survey the detailed sections of the Conemaugh are given.

In some sections of the Dunkard in Pennsylvania the red beds seem locally to be nearly missing, while there are several beds present in other localities.<sup>23</sup>

These red beds are unknown below the Round Knob or "Pittsburgh Reds" horizon of the Conemaugh. In the region south of the outcrop of the present Conemaugh formation nearly or quite all of the upper Conemaugh and perhaps much of its lower part would probably have been red had not these rocks been removed by erosion; so that it is impossible to

<sup>22</sup> Condit: Ohio Geol. Survey, Bull. 17, p. 36, 1912.

<sup>23</sup> Data from West Virginia Geological Survey reports.

determine the position of what may have been the oldest red beds of the Appalachian region.

Turning now to the western section, we find the clearest record of the oldest red beds in Oklahoma, especially north of Arbuckle Mountains. On approaching Oklahoma and the Arbuckle Mountains from well up in southern Kansas, the strata are seen to become red as one goes south along the outcrops, and soon the stratigraphic level of the red beds grows lower and lower until Pottawatomie and Seminole counties are reached. The details and general principles of this color change and accompanying lithological facies of the deposits has been discussed by Gould in Water Supply Paper 148, and by Snider<sup>24</sup> and Beede,<sup>25</sup> and will not be repeated here.

Fritz Aurin prepared a paper on the Red Beds of Oklahoma,<sup>26</sup> in which he published a lithobathic map of the Oklahoma red beds showing their thickness by contours. In this article he discusses the depth to which the red beds are found in the Pennsylvanian rocks, and states:

"The red Pennsylvanian is a term applied to an undifferentiated series of sandstones and shales, predominantly red in color and very similar to the Permian red beds, occupying an interval between the non-red Pennsylvanian and the Neva limestone or equivalent horizon. . . .

"The red Pennsylvanian and Seminole conglomerate in a section across the northern part of Pottawatomie and Seminole counties is the approximate equivalent of the following named formations: Ladore shales, Mound valley limestone, Galesburg shale, Dennis limestone, Cherryvale shales, Drum limestone, Chanute shales, Iola limestone, Lane shales, Allen limestone, Vilas shales, Stanton limestone, Le Roy shales, Kickapoo limestone, Lawrence shales, Oread limestone, Kanwaka shales, Lecompton limestone, Tecumseh shales, Deer Creek limestone, Calhoun shales, Topeka limestone, Severy shales, Howard limestone, Scranton shales, Burlingame limestone, Willard shales, Emporia limestone, Admire shales, Americus limestone, and Elmdale formation. The thickness of the red Pennsylvanian and Seminole section is approximately 800 feet, while that of the equivalent Kansas section is 1,800 feet."

From this it is evident that the red beds began in the region north of the Arbuckle Mountains as early as the Bethany Falls limestone, or very near the base of the Missourian, which is fully as low, if not lower, stratigraphically than the base of the Round Knob formation of West Virginia and Ohio.

The similar transition of beds of sands and shales into red sediments in Texas is given by Gordón as follows:

<sup>24</sup> L. C. Snider: Bull. Okla. Geol. Survey, 1913, p. 11.

<sup>25</sup> Bull. Okla. Geol. Survey, 1914, p. 21.

<sup>26</sup> Bull. No. 30, Okla. Geol. Survey, 1917. Quotation from p. 23.

"A feature of importance in the Cisco formation, and one which it shares with the next formation, is the series of changes observed as the formation is traced northward along the strike. These changes relate both to changes in lithologic character and to thickness of beds. In the Colorado Valley, interstratified with sandstones, clays, and conglomerates, are six or more beds of limestone, each from 5 to 25 feet thick and all aggregating a thickness of 100 to 150 feet. In the southern part of the Brazos Valley the calcareous divisions are only about half as thick as they are farther south, and clays show a corresponding increase in thickness. In Young County the calcareous material diminished in thickness northward at an increased rate until, at the northern boundary of the county, the limestones have practically disappeared, and beyond that point they are represented apparently by irregular nodular masses of earthy limestone in a matrix of clay. With the thinning out of the limestones, the shales and sandstones increase in thickness. In Stephens County and farther south the shales are prevailingly blue and the sandstones gray. Red beds are dispersed sparingly through the formation. The blues gradually give place to reds until in the vicinity of Red River the red color dominates. In this part of the region the rocks consist, for the most part, of red sandstones, clays, and sandy shales, with a few beds of blue shale and bluish to grayish white sandstones. Limestones are conspicuously absent."<sup>27</sup>

The data here briefly summarized clearly show that the red sediments set in quite as early in the Arbuckle Mountain region, or north and south of it, as they did in the Appalachian region. Indeed, were all the Appalachian red beds still intact, there would be little reason to doubt that they would be found to be practically equivalent in age with the lowest of the red beds of the Pottawatomie-Seminole region and similar regions south of the Arbuckle Mountains.

For this reason it is apparent that it is unnecessary to postulate a different climate for the Appalachian region than that which existed in the western interior region.

Nevertheless, the fact that the red beds are as old in the western interior region as in the Appalachian Plateau does not explain the peculiar distribution of the vertebrates under consideration—that is, that the younger forms occur in the western region, while the older forms are known only from the region east of the Mississippi River. There are two factors bearing on this point that need to be discussed, neither of which is necessarily conclusive in itself, but between them they appear to include the probabilities of the case.

First. In the basal Permian, White, as quoted above, has shown that *Walchia* and some other plants are present in the western province while wanting in the eastern. This would imply that at the inauguration of the basal Permian the Appalachian region was isolated from the western region in such a manner as to prevent the intermigration of the plants.

<sup>27</sup> C. H. Gordon: U. S. Geol. Survey, Water Supply Paper 317, 1913, p. 18.



If this is true, it would likewise prevent the migration of the vertebrates which may have originated in the eastern province.

But to have prevented previous migrations it must be assumed that the regions were permanently separated by a water barrier from the late Pottsville to the upper part of the Wabaunsee stage, or about middle Monongahela time. This assumption is too sweeping to have much weight until further data are at hand on which to base it. A consideration which makes this proposition still more doubtful is the fact that species of plants of this interval are common to both regions.<sup>28</sup>

Second. The alternate suggestion is that they existed contemporaneously in both regions, but as yet are known only from the eastern one, where detailed study of the formations has gone on for many years. There are three reasons why this supposition may be correct:

A. These forms would only be preserved under very special conditions and in isolated localities, and as a result relatively few of these forms were preserved, allowing only rare chance of being exposed at the present time, as is demonstrated by the extremely few vertebrate-bearing localities now known east of the Mississippi River, where the rocks have been more intensely studied. Therefore they may be present and not exposed in the western interior region.

B. They may well be present in formations in the west which are now exposed and have not been discovered. So far as known, no search for them has been made in the oldest red beds of Pottawatomie and Seminole counties. In this connection it should be mentioned that exposures in the red beds of the Wichita and Clear Fork stages are vastly more favorable for finding fossils than are more thoroughly vegetation-covered regions farther east, in the lower formations of Texas and Oklahoma.

C. The remains of an amphibian and a reptile were found in the Wabaunsee formation of Kansas, probably at about the level of the middle Monongahela stage of Pennsylvania and West Virginia. It is the writer's opinion that when the outcrops of the rocks have all been thoroughly searched for fossil air-breathing vertebrates, they will be found in western beds which are nearly as old as those from which they are known east of the Mississippi River.

#### CONCLUSIONS

1. It seems that the correlation of the eastern and western interior regions based on evidence of fossil animals and plants is well established. It is about as harmonious as might be expected from these two types of evidence.

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<sup>28</sup> D. White: U. S. Geol. Survey Bull. 211, 1903, pp. 110-115.

2. The horizon of the Ames limestone is probably no higher than the top of the Oread limestone, and the top of the Conemaugh is at least as low as the top of the Shawnee stage, and that the Neva limestone is as high as the base of the Dunkard formation.

3. That marked changes in the fauna set in at the base of the Schwagerina horizon (Neva limestone).

4. In the formation below the Schwagerina horizon (Elmdale) only transition plants are known which go over into the Permian of Europe and America.

5. In the first known plant horizon above the base of the Schwagerina horizon (in the Wrexford limestone) the flora has a decided Permian aspect.

6. The vertebrate faunas older than the Schwagerina horizon are strongly Amphibian in character.

7. That the known vertebrate faunas above this horizon are strongly reptilian in character and they are even highly specialized.

8. The oldest known red beds of the Appalachian and western interior regions are almost equivalent in age, the latter apparently quite as old as the former.

9. The climatic conditions were essentially the same in both regions throughout Pennsylvanian time.