Memoirs of the Museum of Comparative Zoölogy
AT HARVARD COLLEGE.
Vol. XVI. Nos. 1 and 2.

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## OR BALD CYPRESS.

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# ON THE ORIGINAL CONNECTION OF THE EASTERN AND WESTERN COAL-FIELDS OF THE OHIO VALLEY.

By N. S. SHALER.

PUBLISHED BY PERMISSION OF N. S. SHALER AND J. R. PROCTOR,
DIRECTORS OF THE KENTUCKY GEOLOGICAL SURVEY.

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Every fact that serves to show a relation between the circumstances that surround an animal or plant and its peculiarities of structure has a certain importance to naturalists. It may aid in the solution of the great problems they now have in hand. I therefore venture to make a record of certain facts concerning the habits of the swamp cypress (*Taxodium distichium*) of our Southern States which seem to me to be important. The observations have been made at various times during the last ten years, but principally in connection with the work of the Kentucky Geological Survey, in the district west of the Cumberland river.

It requires but little attention to this species to make it plain that it is subject to great changes of conditions, arising from the peculiar character of the soil in which it lives. The condition of the low lands where it finds its station may bring it into any one of several widely divergent conditions of soil, with very slight variations of position. I wish to trace the effects of these changes of condition upon the peculiar projections from the roots, which are commonly known as knees. These excrescences of the roots have received so little attention from naturalists that it will be necessary to premise an account of their variations by some statement concerning their nature.

Along the main roots of the Taxodium, as it exists in the swamps, we have a series of projections which at first appear as slight tuberosities on the upper side of the root. These projections are formed somewhat irregularly, but they frequently occur at intervals of no more than two or three inches along the crest of the root. The result of these frequent excrescences is that the root is vertically flattened, presenting in transverse section an elliptical shape, the vertical axis being double or treble the length of the horizontal axis. Certain of these tubercles grow more rapidly than the others, and present a curiously dentate appearance; so that the root, seen transverse to the length, reminds one of the jaw of a saurian reptile. This likeness is enhanced by the fact that the projections are at first sharply conical and slightly bent back towards the main stem of the tree. The young knees grow very rapidly until they lift themselves to the height of from two to ten feet, and are well above the level of the swamp waters; they then increase in diameter, while they cease to grow in height. Their tops lose their conical shape, and become knotty, or carunculated. During the process of growth, the summits of these knees are exceedingly bud-like and vascular, always presenting a considerable surface of fresh bark. The rupturing of the outer bark layers, as the growth goes on, serves to give the bulbous top of the knee the look of an opening bud. The gnarled and knotty growth of the old knees, which have ceased to increase in height, serves also to expose the fresh inner bark over considerable surfaces of the carunculated head that crowns the knee.

The height of these knees vâries a great deal with the different positions occupied by the trees that bear them. Generally they do not rise more than two or three feet above the level of the main root; but at times they rise to four or even ten feet above its level. Observation has led me to believe that the height of the knees is in good part determined by the average height of the waters in the swamp, the knees endeavoring to attain a level which will bring their more vascular parts above the surface of the water as it stands in the season of most active growth of the tree, which occurs between April and July. If we take any swamp area occupied by these trees, and examine carefully the development of the cypress in its various parts, we shall see the evidence bearing on this point. In the first place, we shall find the cypress on the higher grounds, near the edges of the swamp, which are not overflowed save in the winter season, growing with fair luxuriance, but quite without knees. The small tubercles along the roots may be visible on close inspection, but they do not rise above the bed of leaf mould. As we go into the wetter parts of the swamp, these knees begin to appear; but it is only when the water stands a good part of the year about the roots that they become a striking feature. The deeper we penetrate into the swamp, the higher the knees rise above the surface of permanent water, and the more abundant they are about the trees. In all cases the top of the knees, when their upward growth is complete, rises above the level of the ordinary spring and summer flooding of the swamps. One other fact is needed to complete the chain of evidence. Whenever the level of the swamp water is raised above the top of their knees, the trees die. A very conspicuous instance of this is afforded by the extensive tracts of land which were flooded by the subsidences that accompanied the earthquakes of 1811. Whenever this sinking brought the tops of the cypress knees below the level of the permanent water, the trees all died. The great areas of Reelfoot and the adjacent lakes are still covered by the stately columns of these trees which were killed in this way two thirds of a century ago, and their submerged knees are still traceable, so that there cannot be any doubt of their position; yet other specimens, in which the knees were nearly buried, still survive.

In various mill-ponds in this district, where artificial flooding of the swamps has brought the permanent level of the water above the top of the knees, the trees have speedily died. This connection between the flooding of the knees and the death of the trees to which they belong is well recognized by the people of the country. They do not hesitate to determine the height of the summer waters by the altitude of the crests of the knees.

It seems to me that these facts, — viz., the failure of the knees to develop when the trees grow on high ground; the development of the knees when the roots are in permanent water; the rise of the knees above the permanent water level, and to a height varying with that level; and finally, the destruction of the trees whenever the level of permanent water rises above the top of the knees, — incontestably show that there is some necessary connection between them and the functions of the roots when the latter are permanently submerged.

It is not unreasonable to conjecture that this function of the knees is in some way connected with the process of aeration of the sap. It is a well known fact that the roots of most plants are intolerant of continuous immersion in water. It seems likely, therefore, that some process connected with the exposure of the sap to the air takes place in these protuberances. This hypothesis is supported by the fact that the knees remain quite vascular, and that the process of their growth assures the constant exposure of considerable surfaces of newly formed bark on the upper part of the knee, a circumstance that would favor the aeration of the sap. The woody part of the knee is also very soft and spongy, differing very much from the ordinary wood of the tree.

It is clear that we have in this tree a singularly variable accommodation to the changeable conditions it encounters in its different stations; and the readiness with which the variations are brought about must remain a matter of surprise to any one who knows the small amount of flexibility in this respect shown by most of our forest trees. I do not know of another case among them where the variations arising from the change of position of the trees occur with the immediateness and distinctness that they do here. In the chestnut-oak, for instance, the bark of the swamp variety becomes smoother and thinner, and contains less tannin, than in the highland forms; but the changes are relatively slight and quite irregular, never presenting the close relation to the conditions of environment that is given in the case of the cypress knees. It has been shown also, by the researches of Mr. DeFriese, assistant in charge of the timber studies made by the Survey, that the hemlock is never found in Kentucky on any other soils except those produced by the decay of sandstones and conglomerates, or more than a few hundred feet from running water, which serves probably to give a certain dampness to the air; but narrowly limited as this species is, it does not give anything like the clear proof of the immediate effect of conditions on the characters of an organic form that is afforded by the swamp cypress. It is doubtful if, in all our American forest trees, another instance can be found where a slight change of surroundings can bring about such important modifications of the conditions of life as in the case of the cypress.

These processes termed knees evidently serve very much to extend the area over which the tree can maintain itself. There can be little doubt that by it the tree has gained access to at least thirty thousand square miles of area in the southern part of the United States, from which it would otherwise have been debarred.

I have been unable to find any account of other species of trees having such knee-like processes. Several species of our ordinary timber trees are apt to make nodulose projections from their main roots; and when they grow in swampy ground are apt to keep their roots rather near the surface; but none of them have developed such specialized structures as are found in the Taxodium, and none of them have anything like the power of adapting themselves to such varied conditions of humidity. So far as is known to me, the Taxodium is the only tree that is able to occupy positions varying from very wet swamps to rather dry uplands. It is not too much to say that its range of station, so far as actual conditions go, is about double that of any other forest-tree belonging to the North American flora.

It is a well known fact that the ancestors of our Taxodium can be clearly traced back to the time of the miocene tertiary. At that time a closely related species was living in Greenland, and its kindred have been traced in Northern Europe and elsewhere; so that this genus has long been a tenant of this continent. Among these ancient cypresses there are some, particularly Taxodium dubium Sternb. sp., which are very nearly related to our existing forms; like it, they seem to have been tenants of swamps, as is sufficiently proven by the fact that their leaves and delicate extreme branches are found in the coal beds of the miocene time. It seems probable that the American varieties have descended from some one of these ancient forms—most likely from T. dubium. Further back, in the Carboniferous flora, we find a number of conifers, from some one of which this genus may be descended. I have been unable to find any evidence of the existence of these knees in the recorded observations of those who have studied the ancient species of Taxodium. Though this failure to observe them in the fossil form may not be taken as evidence that the knees are of modern origin, it certainly suggests the interesting question whether this may be the case, and makes it very desirable that the observers who may hereafter encounter fossil species of this genus should endeavor to determine the presence or absence of these processes. The fact that the ancient species were swamp-dwellers makes it likely that the knees were present.

From the existing distribution of this tree, it seems to me that it has probably been driven from an association, on the elevated lands, with the other trees of the forests in the Mississippi Valley, and has found a refuge in the swamps; and that but for this special adaptation to different conditions afforded it by the knees, it would have been altogether driven out by the deciduous vegetation of the country where it is found. It is clear that this last remnant of a great lineage of forest trees is no longer able to maintain itself in the contest with forms with which it, in miocene days, associated on something nearer equality. Although its seeds are borne in vast quantities on to the elevated ground that borders the swamps, we never find it in the woods where it would have had to struggle with the other trees. This arises from no incapacity to live and flourish upon the soils of the uplands, for I know many very flourishing trees growing in a variety of open grounds in gardens and lawns in various parts of Kentucky. In many gardens and arboretums in Europe it has proven a hardy and rapid growing tree. Its rate of growth on the elevated terrace deposits at Frankfort, Kentucky, has been much more rapid than the average of our forest trees. Trees fifty years old have there attained a height of sixty feet and a diameter of eighteen inches. We must ascribe its incapacity to maintain itself in the existing forests of the Mississippi Valley to some unknown influence of the other trees upon its functions.

In the miocene and pliocene times this genus was one of the most wide-ranging of all the forest-trees. Oswald Heer cites it from Switzerland, Germany, Austria, France, Italy, Spitzbergen, Siberia, Kamtschatka, and the Alutian Islands.* The circumstances in which we find its remains in these ancient formations are such as to make us suspect that it shared the ground with many forms with which it no longer willingly grows. In eocene and pliocene times it seems to have mingled its leaves in the forest beds with the ancestors of our poplars, beeches, walnuts, oaks, persimmons, &c., &c. To-day we find none of the species of these genera growing in the same localities where the Taxodium flourishes. It may be suggested that the fossil remains we find are those of species that did not occupy the same stations, but were brought together by floods in their common burial places. I do not think that this hypothesis explains their association. The deposits now making in our cypress swamps do not contain such minglings of the leaves of a wide area as we find indicated in the fossils of the Greenland miocene beds. If they were fossilized, we should not find, as explorers have found in the Greenland beds, the entire leaves of beeches, persimmons, and half a dozen other forms that now belong on higher ground, mingled with twigs and leaves of the Taxodium in the same square yard of space.

It seems to me that we are led by these facts to the conclusion that the association between the ancestral Taxodium and those of the other forest trees whose descendants now occupy the uplands alone, was once much more intimate than it is at present. This intimacy of association may have been brought about by the less definite limitation to particular stations of the trees that made up our ancient forests, or by the greater range of the Taxodium in the olden days. As experience goes to show that the Taxodium will still live and flourish on a great range of soils, and that it does not require access to moisture more than most of our forest trees, while there is good reason to believe that the other forest trees are much less tolerant of swamp conditions, I am disposed to think that the greater part, at least, of the change of habits has been in the cypress itself; that it has gradually

* Flora Fossiles Arctica: Zurich, 1868, p. 12.

given up its wider place in the forests, and limited itself to the swamp areas, where it has no struggle to maintain with other trees. It may be remarked that the limiting of the Taxodium to a narrow station, if such a limitation has occurred, would find its parallel in the conditions of many of our other coniferous trees. The white pine (*Pinus mitis*) in Kentucky is circumscribed within very narrow boundaries, and only maintains itself at a disadvantage against the vigorous deciduous woods. The same may be said of the hemlock, which is limited to stations that are really unsought by our other trees. The western part of the United States affords an even more remarkable example of the narrow limitation of a tree that once was very widely distributed. The Sequoia gigantea is a noble representative of a long lineage of trees that once ranged throughout the Northern Hemisphere, and now is limited to a very small area on the Pacific coast. It seems certain that in Kentucky the conifers are fighting at a disadvantage against the deciduous trees, which are gaining upon their ground; and it seems not unlikely that the conifers, as a whole, are losing ground and giving place to the more varied and more plastic deciduous forests. Loss of adaptation to varied conditions is a common phenomenon in all organisms of which we have an extended geological history.

A similar narrowing down of the field occupied by the form is seen also in the somewhat kindred conifer, the sequoia, and in a less degree in many of the old associates of the Taxodium in Europe and Asia. Yet this limitation to a narrow geographical range is not quite parallel to the peculiar exclusion of the Taxodium from the upland forests of the continent. I am unable to point to any source of weakness that is the basis of this restriction. The cypress is a very rapid grower even on the uplands. It easily overtops and makes head against the timber on the edge of the swamp whenever a chance specimen may secure a foothold. The seeds are plentiful and easily grown, the young trees appearing vigorous from the beginning of their growth.

There is yet another problem connected with the conditions of the Taxodium that is worthy of note. The trees are often found growing from the center of permanent pools of water, where it is hard to suppose that they could have originated save from seeds. I have not been able to find that they ever spring from the roots of other trees. A careful search of many specimens has not shown the trace of root-budding, and many other observers have failed to find any case of this kind. It is very hard to imagine any coniferous seed sprouting at the depth of a foot or more below the surface of water, and growing until it lifts itself above the water surface. It seems to me that the hypothesis that they spring from root buds is highly improbable, for I have several times found young and thrifty specimens growing up from permanent water at the distance of several hundred yards from any other tree of the species. I am told that the tree may be readily propagated from twigs, provided they are of the new wood, and are immersed in water or soft mud, and are kept in the shade. Such twigs are often broken from the branches of the trees by the wind, aided perhaps by the collision of boughs against each other in high winds. The extreme branches are much more brittle than those of any of our other conifers known to me; and this, together with the readiness with which they root, makes a special method of propagation peculiarly suited to the conditions of growth under which the species live. I am not aware that the power of sending out roots from twigs exists in our other conifers. I am inclined to believe that the planting of these trees in water too deep for the germination of seeds is generally brought about through the fallen branches rather than by means of seeds or buds from the roots.

## PRESENT DISTRIBUTION OF THE TAXODIUM DISTICHIUM.

As this species is the last remnant of what was once a very cosmopolitan genus, it is worth our while to consider its present limitations of the form. I shall therefore give a brief synopsis of the present limits of the species as far as I have been able to ascertain them.

Although singularly limited in its station, the swamp cypress nevertheless endures a wider range of climate than many of our forest trees that occupy a great range of soils and of exposures. The northernmost point where it now exists is central New Jersey. In this district it is apparently in its decadence—the individuals few and much smaller than those which lie buried in the swamps of that district. Its northern limit in this district does not seem to depend upon its endurance of cold, as it is not killed by much lower temperatures than it finds in the swamps of New Jersey. No trace of this species has ever been found in the ancient swamps that are so frequently excavated in New England, although they are said to be abundant in New Jersey. This leads us to the conclusion, that since the last glacial period it has never extended farther north along this shore than the last-named district.

Southward from New Jersey we find it sparsely distributed until we come to the district south of the James river. Here we enter upon extensive forests of this tree, and it appears afterwards at any point affording favorable conditions for its growth along the whole Atlantic coast.

In Virginia it does not occur much beyond the limits of the swamps that lie within a height of fifty feet above tide-water. The swampy borders of the inland streams are not occupied by it. In this region it struggles very little beyond the limits of the shore swamps.

In the Carolinas its westerly extension somewhat increases, yet its limitation to the region within about one hundred feet above tide-water remains a marked feature.

In Georgia the limits of the species are again forced nearer to the sea by the greater general height of the surface of the country.

In Florida the species is said to be common throughout the length and breadth of the peninsula.

In Alabama and Mississippi the cypress follows all the stream borders much farther into the uplands than on the Atlantic slope. It is common in all the swamps in those States.

In Tennessee the species is limited to the district west of the Tennessee river, and to the borders of that stream in the lower part of its course. I have been unable to find that it extends above the level of the Muscle Shoals.

In Kentucky the limitation of this species is even narrower than in Tennessee. It is not common except in the district west of the Tennessee river. It is rarely found on the Ohio river above the mouth of the Cumberland. On the Tennessee and the Cumberland rivers it is found in the swamps near those streams to the State line or a little beyond. On the Green river it is occasionally found, but I have never seen it in the shape of connected forests. East of the Green it is unknown to me, and on that stream it does not extend above the junction of the Barren river.

North of the Ohio the cypress occurs in the swamps of southern Illinois and southwestern Indiana; but its northward extension along the rivers of those States seems to be very limited, though I have no means of tracing it in detail.

Along the main Mississippi it does not extend much above the junction of the Ohio.

West of the Mississippi the extension of this species is much more limited than on the eastern side of the river.

I have no knowledge of the species on the Missouri river, or any part of Missouri, except near the Mississippi.

The whole of the swamp districts of Arkansas, Louisiana, and Texas afford it congenial stations; and it probably occupies larger areas in those States than in any others.

Beyond the limits of the United States its extension is difficult to determine. It is not found in the West India Islands, and I have no information of its occurrence along the Mexican shore.

The economic uses of the timber are as yet limited. The larger knees are occasionally taken for well-buckets. When of the fullest growth they are hollow, their cavities being large enough to contain a gallon or two of water. They are also occasionally used as bee-hives, though they are generally much too small to serve this purpose.

The tree itself has long been used for the purposes to which the other coarser coniferous woods are applied. The wood is easily worked, and though rather brittle, is used for clapboards and other house-building purposes. It is fairly enduring both above and below the ground level. As yet but little of it has found a market save in the rural districts of the Lower Mississippi. With the progressive destruction of our forests, and the consequent increasing scarcity of coniferous woods, the resources offered by this species will doubtless be largely drawn upon. The supply offered by this tree bids fair to remain important for many years. It now exists on not far from thirty thousand miles of surface within the United States. At almost all points within the areas where it is found it grows with rapidity and to great size, and it is more generally accessible to water transportation than any other timber tree. The ground it occupies is usually irreclaimable, or of difficult subjugation. There is, therefore, no better nursery for timber than these swamps. If, as is likely, the artificial planting of these trees can be easily managed, there can be no doubt of the profitableness of their culture. Lands suitable for such purpose can be bought for a few cents per acre. Much of it is still Government land that can be acquired under the law regulating the sale of swamp lands. Besides the advantage of cheap lands and easy transportation, these forests have a perfect security from the devastations of fire, which are so serious a hindrance to the profitable cultivation of most of our economic woods, especially the conifers. It needs no argument to show that a cypress swamp is perfectly secure from this danger. I do not believe that in our ordinary swamps the trees could be placed nearly as close together as the trees in a pine woods.

All our cypress swamps commonly have a good deal of their surface occupied by pools and sloughs, where the water is too deep for the trees, or by hummocks, where the land is too high to afford the best stations for this species. I am inclined to believe, however, that it can be safely estimated that the trees may be planted twenty feet apart, or about one hundred to the acre, and that they will, in twenty years, attain a size at which they begin to be merchantable. The tree is probably adult at sixty years, attaining then an average diameter of about three feet, and a height of about ninety, although it continues to grow until, in favorable positions, it attains a height of one hundred and fifty feet, and a diameter of seven feet or more. With the increased height, it rapidly becomes of less merchantable quality. I am satisfied that the trees may be grown to the full size that utility requires at no greater distances than forty feet apart, or about twenty trees to the acre. The spaces between may be occupied by the younger trees, for the young cypress is tolerant of the densest shade.

It seems to me not unreasonable to estimate that an area of planted cypress would yield not less than one adult tree annually to each two acres of surface, besides the immature trees removed in thinning; and that the economic value of the trees is likely to be as considerable as those of our white-pines. Including the young trees, I believe that our swamps, after twenty-five years of care in securing the planting of the cypress seeds, could easily be made to yield an average return of two dollars per acre; and if a large area were controlled by one management, the expense of planting and care would be very small.

There is a general belief that the cypress tree exercises a destructive influence on the malarious exhalations of the swamps where it plentifully abounds. By the peculiar impenetrability of its shade, which is far denser than that made by any other of our American trees known to me, it greatly diminishes the evaporation of the swamps where it abounds, and thereby serves to keep the waters of the morass nearer the same level throughout the warm season. Where they grow very thickly their knees, their plentiful and slowly decaying leaves, and the falling débris of bark and limbs, make a sponge that retains the water throughout the year, so that decay takes place very slowly, and a thin peaty mass is formed. It is a well known fact that peaty swamps, owing to the absence of decay or to the antiseptic vegetable acids developed in such swamps, or to other causes, are rarely, to any great extent, malarious. The great peat swamps of the North are wholesome, while a new-drained pond may give ague germs in abundance. I am therefore disposed to think, that, as this cypress favors the formation of peaty matter in the swamps, its extensive planting would do much to diminish the malaria of those areas. Moreover, in common with all our coniferous trees, the cypress exhales a certain balsamic vapor that perhaps serves, to a certain extent, to better the quality of the air for man's use. This purifying power seems to extend to the roots as well; for while the water from an ordinary earthy swamp is unfit to drink, that from a cypress swamp is exceedingly potable, and is sought for use on ships, as it does not putrefy as seemingly purer waters do.

It may be too much to hope that the malarious nature of the swamp lands along the Western and Southern rivers may be, at least in part, taken away by the careful extension of this tree; but I am satisfied that it is the only American tree to which we can look for any considerable amelioration of the malarious conditions that now render extensive regions in the Mississippi Valley unfit for the occupation of man. None of the species of the Eucalyptus can be expected to flourish in the region north of Louisiana. I am disposed to doubt the great febrifugic power of this much talked of tree, and to question whether it does more than hinder the ground from becoming a good nidus for spores by keeping it permanently covered by a mass of leaves that are filled with gummy matters. Such deposits are probably prejudicial to the peculiar plants that produce the malarial spores, while, at the same time, they favor the retention of permanent moisture that also tends to prevent the production of malaria.

I have before this called attention to the fact that it is not the wetness of the swamp areas that favors the production of malaria, but the alternation of wetness and dryness with the changing seasons. Whatever operates to arrest, to any considerable degree, these changes of water level in the swamps will contribute, in the same proportion, to the diminution of the malaria generated there.

At present the course of events is leading to a considerable reduction in the number of cypress trees in our Western swamps. Although the business is manifestly in its beginning, there are some hundreds of thousands of cypress trees cut out of the swamps of the Mississippi Valley each year. As there is no replanting, the result is to give an advantage to the worthless and malaria-breeding cottonwoods, pin oaks, and other swamp trees, or to leave the swamp open to the festering heat of the sun in case these species cannot crowd into the places made vacant by the removal of the cypresses. The extension of this process will convert into unshaded pools a great many swamps that are now made comparatively wholesome by the deep shade that this tree secures to them.

# ON THE ORIGINAL CONNECTION

OF THE

# EASTERN AND WESTERN COAL-FIELDS

OF

# THE OHIO VALLEY.

By N. S. SHALER.

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Among all the debated matters concerning the development of American geography, perhaps none have been the subject of a more extended discussion than the question of the original relation of the several coal-fields of the carboniferous era that lie within the Valley of the Mississippi. On the one side it has been maintained that those areas were originally parts of one and the same field, owing their separation to the wasting they have received; on the other, that they were, from the beginning, distinctly separated areas, and have had their physical and vital problems as individualized as are those of widely separated seas.

It has been especially contended, and this with a great deal of vigor and effect, that the eastern and western basins of the Ohio Valley, commonly known as the Appalachian and the Illinois fields, were, at their time of formation, separated from each other by the ridge known as the Cincinnati axis.

A careful study of this problem in the State of Kentucky, where alone exists the data for its solution, has served to convince me that there is a considerable error involved in this generally accepted opinion, an error likely, if it continues unassailed, to confuse all our notions of the geological history of the continent. I shall therefore set forth in brief the nature of the evidence that has led me to the opinion that these coal areas, lying to the east and west of the Cincinnati anticlinal, were not only originally united into one area, but were actually connected down to a very recent time, in the geological sense of the word.

A reference to the geological map of Kentucky, published by the Survey, will show that these two fields have now their nearest escarpments within less than eighty miles of each other. It will also show that there are many over-outliers, which are clearly relics of a once continuous field, which diminish the gap between these coal basins, so that at one point it is not over forty miles between the outlying remnants of either field. Standing upon the heights of either escarpment, the eye ranges over the intervening country to the outliers on the other side. A little observation shows us that if we but protract the plane given us by the upper surface of the two fields across the intervening space, we would replace the beds in the gap that separates them. This suggestion of original continuity that is made to the eye on simple inspection, is abundantly borne out by other evidence, which I will now proceed to consider, taking up the several series of facts in the following order:

1st. The physical evidences of a continuous sea or swamp over the whole of Kentucky at the several stages of the carboniferous period.

2d. The vital evidences of a similar unity of the physical conditions at the before mentioned time.

3d. The evidences of the amount of wear to which this district has been subjected since its last continued depression below the level of the sea.

The evidences of a physical nature going to prove the former existence of any particular series of deposits in any area where they are no longer found, may differ very much in different conditions, but are in the main limited to two classes of facts. In the first place, we may have the débris of ancient deposits lying in variously distributed ruins in the region where the beds they represent have long since been destroyed; in the second place, we may have a given district showing by its topography, inherited from a more ancient time, that it has had its drainage system formed in beds other than those which now cover its surface.

Searching over the district that lies between the ragged borders of the eastern and western coal-fields, I have found at many points the most unquestionable indications of ruined carboniferous beds. In the very centre of the Muldraugh-hill escarpment of the Subcarboniferous series, the beds of lower St. Louis limestone are covered by the waste of a conglomerate that is no longer in place. This waste consists not only of a great quantity of detached pebbles of quartz, but also of considerable slabs of a coarse ferruginous sandstone with like quartz pebbles, the slabs with their angles unrounded, and evidently not transported by water. This waste, occurring upon the high summits and not upon the lowlands, puts it beyond a doubt that it is the waste of a conglomerate that once capped these hills. The character of this conglomerate is quite unmistakable; no one familiar with the geology of this district can doubt that it is from the Subcarboniferous conglomerates, the millstone grits of many geologists. The lower lying rocks of our Kentucky series are so well known as to make it quite impossible to suppose that there is any other conglomerate for which this could be mistaken. At certain points traces of vegetable impressions may also be found in these deposits. They are very indistinct, but quite resemble the impressions so common in some parts of the conglomerate series, both in the eastern and the western fields. Associated with this débris, when found along the Muldraugh-hill district, we have a quantity of the waste from the St. Louis limestone, the uppermost purely calcareous member of our Subcarboniferous limestone series. This association is strongly confirmatory of the idea that this conglomerate is that of the coal period.

The whole of the Green river basin in the counties of Adair, Green, Metcalfe, and parts of others, has its hill-tops covered by the beds of the Warsaw division of the St. Louis group. From this level to the base of the coal-bearing series, where that is left in the region, to the east of this district, is not over one hundred and fifty feet. In the district to the west, the thickness of the St. Louis is greater, being about two hundred and fifty feet on the average. Above the St. Louis the Chester sandstone, which is the transition series from the deep sea limestones below to the land beds above, is perhaps about one hundred feet thick. In its upper part we have some thin coal seams, one of which is about eight inches thick, and is found over an extensive section in the western coal-fields; so we are safe in asserting that there is only required to be restored to this district of the upper Green river a total thickness of from two hundred to two hundred and fifty feet to return the carboniferous horizon to it. Is it likely that this thickness of deposits has disappeared from this region? It seems to me that we are forced to give an affirmative answer to this question. It needs but a glance at the conditions of this district to make it clear that it is wearing down with great rapidity compared with other parts of the Mississippi Valley. We know, from the labors of Humphreys and Abbott, that the erosion of the Mississippi Valley is now going on at the rate of one foot in seven thousand years. As this erosion is in the main proportionate to the amount of rainfall, it is doubtless about twice as great in this section of the Ohio Valley as it is over the whole Mississippi drainage system. I am satisfied that one foot in three thousand five hundred years is not too much to allow for the ablation of the surface of this region. At this rate the destruction of the three hundred feet of beds which I believe have been wasted from this district between the coal-fields since the conglomerate continued over the Cincinnati axis, would have required not far from one million of years. No geologist who has attentively considered the evidences of duration given us by many geological facts can doubt that far more than this time has elapsed since the beginning of the tertiary period. The best computations of the duration of time represented by that period, — those made by Mr. James Croll, — assign a duration of over four million years from the beginning of the eocene to the present day. It would require not more than half this time to take away a section which, if restored to this district, would give us the drainage surface within the beds above the level of the conglomerate. Without setting too much value on the estimates of the duration of the tertiary period, we are certainly safe in saying that the time that has elapsed since the close of the carboniferous period must much exceed five millions of years; yet this period, probably but a small part of the age that has elapsed since our coal-beds were laid down, is sufficient, at the present rate of erosion, to have taken away something like fifteen hundred feet of strata from this region. It is therefore necessary for us to suppose that the carboniferous strata originally extended over this region; or else we must arbitrarily, and without a trace of affirmative evidence, suppose that while the carboniferous series was not deposited in this region, the trias, the jurassic, or the cretaceous beds were laid down, and since their deposition utterly wasted away, leaving no débris to mark their former occurrence in these parts. One or the other of these suppositions is necessary. The geological reader can safely be left to choose between them.

While I regard the physical evidence of the original extension of the carboniferous deposits across the upper Green river district from the eastern to the western fields as practically complete, it is necessary to add that it cannot be inferred from this that the whole of the Cincinnati axis was so covered by the formations of the carboniferous series. As is evident from a mere inspection of the Cincinnati axis, the two extremities of the ridge are geologically much higher than the intervening district. The amount of the central deflection is several hundred feet, and it is through it that we have complete proof of the former connection of the two coal-fields by a coal-bearing belt of not less than fifty miles in width. The question of the former extension of the coal over the Cincinnati and Nashville ends of the axis must remain, for the present, an open question. I will only assert here that there is much evidence to be found to support the affirmative side of this question. At various points in the great area of the exposed Cincinnati-group beds,—which I am disposed to term the Kentucky dome, from the fact that while a part of that area extends beyond that Commonwealth, its centre and the larger part of its area are within its borders,—we find the waste of a pebbly deposit such as cannot be referred to any other than the conglomerate of the coal series. At one point in the southern part of Campbell county, about eighteen miles south of Newport, I found in a valley elevated one hundred feet or more above the Licking river, and some miles from its present bed, in the alluvial deposit such as borders all our smaller streams, a quantity of fragments of bituminous and cannel coal. Although for years the neighboring farmers had gathered these fragments, there was no difficulty in finding a dozen pieces averaging five or six cubic inches in size from the low bluff along the small stream. They were fairly well preserved, owing their resistance to decay to the fact that they were coals of a somewhat dense nature, and were bedded in a rather impervious clay. With them were occasional fossils of the Subcarboniferous horizons, and some pebbles of the millstone-grit age. I was at first disposed to refer these deposits to the action of the Licking river flowing at higher levels, but a careful search along the banks of this stream up to within a few miles of the edge of the coal-field has failed to bear out this idea; for fragments of coal are exceedingly rare in its alluvium, and where they occur they are very much rounded, while those in this high-lying alluvium in this small elevated valley are rather angular. At a point in Taylor's creek, just above Newport, there was exposed some fifteen years ago, in the stratified gravel-beds at about high-water mark of the Ohio, a thin bed of much comminuted bituminous coal, about one inch thick, and extending several yards along the freshly excavated bank. These beds lie near the mouth of a small stream the head waters of which are about fourteen miles north of the other above described locality of coal débris. I have reports of various similar localities in central Kentucky, showing a curious amount of coal waste over the Upper Cambrian or Siluro-cambrian area of the State.

On account of these peculiar patches of coal period débris in central Kentucky, I am now disposed to suggest that it is possible that a part at least of the coal series wrapped over the Kentucky dome, covering it with a thin coating of beds which have since been brought to utter ruin by the action of various agents. In order to avoid the charge of inconsistency that may be brought against my position on this point, I must endeavor to reconcile this view of the condition of the Cincinnati axis during the coal period with what I elsewhere held concerning the physical history of this important mountain fold. I have long been satisfied that the Cincinnati axis began to lift itself above the sea floor very early in the Upper Cambrian period. The fact that in the horizon of the calciferous sandstone we have an abundant supply of very saline brines, is of itself proof that at the time of this horizon there was, from time to time, an exposure of the deposits making on the old sea floors above the surface of the sea. Again, in the horizon of the Cincinnati group, we have a repetition of the evidence of shallow water or low-lying islands.

I am inclined to think that there can be no reasonable doubt as to the extreme antiquity of this axis. It is to be remembered, however, that the subsidence of the continent at various times in its history has been great enough to have entirely submerged this low axis beneath the sea. A sinking of the continent by twelve hundred feet would bring the ocean over the top of this axis, though it might not have any distinct effect upon the altitude of the axis as determined by its other relations. There can be little doubt that during the formation of the Black, or, as I have termed it in the Kentucky reports, the *Ohio Shale*, the whole of this Cincinnati axis was deeply buried beneath the sea. The entire absence of pebble beds in the deposits of the Waverly and higher Subcarboniferous beds is an equally strong argument against the exposure of this axis during the time when they were being laid down. Nor in the time of the millstone grit, when pebbles were swept by strong currents in a lifeless sea from the mountains of Carolina, and possibly from the Laurentian Hills as well, far and wide over our ocean floors, do we find a trace of the waste this axis would have given if it had been above the level of the sea. There is, therefore, no reason to look upon it as forming a natural barrier between the eastern and western districts of Kentucky in the times immediately anterior to the coal period. It is far more reasonable to suppose that while this axis was traced out in our rocks from an early age, it was not until after the close of the carboniferous period that it took on its present form, and became so dome-shaped in the region about Nashville and in the district of which Lexington is the centre and summit. This is clearly the view that is most reconcilable with the present conditions and the record of ancient conditions which is sent down to us in the physical record of the rocks.

The biological evidence which we may derive from the rocks about the Cincinnati axis does not favor the idea of its having been a barrier during any stage of the carboniferous time, from the base of the Waverley to the highest coal-bearing strata. The only level where we find evidence of its having been a distinct barrier is in the time between the upper Cincinnati beds and the base of the Black Shale. During this time, when the upper hundred feet of the Cincinnati series was depositing, and during the whole of the Niagara and Corniferous periods, the Cincinnati axis gives us evidences that it was a distinct ridge, rising to or above the surface of the sea; but from that time down to the last of our records of the ancient seas it appears to have been always merged in the uniform oceans or swamps of those days. The fossils of the subcarboniferous period do not, so far as I have been able to examine them, indicate shore-lines along this axis. It is true they differ on the two sides of its central line, but this difference seems to me to indicate the steady deepening of the sea from its eastward shore-line towards what is now the centre of the Mississippi Valley.

The conclusions which I believe we are forced to accept from the evidence the rocks afford may be briefly summed up as follows:

1st. That the Cincinnati axis was about the level of the sea during a part of the Hudson River, Medina, and Niagara epochs.

2d. That during the subsequent ages, down to and including the carboniferous series, the axis was probably of no importance as a physical or zoölogical barrier.

3d. That the coal-period swamps, and the seas into which they from time to time sank down to receive their burial in the drifting sands and muds, extended over the most if not the whole of this axis.

A study of the evidences of a former connection of the eastern and western coal basins in Kentucky affords us some data for estimating the former extension of these deposits in the other parts of the Ohio Valley.

It is clear that an erosion scarcely more considerable than that which has taken place in Kentucky would have sufficed to separate the basin of the Appalachian region from that of Michigan.

Allowing for an erosion rate of one foot in seven thousand years, which is now about the average of the Mississippi Valley, the loss of strata in a million of years would be about 150 feet. Assuming that this region has been subjected to erosion since the close of the carboniferous, and allowing only this low rate of decay to the rocks, at least fifteen hundred feet, and perhaps twice this amount, have gone off of the region which remains between the Appalachian and the Michigan field.

As this region north of the Ohio has been the seat of considerable glacial action, we cannot expect to find evidences of the former presence of the coal-measures such as we have noted in Kentucky. In Kentucky the glacial sheet did not affect more than a few hundred square miles of its area in the northern part of the State, so that nearly every hill-top retains some evidences of the deposits that have disappeared by erosion. No such relics of eroded strata can be looked for in any glaciated region.

Accepting fifteen hundred feet as the minimum of erosion that must have taken place in this district since the time of the coal-measures, it is clear that the larger part of the region east of the Mississippi, which now has beds below the carboniferous exposed at the surface, must have been at one time covered by the coal-measures. All the coal-fields from Iowa, Kansas, and Missouri must have been connected together and joined with the Appalachian coal-field.

Whoever will watch the process of erosion as it now goes on upon the carboniferous strata of this region, will easily see that the wearing away of these beds goes on more rapidly than it does in any other deposits of the Ohio Valley. This is shown on the topography of the district, which is marked by the very deep erosion of the smaller streams. The sandstones and shales above the conglomerate beds of the millstone grit are singularly incapable of resisting the action of running water. The streams that drain this district pour out torrents of sand in their times of flood. This sand being composed principally of quartz, is easily transported by flood, waters. The granular character which it gives the rocks of the country favors the absorption of water, which, under the action of frost, breaks up the beds with great rapidity. In the coal-measures there are none of those dolomitic limestones which, in the lower parts of the palæozoic beds, interpose such enduring resistance to the action of water. Accepting the determinations of the erosion rate given by the sediment carried by the Mississippi river, it seems to me reasonably certain that these carboniferous strata are now wearing down at the rate of one foot in about three thousand years, or about twice as fast as the average erosion of the valley in which they lie. On the supposition that only ten million years have elapsed since the erosion of this country began, there must have been something like three thousand feet of erosion upon the carboniferous section.

When we add to these considerations the fact that the present erosion rate is probably much less than it was during the greater rainfall of the glacial period; and further, that the time that has elapsed since the carboniferous period is in all probability twice as long as that we have estimated, — we see how great is the probability that the coal-measures once covered all the surface of the continent, from the western plains to the Atlantic, and north to the position of the great lakes.

There are several important conclusions which follow from this evidence of the former wider extension of the coal-measures. The most important of these is that the uplifting and down-sinking of the sea, or of the continent, which brought about the rapid changes in the nature of the deposits of the coal time, must have affected, not portions of the continent, but nearly the whole of its area. This much increases the difficulty of the problems brought us by the conditions of the carboniferous period. It is not possible to discuss them here; they will, however, be treated in the final report on the geology of Kentucky, which is now in preparation.