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THE TERTIARY LAKE-BASIN

AT

FLORISSANT, COLORADO.

BY

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THE TERTIARY LAKE BASIN AT FLORISSANT, COLO., BETWEEN SOUTH AND HAYDEN PARKS.*

[With a map.]

By SAMUEL H. SCUDDER.

The following remarks are based upon collections and notes made during a visit to Florissant, in the summer of 1877, in company with Messrs. Arthur Lakes, of Golden, Colo., and F. C. Bowditch, of Boston, Mass. As five days only were spent in the place, most of the time was given up to the collection and care of specimens, so that only a general survey of the locality was possible. Mr. Lakes especially gave himself to the study of the geology of the district, and as he was previously familiar with the structure of the surrounding country, and placed his notes at my disposal, the first part of this paper should be considered our joint production.

GEOLOGY.

The tertiary lake basin at Florissant, already famous for its prolific beds of plants and insects, is situated in a narrow valley high up in the mountains at the southern extremity of the Front Range of Colorado, at no great distance from Pike's Peak. The first, and, so far as I am aware, the only notice of it which has been published, is that by Mr. A. C. Peale, in his account of the geology of Hayden Park and the country lying between it and the upper cañon of the South Platte.† As it is brief, it is given here in full:

"The latter [Beaver Creek] flows to the northwest, and empties into the South Platte just below the upper cañon. About five miles from its mouth, around the settlement of Florissant, is an irregular basin filled with modern lake deposits. The entire basin is not more than five miles in diameter. The deposits extend up the branches of the creek, which all unite near Florissant. Between the branches are granite islands appearing above the beds, which themselves rest on the granite. Just below Florissant, on the north side of the road, are bluffs not over 50 feet in height, in which are good exposures of the various beds. The following section gives them from the top downward:

"1. Coarse conglomeritic sandstone.

"2. Fine-grained, soft, yellowish-white sandstone, with bands that are more or less argillaceous, and containing fragments and stems of leaves.

"3. Coarse gray and yellow sandstone.

"4. Chocolate-colored clay shales with fossil leaves. At the upper part these shales are black, and below pass into—

"5. Whitish clay shales.

"These last form the base of the hill. The beds are all horizontal.

*Reprinted with additions and alterations from the Bulletin of Survey, vol. vi, art. xi.

†Ann. Rep. U. S. Geol. Surv. Terr. 1873, p. 210. 8vo. Washington, 1874.

Scattered around are fragments of a trachyte, which probably caps the beds. In one of the valleys Mr. Taggart discovered, near an old well, pieces of trachyte, which, on looking at the excavation, was found to be the first layer penetrated. The point of overflow from which this material came is probably to the southward, in Dr. Endlich's district. The lake basin may possibly be one of a chain of lakes that extended southward. I had thought it possible that the beds were of Pliocene age. The specimens obtained from bed No. 4, of the section above, were submitted to Professor Lesquereux, who informs me that they are 'Upper Tertiary.' 'But I do not believe, as yet, that the specimens of the Green River group, to which your species are referable, authorize the conclusion of Pliocene age. I rather consider it, as yet, as Upper Miocene. The species known of our Upper Tertiary are as yet too few and represented in poor specimens for definitive conclusion. Your specimens have a *Myrica*, a *Cassia*, fragments of *Salix angusta* (A. Br.), a *Rhus*, an *Ulmus*, and a fragment of *Poa* or *Poacites*.'

"The shales were so soft and friable that it was rather difficult to obtain any specimens.

"About one mile south of Florissant, at the base of a small hill of sandstone, capped with conglomerate, are 20 or 30 stumps of silicified wood. This locality has been called 'Petrified Stumps' by the people in the vicinity. The specimens of wood are not particularly good."

This basin is shown on sheet 13 of the geological atlas of Colorado published by Dr. Hayden's survey, and its outlines are marked with considerable accuracy, although upon a comparatively small scale. The data upon which that sheet was constructed have formed the basis of the accompanying map, in which the limits of the basin are given with closer accuracy and in greater detail.* The point of greatest difference is in the valley of Fish Creek, where we noticed no extended prolongation of the lacustrine deposits; and as the contours of Dr. Hayden's parties themselves seem to forbid the probable extension of the deposits in this direction, we have closely limited them to what we saw.

The ancient lake lies in the valley of the present South Fork of Twin Creek, and of the upper half of the main stream of the same after the South Fork has joined it. Following the road from South Park to Colorado Springs, and leaving it just above Florissant Post Office,† and then taking the track—half road, half trail—which leads over the divide toward Cañon City, we shall pass between the Platte River and the Arkansas divide, through the entire length of the basin. This road crosses the South Platte a short distance, say a kilometer and a half, below the mouth of Twin Creek, climbs a long, gradual slope on the east bank of the river to an open, grassy glade, about 2,500 meters above the sea, and then descends a little more than three kilometers from the river to join the valley of Twin Creek. We scarcely begin the descent before our attention is attracted by the outcropping of drab-colored shales, which continue until almost the very summit of the divide is reached and the descent toward the Arkansas begun, a traveling distance of not far from thirteen kilometers.

By climbing a neighboring peak, thrice baptized as Crystal Mountain, Topaz Butte, and Cheops Pyramid, we obtain an admirable bird's-eye view of the ancient lake and the surrounding region. To the southeast

* The heights are given in feet.

† Florissant is merely a post-office at Castello's Ranch, which is also provided with a store, the basis of supplies for all the inhabitants within a radius of fifteen kilometers. One would have to look far to find in Colorado a more comfortable hostelry than that to which "Judge" Castello will welcome us.

is Pike's Peak; to the west South Park and the cañon of the South Platte, shown by a depression; to the extreme south, the grand cañon of the Arkansas; while to the north a few sharp, ragged, granite peaks surmount the low wooded hills and ravines characteristic of the nearer region. Among these hills and ravines, and only a little broader than the rest of the latter, lies, to the south, the ancient Florissant Lake basin, marked by an irregular L-shaped grassy meadow, the southern half broader and more rolling than the northwestern, the latter more broken and with deeper inlets.

Recalling its ancient condition, and it will appear that this elevated lake must have been a beautiful, though shallow,* sheet of water. Topaz Butte, and a nameless lower elevation lying eight kilometers to its southwest, and which we may call Castello's Mountain, guarded the head of the lake upon one side and the other, rising three or four hundred meters above its level. It was hemmed in on all sides by nearer granitic hills, whose wooded slopes came to the water's edge; sometimes, especially on the northern and eastern sides, rising abruptly, at others gradually sloping, so that reeds and flags grew in the shallow waters by the shore. The waters of the lake penetrated in deep inlets between the hills, giving it a varied and tortuous outline; although only about sixteen and a half kilometers long and very narrow, its margin must have measured over seventy kilometers in extent. Still greater variety was gained by steep promontories, twenty meters or more in height, which projected abruptly into the lake from either side, nearly dividing it into a chain of three or four unequal and very irregular open ponds, running in a northwest-southeast direction, and a larger and less indented sheet, as large as the others combined, connected with the southwesternmost of the three by a narrow channel, and dotted with numerous long and narrow wooded islets just rising above the surface.

The ancient outlet of the whole system was probably at the southern extremity; at least the marks of the lake-deposits reach within a few meters of the ridge which now separates the waters of the Platte and Arkansas; and the nature of the basin itself, the much more rapid descent of the present surface on the southern side of this divide, with the absence of any lacustrine deposits upon its slopes, lead to this conclusion. At the last elevation of the Rocky Mountain chain, the drainage flow of this immediate region was reversed; the elevation coming from a southerly or southeasterly direction (perhaps from Pike's Peak), the lake, or series of lakes, was drained dry by emptying at the northwestern extremity. The drainage of the valley now flowed into a brook which followed the deeper part of its former floor, and the waters of the region have since emptied into the Platte and not the Arkansas, passing in their course between Topaz Butte and Castello's Mountain.

The promontories projecting into the lake on either side are formed of trachyte or other volcanic lavas, apparently occurring in fissures directly athwart the general course of the northwestern or upper series of lakes; and masses of the same occur at many different points along the ancient shore, such as the western corner where the waters of the lake were finally discharged; in the neighborhood of Castello's Ranch; along the eastern wall of the lowermost of the chain of upper lakes, near where the present road divides; and at points along both eastern and western walls of the lower southern lake. In general the trachytic flows seem to be confined to the edges of the lacustrine basin, but some, if not all, of the mesas or ancient islands of the southern lake have trachytic flows

* The shallowness of the lake is indicated by the character of the fish, the sun cracking of some of the shales, and the erect sequoia stumps.

over them; and toward the southern extremity of the lake a larger island will be seen upon the map, now forming a rounded hill with steep northern walls, crowned by heavy beds of dark trachyte, and its slopes covered with quantities of vesicular scoriae. The rough and craggy knoll immediately overlooking Castello's Ranch, the reputed scene of Indian combats,* was witness of hotter times than those; vertical cylindrical holes, with smooth walls, in which a man could hide from sight, funnels scored by heat, mark, perhaps, the presence of former geysers; the basaltic rocks themselves are deeply fissured by the breaking up of the planes of divisions between the columns, affording the best protection to the Ute and Arapahoe warriors. But the very shales of the lake itself, in which the myriad plants and insects are entombed, are wholly composed of volcanic sand and ash; fifteen meters or more thick they lie, in alternating layers of coarser and finer material. About half of this, now lying beneath the general surface of the ground, consists of heavily bedded drab shales, with a conchoidal fracture, and totally destitute of fossils. The upper half has been eroded and carried away, leaving, however, the fragmentary remains of this great ash deposit clinging to the borders of the basin and surrounding the islands; a more convenient arrangement for the present explorer could not have been devised. That the source of the volcanic ashes must have been close at hand seems abundantly proved by the difference in the deposits at the extreme ends of the lake, as will be shown in the sections to be given. Not only does the thickness of the different beds differ at the two points, but it is difficult to bring them into anything beyond the most general concordance.

There are still other proofs of disturbance. Around one of the granitic islands in the southern lake basin the shales mentioned were capped by from one and a half to two and a half meters of sedimentary material, reaching nearly to the crown of the hill, the lowest bed of which, a little more than three decimeters thick, formed a regular horizontal stratum of small volcanic pebbles and sand (A and B of Dr. Wadsworth's note further on); while the part above is much coarser, resembling a breccia, and is very unevenly bedded, pitching at every possible angle, seamed, jointed, and weather-worn, curved and twisted, and inclosing pockets of fine laminated shales, also of volcanic ash, in which a few fossils are found (C of Dr. Wadsworth's note). These beds cap the series of regular and evenly stratified shales (D of the same note), and are perhaps synchronous with the disturbance which tilted and emptied the basin. The uppermost evenly bedded shales then formed the hard floor of the lake, and these contorted beds the softer, but hardening, and therefore more or less tenacious, deposits on that floor.

The excavation of the filled-up basin we must presume to be due to the ordinary agencies of atmospheric erosion. The islands in the lower lake take now as then the form of the granitic nucleus; nearly all are long and narrow, but their trend is in every direction, both across and along the valley in which they rest. Great masses of the shales still adhere equally on every side to the rocks against which they were deposited, proving that time alone and no rude agency has degraded the ancient floor of the lake.

The shales in the southern basin dip to the north or northwest at an angle of about two degrees, and an examination of the map will show that the southern end of the ancient lake is now elevated nearly two hundred and fifty meters above the extreme northwestern point. The greater part of this present slope of the lake border will be found in the

*Their rude fortifications still crown the summit.

southern half, where it cannot fail to strike the observant eye upon the spot, the southernmost margin, close to the summit of the divide, being nearly two hundred meters higher than the margin next the school-house hill.

Our examination of the deposits of this lacustrine basin was principally made in a small hill, from which perhaps the largest number of fossils have been taken, lying just south of the house of Mr. Adam Hill, and upon his ranch. Like the other ancient islets of this upland lake, it now forms a mesa or flat-topped hill about ten or a dozen meters high, perhaps a hundred meters long and twenty-five broad. Around its eastern base are the famous petrified trees, huge, upright trunks, standing as they grew, which are reported to have been five or six meters high at the advent of the present residents of the region. Piecemeal they have been destroyed by vandal tourists, until now not one of them rises more than a meter above the surface of the ground, and many of them are entirely leveled; but their huge size is attested by the relics, the largest of which can be seen to have been three or four meters in diameter. These gigantic trees appear to be sequoias, as far as can be told from thin sections of the wood submitted to Dr. George L. Goodale. As is well known, remains of more than one species of sequoia have been found in the shales at their base.

At the opposite sloping end of this mesa a trench was dug from top to bottom to determine the character of the different layers, and the section exposed was carefully measured and studied. In the work of digging this trench we received the very ready and welcome assistance of our companion, Mr. Bowditch, and of Mr. Hill, the owner of the grounds.

From what information we could gain about the wells in this neighborhood it would appear that the present bed of the ancient Florissant lake is entirely similar in composition for at least ten meters below the surface, consisting of heavily bedded non-fossiliferous shales, having a conchoidal fracture. Mr. Peale does not say whether the well seen by Mr. Taggart passed below the trachyte, which he says it first entered. Above these basal deposits, on the slope of the hill, we found the following series, from above downward, commencing with the evenly bedded strata:

Section in southern lake.

[By S. H. SCUDDER and A. LAKES.]

	Centimeters.
1. Finely laminated, evenly bedded, light-gray shale; plants and insects scarce and poorly preserved	3.2
2. Light-brown, soft and pliable, fine-grained sandstone; unfossiliferous	.5
3. Coarser, ferruginous sandstone; unfossiliferous	3.8
4. Resembling No. 1; leaves and insect remains	21
5. Hard, compact, grayish-black shale, breaking with a conchoidal fracture, seamed in the middle with a narrow strip of drab shale; fragments of plants	28
6. Ferruginous shale; unfossiliferous	1.5
7. Resembling No. 5, but having no conchoidal fracture; stems of plants, insects, and a small bivalve mollusk	9
8. Very fine gray ochreous shale; non-fossiliferous	0.5
9. Drab shales, interlaminated with finely-divided paper shales of light-gray color; stems of plants, reeds, and insects	46
10. Crumbling ochreous shale; leaves abundant, insects rare	7.5
11. Drab shales; no fossils	7.5
12. Coarse, ferruginous sandstone; no fossils	3.8
13. Very hard drab shales, having a conchoidal fracture and filled with nodules; unfossiliferous	63
14. Finely laminated yellowish or drab shales; leaves and fragments of plants, with a few insects	30

	Centimeters.
15. Alternating layers of darker and lighter gray and brown ferruginous sandstone; no fossils	10
16. Drab shales; leaves, seeds, and other parts of plants, and insects, all in abundance	61
17. Ferruginous, porous, sandy shale; no fossils	5.7
18. Dark gray and yellow shales; leaves and other parts of plants	9
19. Interstratified shales, resembling 17 and 18; leaves and other parts of plants, with insects	17.8
20. Thickly bedded chocolate-colored shales; no fossils	41
21. Porous yellow shale, interstratified with seams of very thin drab-colored shales; plants	7.5
22. Heavily bedded chocolate-colored shales; no fossils	30
23. Thinly bedded drab shales; perfect leaves, with perfect and imperfect fragments of plants, and a few broken insects	20
24. Thinly bedded light-drab shales, weathering very light; without fossils; passing into	20
25. Thick bedded drab shales, breaking with a conchoidal fracture; also destitute of fossils	18
26. Coarse arenaceous shale; unfossiliferous	9
27. Gray sandstone, containing decomposing fragments of some white mineral, perhaps calcite; no fossils	178
28. Coarse, ferruginous, friable sandstone, with concretions of a softer material; fragments of stems	60 (?)
29. Thinly bedded drab shales, having a conchoidal fracture; somewhat lignitic, with fragments of roots, &c	25
30. Dark-chocolate shales, containing yellowish concretions; filled with stems and roots of plants	25
Total thickness of evenly bedded shales (D of Dr. Wadsworth's note) above floor deposits	(meters) 6.668

The bed which has been most worked for insects and leaves, and in which they are unquestionably the most abundant and best preserved, is the thick bed, No. 16, lying half way up the hill, and composed of rapidly alternating beds of variously-colored drab shales. Below this insects were plentiful only in No. 19, and above it in Nos. 7 and 9; in other beds they occurred only rarely or in fragments. Plants were always abundant where insects were found, but also occurred in many strata where insects were either not discovered, such as beds 18 and 21 in the lower half and bed 6 in the upper half, or were rare, as in beds 10 and 14 above the middle and bed 23 below; the coarser lignites occurred only near the base.

The thickest unfossiliferous beds, Nos. 20 and 27, were almost uniform in character throughout, and did not readily split into laminae, indicating an enormous shower of ashes or a mudflow at the time of their deposition; their character was similar to that of the floor-beds of the basin.

These beds of shale vary in color from yellow to dark brown. Above them all lay, as already stated, from fifteen to twenty-five decimeters of coarser, more granulated sediments, all but the lower bed broken up and greatly contorted. These reached almost to the summit of the mesa, which was strewn with granitic gravel and a few pebbles of lava.

Specimens of these upper irregular beds, and also of the underlying shales, were submitted to Dr. M. E. Wadsworth, of Cambridge, who caused thin sections to be made from them, and has furnished the following account of their microscopical structure:

TUFA FROM FLORISSANT.

The method and scheme of classification employed here is that briefly sketched in the Bulletin of the Museum of Comparative Zoölogy (vol. v, pp. 275–287). By this system only do we think that the inclosed fragments could be named, for they contain so few crystals that in most cases the base is the principal thing upon which the decision must rest.

A.—The finer deposit just above the shales.

A medium-grained gray tufa, containing crystal and fragments of feldspar, augite, &c., cemented by a fine earthy groundmass.

In the thin section it is seen to be an epitome of the volcanic rocks of the Cordilleras. The groundmass holds fragments of basalt, andesite, trachyte, and rhyolite, with detached minerals derived from them.

The basaltic fragments have in part a dense globulitic base porphyritically holding ledge-formed plagioclase crystals and a few augite granules. Some of the basalt is quite coarsely crystallized, approaching the doleritic type. Olivine was observed in some of the fragments, but it is largely altered to a reddish-brown serpentine. Magnetite is abundant. In many of the fragments the groundmass has decomposed to a reddish-brown mass, which is untransparent and holds clear crystals of plagicoclase. The basaltic fragments have suffered more from alteration and decomposition than any others in the tufa.

Of andesite, both varieties pointed out by us (1. c., p. 280) occur in this tufa. The first, which is nearest the basalt in composition, has a brown glass as its base, filled with microlites. This base holds minute rectangular and oblong crystals of feldspar. Large microlites of augite and grains of magnetite were seen. Fragments of this are common, and are clear and unaltered. The second variety of andesite was seen to have a dense gray micro-felsitic base, holding ledge-formed feldspars and magnetite grains. Some contained the reddish-brown fibers of the destroyed hornblende. Fragments of this variety of andesite are quite abundant.

The trachyte has a light gray, felty, and glassy base, some fragments showing besides this only faint traces of polarization caused by incipient feldspars. Other fragments show minute, well-formed crystals that appear to be sanidin. Grains of magnetite occur scattered through the base. This is also quite abundant, and it, as well as the basalt and andesite, surpasses the rhyolite in amount.

The rhyolite occurs in the form of a more or less clear glass, often cellular. The cells are often drawn out in the direction of the original flow, forming a fibrous structure, which when of a grayish or reddish brown color resembles woody fiber. Some of the fragments contain elliptical cells, and a few shards of water-clear glass free from inclusions were seen.

Many crystals, entire or broken, are scattered throughout the groundmass of the tufa. These crystals belong to plagioclase, sanidin, olivine, magnetite, augite, and quartz. But little quartz was observed; one crystal contained trichites and vapor cavities. The trichites are the same as those commonly seen in the quartz of granite, but this appears to have been derived from the lava. The feldspar contains inclusions of base, glass, and microlites, and through these the rock from which the feldspar was derived can often be told. The augites have the characters of andesitic augite. A little palagonite and one crystal of microline were seen.

The groundmass of the tufa is composed of comminuted and decomposed material derived from the lavas before described. In the groundmass trachytic and rhyolitic material appears to predominate. This specimen was chosen for description, as it best represented the general characters of the tufas.

B.—The coarser deposit just above the shales.

This is more coarsely fragmental than any of the others, and is composed of a yellowish brown earthy groundmass, holding fragments of quartz, feldspar, basalt, &c. Some of the fragments appear to belong to the older rocks, but none of them were seen in the section. Under the microscope the tufa is similar to the first one described, but its fragments are larger and sometimes better marked. Some kaolinized feldspars and a little biotite were seen. The hornblende in the andesite is in the usual broken forms, with blackened edges.

C.—A specimen from finer portion of the upper contorted beds.

A yellowish earthy groundmass holding crystals and fragments of augite and feldspar. On one side is a layer of fine detritus, composed of the same material as the groundmass of the more coarsely fragmental portion. Its microscopic characters are similar to those of A, except that its materials are more decomposed and sanidin is more abundant. One kaolinized feldspar was observed.

D.—Three specimens of the insect-shales.

These are brownish and grayish brown shales, being simply the finer material of the tufas laid down in laminae of varying thickness and coarseness. One is very thinly bedded.

This volcanic material has evidently been worked over by water, but the conditions can of course best be told in the field. So far, however, as we can judge by micro-

scopic examination, when the water commenced its work the material was in loose unconsolidated deposits. That it was thrown out as an ash, or rather deposited as a *moya* near its present location, is the most probable supposition. It seems, then, to have been taken up by the waves and spread out as it is now found. The reason for this opinion is that the fragments are not worn as they would naturally be if they had been derived directly from solid rock by water action, and the decomposition is not so great as we should expect. The deposition appears to have been gentle but comparatively rapid, for there is no sign of violence or even of such decomposition as we should expect in slow deposition; and showers of ashes falling on still water or a lake acting on an unconsolidated tufa bank answer best the conditions called for here. It is probable from the kaolinized feldspars and the macroscopic fragments of apparently older rocks that the latter are present in the tufa to some extent. This can best be explained by the supposition that it was deposited as a *moya* or mudflow within reach of the waters that have worked it over and deposited it in its present position. As we said before, the field evidence must be relied upon mainly in deciding such questions as these.

M. E. WADSWORTH.

CAMBRIDGE, MASS., *April* 15, 1880.

Another section, less carefully measured and noted with less detail than the other, was taken at or near the same place as Dr. Peale's mentioned at the beginning of this article, viz, at the extremity of one of the promontories jutting in a southwesterly direction into the middle of the upper chain of lakes, just west of the school-house* and about three kilometers west of Castello's Ranch. The top of the hill was covered with granitic gravel and loose bowlders of dark scoriaceous trachyte; below this we found, passing, as before, from above downward, the following succession:

Section in the northwestern lake.

[By S. H. SCUDDER and A. LAKES.]

	Decimeters (estimated).
1. Finely laminated yellow-drab shales; no fossils	12
2. Coarse decomposing yellowish shales; no fossils	12
3. Fine compact drab shales; perfect remains of plants and insects. Passing into	15
4. Arenaceous shales; very lignitic	6
5. Heavily bedded, coarse-grained, crumbling sandstone, of a grayish yellow and whitish color, becoming ferruginous in places; partially lignitic	60
6. Chocolate and drab colored shales having a conchoidal fracture, passing below into whitish paper-like shales inclosed between coarse arenaceous laminae; plants and insects	45
Total thickness of shales above floor deposits	(Meters, estimated) 15

These measurements being estimated are undoubtedly too great. The composition of this bluff is coarser in character than that of the section in the southern extension of the lake. The lignitic beds, which have been used for quarrying purposes, contain numerous fragments of reeds and roots not well preserved. The lower portions of the section correspond better with the other than do the upper beds, where it is difficult to trace any correspondence; No. 3 of the northwestern seems, however, to correspond to No. 16 of the southern series. The whitish paper shales lying at the base of this appear to be entirely absent from the southern section, and the distorted beds which crown the mesa are not apparent in the bluff, or, if present, are wholly regular. A more careful and detailed section of the bluff (for which we had not time), and particularly the tracing of the beds along the wall of the lake, would probably bring to light better correspondences. Directly in front of Judge Castello's house, at a level of a little more than 2,400 meters, is a bed of fossil fish.

Judging from the present physical condition of the basin, its age is marked as later than the movements which closed the cretaceous epoch and earlier than the last upheaval in the tertiary, which seems to have

* Not the school-house before mentioned, which lies to the south of Castello's Ranch.

taken place during or after miocene times, but there are no physical data yet at hand to warrant definite conclusions on this head.

PALEONTOLOGY.

The insects preserved in the Florissant basin are wonderfully numerous, this single locality having yielded in a single summer more than double the number of specimens which the famous localities at Oeningen, in Bavaria, furnished Heer in thirty years. Having visited both places I can testify to the greater prolificness of the Florissant beds. As a rule, the Oeningen specimens are better preserved, but in the same amount of shale we still find at Florissant a much larger number of satisfactory specimens than at Oeningen, and the quarries are fifty times as extensive and far more easily worked.

The examination of the immense series of specimens found at Florissant* has not gone far enough to yield data sufficiently definite for generalization of any value, or which might not be altered or even reversed on further study. It may, nevertheless, be interesting to give a running notice of what has been observed in assorting the collection, and to make the single comparison with the Oeningen insect fauna which the number of individuals will furnish. This is indicated by the following table, based on a rough count of the Florissant specimens, but which cannot be far astray:

Percentage of representation by—	At Florissant.	At Oeningen.
Hymenoptera	40	14
Diptera	30	7
Coleoptera	13	48
Hemiptera	11	12
Neuroptera	5	17
Orthoptera	½	3
Arachnida	½	½
Myriapoda	½₅	
Lepidoptera	1/25	1/10
	99. 58	101. 6

It will be seen that the proportion of specimens of each order is very different in all that are well represented, with the sole exception of the Hemiptera, while the same groups (Orthoptera, Arachnida, Myriapoda, and Lepidoptera) are feebly represented in both. The greatest difference occurs in the Diptera, which are less than 7 per cent. of the whole at Oeningen and about 30 per cent. at Florissant; in the Hymenoptera, which have less than 14 per cent. at Oeningen and 40 per cent. at Florissant, due largely to the prodigious number of ants; while the case is reversed in the Coleoptera, which form nearly one-half the specimens found at Oeningen and only 13 per cent. at Florissant. We possess no count of the specimens found at Radoboj, in Croatia, which is regrettable, since the fauna of Florissant appears to agree much better with it than with any other, at least if one may judge from the comparatively minor part played by the Coleoptera and the great number of ants; these latter number 57 species in Radoboj, and one of them has furnished 500 specimens. Still the comparison cannot be carried very closely into other departments; for instance, only one rhynchophorous Coleopteron has been reported from Radoboj, while they are very numerous and rich

*Among these are included about 1,000 specimens submitted by the Princeton expedition.

in species at Florissant, and local causes must have had much to do with the fauna of each of these localities. It is hardly worth while to institute any inquiries into the proportion of the groups represented at Florissant and in amber, since the nature of the entombment is entirely different.

Let us pass, then, to a rapid sketch of the Florissant insect fauna, from which as yet only 16 species have been published; these will be enumerated in their proper place.

In Hymenoptera none have yet been described. About a dozen specimens are referred to Apidae and Andrenidae; several species are represented, but most of them are badly preserved; the largest appears to be a Bombus. Of Vespidae and other large wasp-like Hymenoptera about 70 or 80 specimens have heen found, referable to about 30 species, one of which is a large Scolia or allied genus; several are Sphegidae, including an Ammophila; one, which seems to be a Polistes, shows traces of a blue-green metallic tint; another, apparently one of the Pompilidae, represents a species with a large subapical fuliginous spot on the wing; another, perhaps of the same family, has a circular clear spot in the center of the wing, surrounded with fuliginous. The ants are the most numerous of all insects at Florissant, comprising perhaps a fourth of all the insects; they form more than three-fourths, perhaps four-fifths, of all the Hymenoptera; I have already about 4,000 specimens of perhaps 50 species (very likely many more); they are mostly Formicidae, but there are not a few Myrmicidae and some Poneridae. I have noticed no Mutillidae. Ichneumonidae are very numerous; of minuter forms, having an expanse of wing of less than a centimeter, there are nearly 200 specimens, unusually well preserved; judging from a cursory examination they are exceedingly numerous in species, perhaps 80 all told, and many genera are represented; the larger forms, whose wings expand more than a centimeter, are even more numerous, both in species and individuals, and most of them are very fine, including a great variety, among which are especially noticeable a good assortment of species of Pimpla and allied genera. I have looked in vain for Pelecinus, or any long-tailed Rhyssae or Thalessae. The Braconidae, Chalcididae, Cynipidae, and Chrysidae, exceedingly few fossil species of which have ever been described, are very abundant, but have not been fairly separated from each other and from other small species; together they number nearly 250 specimens and probably 50 species. Among others there is a Chrysis, showing metallic green reflections on the abdomen; and also more than half a dozen species of Chalcididae, with expanded femora, represented by over 20 specimens. Finally, there are about 60 Tenthredinidae of 14 or 15 species, and several genera; besides a single species of Uroceridae.

A few Lepidoptera occur. One butterfly in a most admirable condition has already been described under the name of *Prodryas Persephone*, and there are two more diurnal species, each represented by a single specimen and each also generically distinct from any living forms, but yet falling in the immediate vicinity of those most nearly allied to Prodryas, namely, among the highest Praefecti. These I shall describe under the generic names of Jupiteria and Lithopsyche. Besides these there are a couple of poorly-preserved butterflies of uncertain position, and I have also set aside about a dozen specimens of perhaps 8 species of nocturnal Lepidoptera; but they are obscure, mostly of small size, perhaps Pyralidae or Tortricidae, and have not been critically studied.

Nearly a third of all the specimens I have seen from Florissant belong to the Diptera. Culicidae and Chironomidae are abundant, but not

generally very perfect. Tipulidae are abundant and admirably preserved; of the larger forms alone there appear to be several hundred specimens, and apparently a considerable number of species. The smaller Tipulidae, including the Limnobina, are also abundant and well preserved. Some beautiful Mycetophilidae have been noticed, but these have not yet been selected from the mass of smaller flies. Bibionidae are the prevailing type among the Diptera; there must be 1,000 specimens belonging to this family, and on a cursory view there appears to be no great variety; probably both here and in the ants, as in some genera of plants, it will appear that there are vast numbers of a single species; a great many specimens are represented by bodies only, or these accompanied by insignificant fragments of wings; but even putting all these aside, there remain a goodly number with tolerably perfect wings, and some in which almost every part of the body is preserved; taken as a whole, however, they are perhaps less perfect than specimens of almost any other family. There are a dozen or more Stratiomyidae, of two or three species; and several species of Midasidae or Hermoneuridae, one admirable specimen of the latter family having been described as belonging to a new genus under the name of *Palembolus florigerus*. There are nearly half a hundred Asilidae and Therevidae, many of them exquisitely preserved, some of great size, and among them a fair variety of forms. Bombylidae are somewhat less abundant, but show some superb specimens of great size and in wonderful preservation; there are certainly six or eight species. Syrphidae are more abundant than the last, nearly 50 specimens having been found, in which the patterns of the abdominal colors are generally well marked, and among which we find a considerable variety. There is a vast host of Muscidae and allied groups, of which no account has yet been taken, and with which, no doubt, many other forms are still commingled; but three or four species of very pretty Ortalidae may be mentioned, with ten or a dozen specimens.

About three-fifths of the Coleoptera belong to the normal series and two-fifths to the Rhyncophorous division. There are 80 to 90 specimens of Carabidae, including, perhaps, 30 species; many of them are very fine and perfect, especially in the sculpturing of the elytra. Water-beetles are not so numerous as would be anticipated; there are not more than 60 or 70 specimens, with perhaps twenty species; there are no large Dytisci, such as occur abundantly at Oeningen; the largest of our species, perhaps an Hydrophilus, not exceeding 12^{mm} in length. The Staphylinidae are rather more numerous than the ground-beetles, with nearly 30 species, some of them tolerably large. There are half a dozen species of Nitidulidae. Some 60 or more Scarabaeidae show considerable variety, there being nearly 30 species among them. Nearly as many Buprestidae have quite as great a variety of form; a considerable number of them are large and nearly all fairly preserved, some remarkably perfect; one species, *Chrysobothris Haydeni*, has been described. Elateridae are more abundant, numbering more than 100 specimens, many of them in beautiful condition; they are abundant in species, over 40 having been separated, and are mostly of a medium, none of a large size. Considerably over 100 specimens are to be referred to the Meloidae, Mordellidae, and Malacodermata, but the specimens do not appear to be very well preserved, although about 40 species may be distinguished. The Cerambycidae are very beautiful, furnishing 30 or more specimens, representing more than half as many species; one fine species of a new extinct genus, *Parolamia rudis*, has already been described, and there are others equally fine. There are a dozen or more species of Bruchidae, one of which,

Spermophagus vivificatus, has been published. Chrysomelidae are not uncommon; thus far I have recognized about two dozen species among the 60 or 80 specimens; one, *Oryctoscirtetes protogaeus*, belonging to a new genus, has already been published. Nearly twenty species of Tenebrionidae have been separated, rarely represented by more than a single specimen each, and there are also a few (from 2 to 10 species each) of Silphidae, Histeridae, Dermestidae, Ptinidae, and Coccinellidae, and a single species each of Cleridae and Telephoridae, the latter already described under the name of *Chauliognathus pristinus*. Two species of Rhynchophora, *Anthonomus defossus* and *Eurhinus occultus*, have been described. I have already mentioned the predominance of this type in opposition to the European tertiaries. The species are very numerous, nearly 120 having been separated, with over 500 specimens, and among them are a goodly number of large and fine species; but some of the minutest are most admirably preserved; especially is this true of the sculpturing of the thorax and elytra; no attempt, however, has yet been made to do more than rudely separate the species, so that no details can now be given. They will occupy seven plates of the forthcoming report, with one hundred and seventy figures.*

Among Hemiptera, to which eleven plates, with two hundred and eighteen figures, will be devoted in the report in preparation, Heteroptera are somewhat more numerous than Homoptera, both in individuals and species. The Heteroptera present a great variety of forms, over 100 species having been detected, three-fourths of which can be referred to their proper place; they will occupy seven plates, with one hundred and thirty-five figures. Lygaeidae, Reduviidae, and Pentatomidae abound. Corimalaenidae of several species are very common; but the most common of all are one or two species of Alydina (one of the groups of Coreidae), comprising perhaps a third of all the Heteroptera. There are two species of Aradidae, and half a dozen specimens of a very pretty species of Tingis, well preserved; but in general the preservation of the Heteroptera is not so good as of the Homoptera. Very few water-bugs occur, but there are two or three species, among them a slender and very prettily marked Corixa. There are about 65 species of Homoptera, of which nearly one-half belong to the Cercopida. One genus, resembling Ptyelus, is represented by a dozen or more species, comprising together perhaps nine-tenths of all the Homoptera, some of the species being represented by 40 or 50 specimens. There are a few large Fulgoridae; one has the long recurved process of the head almost perfectly preserved. Two gigantic Aphrophorina have already been described as belonging to a new genus, and been named *Petrolystra gigantea* and *P. heros;* but as a whole the species are of medium size, with some minute and slender forms, the position of which is as yet undetermined. Plant-lice are common, and include probably 8 species, all Aphidiinae excepting one, which is referred to Schizoneuridae; an entire plate is devoted to them, with nineteen figures. Many of the Homoptera have their markings beautifully preserved; especially is this the case in a variegated Typhlocypha or allied genus, and the venation of others is as complete as in the living form. No Stridulantia have occurred.

Sixty or seventy specimens of Orthoptera have been found, all the families being represented excepting Gryllidae and Mantides. Six specimens and nearly as many species of Locustariae are present; the finest,

*The execution of these plates, which are drawn by Mr. J. H. Blake, and engraved by Messrs. Sinclair & Son, is far superior to that of any illustrations of tertiary insects which have yet been published. It leaves nothing to be desired, either in accuracy or finish.

belonging to a new genus, has been described under the name of *Lithymnetes guttatus*. There are about the same number of Acridii, a single species of Phasmida, and two or three Blattariae, one of which has been described under the name of *Homoeogamia ventriosus*. But the mass of Orthoptera, including about 50 specimens and 8 to 10 species, belong to the Forficulariae; two of them, *Labidura tertiaria* and *L. lithophila*, have been described, but they are among the least interesting, several of the species exhibiting forceps of very great length; an entire plate has been devoted to them in a forthcoming report, with twenty-four figures, and the remaining Orthoptera, with nineteen figures, will occupy another.

The Neuroptera are made up in large part of Phryganidae, but no larval cases have been preserved; there are about 100 specimens representing 15 or 20 species which are determinable, and which occupy one plate of the report and parts of others, including twenty-two figures; besides these there are several hundred which perhaps a severer study will classify; one species has wings 2 centimeters long, while others are minute; several of the subfamilies appear to be represented, true Phryganidae certainly, and probably Rhyacophilidae, Leptoceridae, and Hydropsychidae.

The collections embrace seven genera and twelve species of planipennian Neuroptera, occupying one plate with fifteen figures. All of the species and four of the genera are new, and belong to five families. The Raphidiidae are the most numerous, embracing Raphidia with a single species and Inocellia with four; the species referred to Raphidia hardly belongs to it in a strict sense, since the costal vein is excessively short, there are no costal veinlets, and the sectors do not originate obliquely from the radius, but more indirectly by transverse veins; all the species of Inocellia, which fall into two sections, differ from living types and also from the species found in the eocene amber of the Baltic, in having no transverse series of regular discoidal areoles below the pterostigma. A single species of Osmylus represents the Hemerobidae, and differs from living forms, as does also the amber species, in the simple character of the costal nervules, the much smaller number of sectors, and the limited supply of cross-veins in the basal half of the wing, giving this region a very different appearance from its rather close reticulation in modern types. It may here be noticed as a very general rule that the neuration of the wing is much closer in modern Planipennia than in their tertiary representatives. There are four species of Chrysopidae, referable to two genera, each of them extinct; Chrysopidae have not before been recognized in tertiary strata, the single species poorly figured by Andrä, and never carefully studied, being much more probably one of the Hemerobidae; these two genera, called Palaeochrysa and Tribochrysa are allied to the living Nothochrysa, but differ from modern types in the zig-zag course of the upper cubital vein and in its direction, which is through the middle of the wing, as well as by the smaller number of sectors, and the entire absence of any transverse series of gradate veinlets; Palaeochrysa is represented by a single species, Tribochrysa by three, and the genera differ from each other in the course of the upper cubital vein, which in Palaeochrysa is direct and bordered by comparatively uniform cells, while in Tribochrysa it is doubly bent in the middle, and is therefore bordered by very unequal cells. The single species of Panorpidae, referable to a new genus, has already been described under the name of *Holcorpa maculosa;* it differs from Panorpa in the entire absence of cross-veins, and is remarkable for the spots on the wings. No planipennian Neuroptera have been found in the Green

River shales, but the tertiary beds of British Columbia have furnished a single species of Hemerobidae belonging to an extinct genus allied to Micromus, and which I have called Bothromicromus. The number of species of tertiary Planipennia is nearly doubled by the discoveries already made in the American tertiaries, but the families and especially the genera are very differently represented on the two continents. In the European tertiaries, the Raphidiidae have only one species of Inocellia; while on the other hand the Hemerobidae show one or more species each of Nymphes, Sisyra, and Hemerobius, besides the species of Osmylus mentioned; the Chrysopidae, as stated, are unrepresented, although two species are indicated by Hagen from the Jura of Eichstätt; the Panorpidae have one species of Panorpa and three of Bittacus; while there are also two species of Ascalaphus and one each of Coniopteryx and Chauliodes, belonging to families not found at Florissant. To pass to other Neuroptera: Embia, too, is represented in Europe by a single amber species, and there are no less than thirteen species of four genera of Perlidae, a family unrepresented in America, and eight species of five genera of Psocidae already described, and a number more shortly to be published by Dr. Hagen; of the latter family Florissant has one highly interesting species of a new genus, Necropsocus, which seems in some measure to unite its two divisions of Atropina and Psocina, and to be curiously related to one of the interesting genera from the amber which Dr. Hagen will soon make known. Larvae and pupae of three species of Ephemeridae and an imago are also found at Florissant; immature stages of Ephemeridae have not before been found fossil, and only a single winged Ephemera has been indicated from the tertiary rocks of Europe (Oeningen), but the Prussian amber has furnished seven species. A very interesting species of Lepisma also occurs at Florissant, the first known from any rock formation, but here again the amber discloses no less than sixteen species of Lepismatidae, besides ten other Thysanura.

The Odonata furnish the first opportunity that has been embraced of a comparison between the insect faunas of Florissant and the Green River shales; the Florissant beds have furnished six species in the perfect state besides two larvae; the Green River shales four species in the perfect state besides fragments of another, concerning which nothing more can be said than that it probably belongs to the Libellulina; two of the Florissant forms belong to Aeschna, besides one of the larvae; all the remainder, four Green River species, and four from Florissant, besides the other larva, belong to the Agrionina; the Green River shales are represented by one species of Podagrion and three species of Dysagrion, an extinct genus of the legion Podagrion allied to the genera Podagrion and Philogenia; the Florissant bed by two species of Agrion and two of Lithagrion, an extinct genus with the same alliances as Dysagrion; the species of Agrion are not sufficiently perfect to decide into what subgenus they will fall, but they are certainly closely related to each other, and appear to be most nearly allied to Amphiagrion, or else to Pyrrhosoma or Erythromma; all the Green River species then belong to the legion Podagrion, while the Florissant species are divided between the legions Podagrion and Agrion; the resemblance of the fauna of the two localities is very apparent, though the species and even the genera are wholly distinct; the facies of both faunas is decidedly subtropical. The European tertiaries have proved far more productive in Odonata than the American, nearly fifty species having been indicated, of which about fourteen are larvae or pupae; as in America, the Agrionina are the most numerous, having eighteen species and mostly representing the true Agrionina (America nine species, wholly Agrionina proper);

Libellulina come next with sixteen species (only indicated in America), of which no less than ten are larvae or nymphs; then Gomphina with seven species (not yet detected here); and Aeschnina with six species (against three in America).

Twenty-six specimens of Termitina have been found, belonging to six species and three genera; among the specimens is a single worker, with one exception the only one that has ever been found fossil; four of the species and two genera belong to the section with branched, the others to that with unbranched, scapular vein. This is the same proportion as holds with the sixteen species of the European teritaries, where eleven belong to the first, five to the second section; of living types, on the contrary, only 35 per cent. belong to the first, 65 per cent. to the second section. Three of the species belong to a distinct genus which I call Parotermes, apparently peculiar to America, but possibly including some from the European tertiaries; another is doubtfully referred to Hodotermes, which has furnished fossil species from several localities in Europe, as well as among living forms; while the other two probably belong to Eutermes and are allied to species from Radoboj, placed with many modern types in this group. Calotermes, which has furnished species from amber and the Rhenish basin; Termopsis, which has more fossil (amber) species than recent; and Termes proper, which is represented at Oeningen and Radoboj, as well as in amber and on the Rhine—all seem to be wanting at Florissant; the composition of the tertiary white-ant fauna of Florissant, therefore, differs considerably from that of any locality in Europe; but it most nearly resembles that of Radoboj in Croatia, where a like number of species has been found.

A single plate with thirty-two figures is devoted to the Arachnida, of which there are 32 species and 78 specimens; all of them are Araneides or true spiders. To show the bearing these have upon our knowledge of fossil Arachnids, it may be well to enter in this single instance into a few details.

Up to the present time a little more than 250 species of tertiary Arachnides have been described. Of these about 190 are true spiders, while the remainder are mostly Acarina, Opiliones, or Chernetidae; all but a single species are from European beds, and nine-tenths of them are preserved to us in the eocene amber. Were this means of restoring the ancient tertiary fauna unknown to us, our information at the present day would be based upon 24 species, although in addition to these half a dozen more are indicated by simple reference to genera or families. This number is exceeded by those already found at Florissant.

Whether we examine the American or European species preserved in stratified deposits (*i. e.*, excluding amber), we find an almost total absence of any but true spiders or Araneides; in each (including a tick from the beds at Green River, Wyoming), a single species of Acarina is known, though a number of others undescribed are credited to European strata. In Prussian amber, on the other hand, though Araneides are vastly in the majority, the other groups of Arachnida form twenty-seven per cent. of the entire number of species.

This greater proportion of true Araneides in tertiary deposits, a proportion intensified at the present day, can scarcely be well compared to what we find in the older deposits, from the extreme paucity of their remains in the latter. Brodiê has found a single species (which he considers a true Araneid) in the secondary rocks of England; and the European Jura has furnished merely half a dozen Arachnids (nominal species, perhaps reducible to four), of which only a single one is referable to the Araneida,—Hasseltides, considered by Weyenbergh one of the Agal-

enidae. In the paleozoic formations, again, a dozen species are known, all but three of which have been considered scorpions,* Phrynidae and Chernetidae, or related to them; indeed, one of the other three has not been placed by its describer among the true spiders, but named Arthrolycosa only from its somewhat marked Araneid features. The remaining two seem to be the only true precursors of this group known to us from the paleozoic rocks. The proportion, therefore, of the Araneides to other Arachnides is reversed between paleozoic and cainozoic times.

The Florissant spiders are distributed among the larger groups as follows: Saltigradae (all Attides), 3; Citigradae, 0; Laterigradae (all true Thomisides), 3; Territelariae, 0; Tubitelariae (Agalenides, 1; Drassides, 5; Dysderides, 2 =), 8; Retitelariae (all Theridides), 4; Orbitelariae (all Epeirides), 14 = 32. Nearly one-half, therefore, are Epeirides, and after these the Drassides are best represented. A comparison with the European tertiary spiders shows that America is far richer in Orbitelariae, and Europe richer in Retitelariae, Laterigradae and Tubitelariae, while the Saltigradae are almost equally represented in the two countries.

If, however, we except the species found in amber, and compare only those taken from the rocks in which they have been preserved, we shall reach perhaps a more just comparison, although the data will of course be far more meager. The greater proportion of Orbitelariae in America is now found nearly the same as before, but is not so great as the now heightened proportion in Europe of Retitelariae, while the Tubitelariae become the group in which the proportion is similar in each; the Laterigradae is the only group where the proportion remains nearly the same as in the previous comparison, while the Saltigradae are nearly lost sight of in Europe, a single species being known.

Carrying the analysis a little further, we shall obtain some interesting results; as will appear from the following table, in which all the groups represented in Europe are introduced, and both the total fauna and the species from the strata tabulated.

Groups.	Whole number of European species.	Species from European rocks.	Species from American rocks.
Saltigradae.—Attides	14	1	3
Saltigradae.—Eresoidae	2	0	0
Citigradae.—Lycosoidae	2	0	0
Laterigradae.—Philodromiae	4	0	0
Laterigradae.—Thomisides	21	4	3
Laterigradae.—(Uncertain—Archaea)	6	.....	.....
Territelariae.—Theraphosoidae	1	0	0
Tubitelariae.—Dysderides	14	0	1
Tubitelariae.—Drassides	38	2	5
Tubitelariae.—Agalenides	14	2	2
Tubitelariae.—Hersilioidae	3	0	0
Tubitelariae.—(Uncertain)	.....	1	.....
Retitelariae.—Scytodoidae	1	0	0
Retitelariae.—Theridides	54	9	4
Orbitelariae.—Epeirides	16	3	14

Here, it appears at a glance that exactly the same groups are represented in the stratified deposits of Europe and America in every instance, excepting the Dysderides, which is unrepresented in Europe, and has a single member in America. It also appears that just those families which are represented abundantly in amber are also represented, to

*Report has just come of a discovery of a considerable number of scorpions in the carboniferous rocks of Scotland, adding several species to those already known.

some extent, in the American fauna, and (excepting, as before, the Dysderides) in the European rocks. Exception should perhaps be made for the six species of the remarkable amber genus, Archaea, the position of which in the Laterigradae is uncertain, and so marked in the table above. The relation brought out by this table is certainly striking, but it should, at the same time, be noticed that the Drassides and Theridides, and especially the latter, are enormously represented in the Baltic amber, and, in comparison with them (though not by any means to the same extent in comparison with the other groups), feebly represented in the stratified deposits of Europe and America.

A comparison of the percentage of representation of the larger groups in the different horizons of tertiary times in Europe with that of Florissant seems to indicate a greater difference between the latter deposits and those of the upper miocene of Oeningen than between the same and either the lower miocene of Rott or the upper eocene of Aix and the Baltic amber; and although the proportionate numbers of Tubitelariae and Orbitelariae of Florissant, and especially the former, are more nearly like those of Rott, the representation of the groups in general allies Florissant on the whole with the upper eocene rather than with the lower miocene of Europe.

Of extinct genera there have certainly been proposed a very large number for the European Araneidae, more than half the genera to which the species have been referred having been described as new and peculiar to tertiary times; these genera include about two-fifths of the species. Among the genera are some remarkable forms, such as Archaea and Mizalia, each of which is considered by Thorell and others as representing a distinct family. Two only of the thirteen genera into which the American species fall are new, and to them are referred 7 of the 32 species. Other genera, not before recognized in a fossil state, occurring in American strata are Titanoeca, Tetrognatha, and Nephila. To enter into brief particulars on this point, 71 genera of Araneidae are now known from the tertiaries, 66 from Europe and 13 from America, 8 being common to both; of these genera, 37 are accounted extinct, 35 from Europe and 2 from America, none of these being found in both countries. As may be supposed, the European genera are largely composed of amber species, no less than 52, including 32 extinct genera, being confined to amber deposits, which also contain other genera in common with the stratified deposits.

To review rapidly the different forms of spiders found at Florissant, we may first call attention to a new genus, Parattus, to which the three species of Attides are referred; the fossil species of this family hitherto recorded are all confined to amber excepting one, *Attoides eresiformis* from Aix; one of the amber genera is Gorgopis, including nearly half the 12 species, a genus allied to Phidippus, richly represented to-day in North America; and it is interesting to find that Parattus, although a very aberrant form, with four large eyes instead of two, is more nearly related to Gorgopis than to any other genus. All but four of the 21 fossil Thomisinae thus far described come from amber, among them one Thomisus; Oeningen also furnishes two species of this genus and Rott another, with a Xysticus; three species of Thomisus come from Florissant. The three families of Tubitelariae which are represented in the European and American strata are the ones most abundant at the present day. The fossil Dysderides of Europe (16 sp.) are all from amber, and include 8 species of Segestria, into which the single species from Florissant falls. The Drassides are very abundant in the European amber, and our own fauna shows four species of Clubiona and one of Anyphaena,

both genera represented in amber, and Clubiona (which has eight amber species) also at Oeningen. Six genera of Agalenides are found in the European tertiaries, and Florissant adds another, Titanoeca (with two species) not found there, but allied to Amaurobius, which has three amber species. There is no family of spiders so abundantly represented in tertiary deposits as the Theridides, more than a fourth of the European species belonging here, with fourteen genera. America is for once poorer here than the stratified deposits of Europe, but possesses a single species of Linyphia, two of Theridium, and some egg cocoons referred for convenience to the comprehensive genus Aranea; Linyphia possesses three species from amber and two from Rott; Theridium is one of the very richest of the amber genera, having sixteen species, while three other species are described from Oeningen and Aix. The proportion of representation is very different in the Epeirides, eight per cent. of the European fossil spiders belonging in this group, while the proportion in America is forty-four per cent; Florissant possessing even more species than the amber, including seven or more species of Epeira, one each of Tetragnatha and Nephila, neither of which have before been found fossil, and four of a new genus, Tethneus, remarkable for its stout front legs. Five species of Epeira are reported from the European tertiaries, two each from amber and from Rott, and one from Oeningen. Not only, then, is Florissant peculiar for its richness in species of this family, but no other group of spiders shows so many novelties for the tertiary fauna.

The only Myriapod is a large species of Iulus, represented by half a dozen fragments, in which only the body segments are preserved.

Finally there is an odd form of animal, which although abundant and tolerably preserved is still of doubtful position. It is flattened oniscifform in shape, the body generally arched, and appears to be formed of only four nearly equal segments; each of the first three bears a pair of long swimming (?) legs, bearing a two-jointed tarsus armed with a single claw; both femur and tibia are compressed, expanded, and the latter fringed with hairs. The first segment has a median slit anteriorly, but there is no sign of a head on the 30 or 40 specimens examined, although the anterior portion of the alimentary canal appears to be extensile, being frequently preserved as protruding beyond the limits of the body and armed at the tip with a broken chitinous ring. There are no other mouth parts nor signs of eyes or antennæ. The abdomen is furnished at tip with a set of harder converging parts, which look as if they served the purpose of dragging the body backward. Larvae of any sort are exceedingly rare in the Florissant deposits, and there is no group known to me to which this seems to bear any similitude. There are sometimes faint indications of several joints to the abdomen, but when closely examined these appear to be illusory; and this would certainly exclude it from the Crustacea, unless indeed it belonged, as has been suggested to me by Prof. A. Hyatt, to a parasitic type. It is from 8 to 10^{mm} long.

Animal remains besides those of insects are rare at Florissant. The most abundant is a species of thin-shelled Planorbis, which is not uncommon, and always occurs in a more or less crushed condition; it is the only mollusk yet found there (excepting a Physa or allied form and a single small specimen of a bivalve, referred to above in the section from the southern lake), and according to Dr. C. A. White is probably undescribed, although very similar to a species found in the Green River shales, differing from it principally in its smaller size.

Fishes rank next in numbers. Eight species have been found, belonging to four genera; of Amiidae we have *Amia scutata* and *A. dicty-*

ocephala; of Cyprinodonts, *Trichophanes foliarum* and *T. Copei;* of Catostomidae, *Amyzon pandatum*, *A. commune*, and *A. fusiforme;* and of Siluridae, *Rhineastes pectinatus.* All the species have been described by Cope* excepting *T. Copei*, which was published by Osborn, Scott, and Speir.

Several bird's feathers have been found in these beds, and a single tolerably perfect Passerine bird, with bones and feathers, has been described by Mr. J. A. Allen under the name of *Palaeospiza bella*, and admirably illustrated by Blake. No other figure of a Florissant animal has yet been published. Besides these, Professor Cope has just described a plover, *Charedinus sheppardianus*, and writes that a finch is also found in these beds.

The plants, although less abundant than the insects, are exceedingly numerous, several thousand specimens having already passed through the hands of Mr. Leo Lesquereux. Of these he has published 37 species in his Tertiary Flora,† about two-fifths of which are considered identical with forms from the European Tertiaries. Of other specimens which he received after the publication of that volume, he has already given a cursory account in the annual report of Dr. Hayden's survey for 1876. He has also mentioned others in his review of Saporta's Monde des Plantes, and still others in letters. From these sources and from memoranda communicated by him, based on the plates of the Florissant species prepared for the eighth volume of Hayden's Report, the following review is drawn:

Among the exogenous plants the following polypetalous families are represented: Some flowers with long stamens are referred doubtfully to the genus Bombax, one of the Malvaceae. Of Tiliaceae, a species of Tilia has been found; of Rutaceae, one species of Ailanthus. Of Anacardiaceae, three species of Rhus are described under the names *Evansi*, *rosaefolia*, and *Haydeni*, and three or four others mentioned. Of Juglandeae one species, and one of Zanthoxyleae. Of Rhamnaceae, *Paliurus Florissanti* is the only species. A few leaves of Celastrus represent the Celastraceae. The Sapindaceae are very abundant, three genera occurring; leaves of *Staphylea acuminata*, numerous specimens of *Sapindus stellariaefolius* and *S. angustifolius*, as well as of two or three other species of the same genus, and two species of Acer, represented by flowers, leaves, and fruit. The flora has a large number of Leguminosae, of the genera Robinia, Colutea, and Cassia, besides *Acacia septentrionalis* and *Mimosites linearifolius*, described in the report mentioned. The Rosaceae show a Prunus, leaves of Rosa, and species of Spiraea, with very finely preserved leaves of an Amelanchier, scarcely distinguishable from some of the varieties of the living species. *Liquidambar europaeum* Al. Br. represents the Hamamelidae; numerous leaves of Weinmannia, the Corniculeae; and, finally, there is a single species of Araliaceae, closely allied to *Aralia multifida* Sap. Excepting the Liquidambar none of the Polypetalae have been shown to be identical with European forms.

Among the monopetalous plants the Ericaceae are represented by *Vaccinium reticulatum* Al. Br., together with one or two species of Andromeda. Two species of Ilex, one described as *I. subdenticulata*, represent the Aquifoliaceae; one of Diospyros, the Ebenaceae; a species of Catalpa, the Bignonaceae. Oleaceae have a flowering branch of Olea and four species of Fraxinus, one referred to Heer's *F. praedicta* and another described as new under the name of *F. Brownelli.*

The apetalous angiosperms show a great variety of forms at Floris-

* See Bull. U. S. Geol. Surv. Terr., 2d ser., No. 1, pp. 3–5, 1875.
† Report U. S. Geol. Surv. Terr., vol. 7, 4to, Washington, 1878.

sant, and among them many are referred to species from foreign tertiaries. Urticacea are the most numerous of all plants; three species of Ulmus occur, *U. tenuinervis* Lesq., peculiar to Florissant, *U. Braunii* Heer, and *U. Fischeri* Heer, both found in the European Tertiaries; of Celtis there are leaves having a close affinity to the existing *C. occidentalis* and its variety *integrifolia* Nutt.; they may, however, represent two species; a single species of Ficus represents a European form, *F. lanceolata* Heer; but the mass of specimens—nearly or quite one-half of all that have been brought from this locality—represent species of Planera; Lesquereux states that he has at least two thousand specimens of "leaves of *Planera longifolia* [Lesq.] and of its varieties, which come near *Planeri Ungeri* [Ettingsh.], and perhaps another species of the same genus." The Juglandaceae are represented by single specimens of *Juglans thermalis** and *Pterocarya americana*, besides species of Palaeocarya and Engelhardtia. The six Cupuliferae recorded are all European species, viz: *Quercus neriifolia* Al. Br., *Q. drymeja* Ung., *Q. salicina* Sap., *Q. antecedens* Sap., *Carpinus grannis* Ung., and *C. pyramidalis* Heer. The Myricaceae are the next most abundant type after Planera, being represented especially by *Myrica acuminata* Ung., and *Callicoma microphylla* Ettingsh. (a true Myrica), both European species; there are, besides, no less than seven other species of Myrica, one of them referable to the European species, *M. Ludviigi* Schimp., another to a variety, *acutiloba*, of another European species, *M. latiloba* Heer; but the others new and either considered allied to *M. Zacchariensis* Sap. and *M. arguta* Sap. of the beds at Aix in Provence, or described under the names *M. Copeana*, *M. Bolanderi*, and *M. insignis;* of the last, two specimens are mentioned; of the other two, only one. Of Betulaceae, Betula and Alnus are represented by a single species each, *Betula dryadum* Brongn. and *Alnus Kefersteinii* Göpp., both again European forms; cones of the latter are found. Salicaceae are tolerably abundant, Salix and Populus being represented by four species each; the four species of Salix are all identified as belonging to forms previously described from Europe or Alaska, viz: *S. Lavateri* Heer, *S. integra* Göpp., *S. media* Heer, and *S. varians* Göpp.; one species of Populus is referred to *P. latior* Al. Br., of the variety represented by Heer as *denticulata;* two others are considered new, one belonging to the section of *P. glandulifera* Heer; while the fourth, represented by a large number of leaves, very variable, especially in size, is considered as identical with *P. Heerii* Sap. of the gypsum beds of Aix. Finally, of undetermined plants in this group there is a species of Trilobium, and a Carpites, described as *C. Pealei.*

Among the Coniferae there is considerable variety, five species occurring, of four genera, all but one of the species represented in the European flora. There is, first, *Pinus palaeostrobus?* Ettingsh.; next, well-preserved branches of *Taxodium distichum miocenicum* Heer; and abundant remains of *Glyptostrobus Europaeus* Heer; as well as two species of Sequoia, *S. Langsdorffii* Brongn., and *S. affinis* Lesq. The presence of the last-named genus is also well attested by the remains of gigantic silicified trunks in an erect position.

Finally, in the lower orders of plants, the following have been found: Of the Palms, a large specimen of a Sabal related to *Sabal major* Ung. of the European miocene; of the Araceae, *Acorus brachystachys* Heer, first described from Spitzenberg; of the Typhaceae, finely preserved leaves of a Typha; of the Naiadaceae, two species of Potamegeton; of the Iridaceae, well-preserved leaves of an Iris; of the Gramineae, two frag-

* "Hot Springs, Middle Park," is the locality given in the text of Lesquereux's Tertiary Flora, but in the table, p. 327, it is also credited to Florissant.

ments of leaves of Phragmites; of Filices, numerous specimens of a single species; of Rhizocarpae, many specimens of *Salvinia Alleni*, described from Florissant and Elko, Nev.; of Musci, *Hypnum Haydeni*, likewise known only from this locality; and of Characeae, two specimens of a Chara.

Mr. Lesquereux has also found large numbers of leaves of a peculiar plant without any kind of neuration, which is apparently referable to the Proteeae.

We have thus from 90 to 100 species of plants already recognized from these Florissant beds, of which nearly half the species belong to the apetalous exogens. About 40 of the species are figured in the Tertiary Flora of Lesquereux.

According to this writer, such an assemblage of plants indicates a climate like that of the northern shores of the Gulf of Mexico at our epoch. "The preponderance of conifers, of shrubs, * * * of trees of small size, * * * gives to the flora a general aspect which recalls that of the vegetation of uplands or valleys of mountains." Palms are almost entirely absent, only a single specimen of one species of Sabal having occurred. "The leaves of some species are extremely numerous, none of them crumpled, folded, or rolled, as if driven by currents, but flat, as if they had been imbedded in the muddy surface of the bottom when falling from the trees or shrubs along the borders of a lake."

It is remarkable for the almost complete absence of hard fruits; and this, with the presence of flowers, of unripe carpels of elm and maple, and of well-preserved branches of Taxodium, which in the living species "are mostly detached and thrown upon the ground in winter time or early spring," led Mr. Lesquereux to believe that the deposition of the vegetable materials took place in the spring time, and that the lake gradually dried during summer.

To this we may add that the occurrence of Acorus, of Typha, and especially of Potamogeton, leads to the conclusion that the water of the lake was fresh, and not saline or brackish, equally proved by the fish, according to Cope, and by the presence of larvae of Odonata and other insects whose earlier stages are passed only in fresh water.

Neither the groups of fishes which have been found, nor the water-plants, the water-insects, nor the mollusks exclude Mr. Lesquereux's suggestion of the annual drying of the body of the lake. Moreover, certain thin layers are found overlying coarser deposits, which are sun-cracked through and through; but on the other hand the thickness of the paper shales, upon which most of the fossil remains are found, and which are composed of uniform layers of triturated flakes of volcanic products, being necessarily the result of the long-continued action of water, excludes this idea. The structure of the rocks rather indicates a quiet deposition of the materials in an unruffled lake through long periods, interrupted at intervals by the influx of new lava-flows or the burying of the bottom sediments beneath heavy showers of volcanic ashes.

The testimony of the few fishes to the climate of the time is not unlike that of the plants, suggesting a climate, as Professor Cope informs me, like that at present found in latitude 35° in the United States; while the insects, from which, when they are completely studied, we may certainly draw more definite conclusions, appear from their general ensemble to prove the same or a somewhat warmer climate. If we inquire what testimony the fossil spiders of Florissant bear to the climate of that district in tertiary times, there is only one answer to be given; the present distribution of their allies certainly points to a considerably

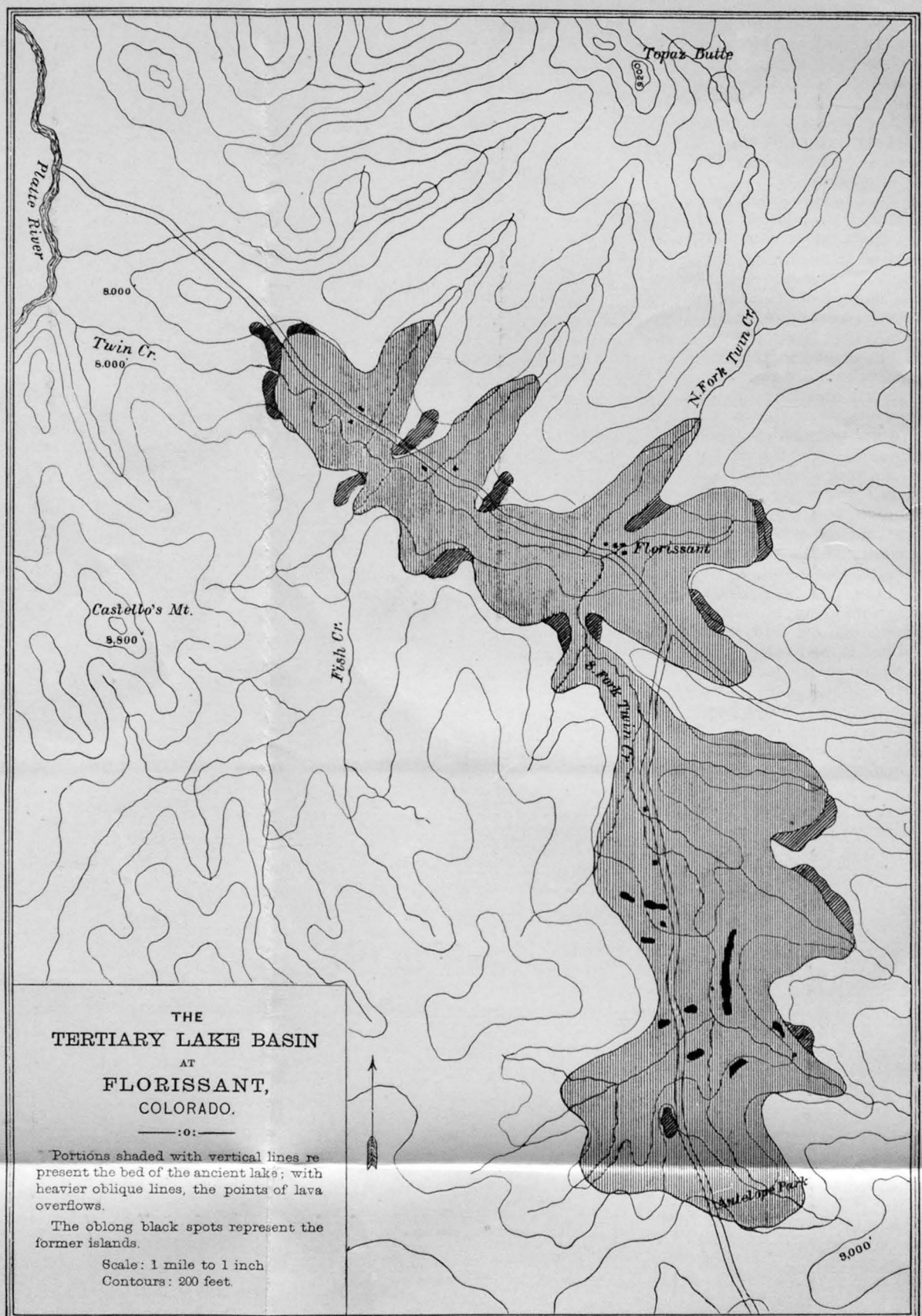
warmer climate than now—a climate which may, perhaps, best be compared to the middle zone of our Southern States. The known living species of the genera to which they belong are in general credited to regions like Georgia in this country and the two shores of the Mediterranean in Europe. The presence of species of Theridium, Linyphia, Tethneus, and Epeira, including two-fifths of the species, has no special significance; but Thomisus, Segestria, Clubiona, Anythaena, and Titanoeca, and especially Parattus, Tetragnatha, and Nephila, certainly present an ensemble, the indications of which cannot be overlooked. White ants are essentially a tropical family, only one or two out of eighty known species occurring north of latitude 40°. In North America only three have been recorded north of the border of the Gulf of Mexico, excepting on the Pacific coast, where one or two more extend as far as San Francisco. Two species, both belonging to the second section, are found in the valleys below Florissant, in 39° north latitude. Florissant itself is situated 2,500 meters above the sea, and the presence of so considerable a number of white ants imbedded in its shales is indicative of a much warmer climate at the time of their entombment than the locality now enjoys. So, too, the occurrence among other Neuroptera, of Raphidia and Inocellia, of Lithagrion, and probably of the peculiar forms of Agrion, bears similar testimony; and the discovery of so many genera represented in or allied to those found in the Prussian amber is also indicative of a much warmer climate, since the amber fauna itself is held to show, for that period and place, a climate not far removed from that of the two borders of the Mediterranean. Investigation of other forms increases the weight of this evidence at every step, for nearly all the species (very few, certainly, as yet) which have been carefully studied are found to be tropical or subtropical in nature. As, however, a large proportion of those studied have been selected for some striking feature, too much weight should not be given to this evidence.

As noted above, the superabundance of specimens of single species of plants (Planera and Myrica) is repeated in the insects, where certain species of Formicidae among Hymenoptera, of Bibionidae among Diptera, of Cercopida and of Alydina among Hemiptera are to be counted by fifties and hundreds.

The only other general feature which may already be noted among the insects is an unexpected paucity of aquatic larvae or the imagos of water-insects. Hardly a dozen neuropterous larvae have come to hand, very few aquatic Hemiptera in any stage, and of Hydrophilidae and other water-beetles no great number. The paucity of neuropterous larvae is the more remarkable from the abundance of Phryganidae, while not a single larva-case has been found.

As to the age of these deposits, the opinions of Mr. Lesquereux, based on the study of tertiary plants, and of Professor Cope, drawn from his knowledge of tertiary fishes, are far more harmonious than one would expect from their known divergence of view concerning the testimony of the fossils to the age of other tertiary beds in the West. Such disparity of ideas did hold at first, Mr. Lesquereux maintaining in his earlier notices of the flora the probability of its later miocene age; in the Tertiary Flora he placed it in the "Upper Green River" division of his "fourth group," together with the flora of Elko, Nev., the Green River beds being placed directly beneath them. In Hayden's report for 1876 he refers the Florissant deposits to the upper miocene. In his review of Saporta's Monde des Plantes,* while still considering it as miocene, he points out certain important relations which it bears to the flora of

*Am. Journ. Sc. (3), xvii, 279. (1879.)


Topaz Butte
9023
Platte River
8,000'
Twin Cr.
8,000'
N. Fork Twin Cr.
Florissant
Castello's Mt.
8,500'
Fish Cr.
S. Fork Twin Cr.
Antelope Park
9,000'
THE
TERTIARY LAKE BASIN
AT
FLORISSANT,
COLORADO.
—:o:—
Portions shaded with vertical lines represent the bed of the ancient lake; with heavier oblique lines, the points of lava overflows.
The oblong black spots represent the former islands.
Scale: 1 mile to 1 inch
Contours: 200 feet.

Aix, in Provence, considered as eocene. But now, after a more careful revision, drawn from more extended sources, he writes that while, by the presence of many genera, "there is an evident relation of the Florissant flora with that of the European miocene, yet by the affinities and even identity of some of the species with those of the flora of the gypsum of Aix, which, according to Saporta, includes types related to those of the whole extent of the tertiaries from the upper cretaceous to the oligocene and above, I should rather refer this group to the lower miocene or oligocene."

Both Lesquereux and Cope agree in placing the Florissant beds at the same horizon as those of Elko, Nev., and also those directly above the Fish-cut beds at Green River, Wyoming. Lesquereux has identical species also from White River, Colorado, among specimens communicated by Mr. Denton. Cope calls the Florissant and Elko deposits the Amyzon beds, from the prevalence of that type of fish, and refers them to the "later eocene or early miocene."

Mr. Clarence King places the Green River deposits in the middle eocene, but considers the Elko deposits of the same age.

We may therefore provisionally conclude, from the evidence afforded by the plants and vertebrates, that the Florissant beds belong in or near the oligocene.

At present no geological conclusions can be drawn from what is known of the insects. So far as specific and generic determination has proceeded, nothing identical has been found in the Green River and Florissant beds,* but some remarkable affinities have been noticed. To attempt, however, to draw any conclusion as to the age of either of these deposits, and especially of that of Florissant, before a closer examination is made, would be folly. The entire series of fossil insects from the beds of Aix, Oeningen, and Radoboj requires a careful generic revision, the Coleoptera alone, perhaps, excepted, and until this is done it will be difficult to make much use of the information given us in the works of European authors. This should not be considered as reflecting upon the character of these works, for it must be remembered that they were nearly all completed thirty years ago and could not be expected to meet present demands. It is, indeed, not impossible that the richer American fields, the exploitation of which has only just begun, may yet be found the best basis for the study of the relationship of the tertiary insect faunas of Europe.

* Some remains of egg cocoons of spiders are referred for convenience to the same species, but, of course, no weight whatever can be attached to obscure remains of this sort.