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NOTES ON THE MAMMALS OF THE LAKE MAXINKUCKEE REGION.[1]

BY BARTON WARREN EVERMANN AND HOWARD WALTON CLARK.

While engaged in a biological survey of Lake Maxinkuckee, Indiana, under the direction of the Honorable George M. Bowers, U. S. Commissioner of Fisheries, we took occasion to observe the various species of mammals occurring in that region and to make notes concerning their abundance and habits. Special attention was paid to those species such as the muskrat, mink and raccoon, whose habits relate them ecologically to the fishes and other life of the lake. Many observations were made and noted, however, regarding other species. These observations seem worth putting on record and this we have endeavored to do in the present paper.

Lake Maxinkuckee is a small glacial lake in the southwest corner of Marshall County, Indiana. It is on the Terre Haute and Logansport Railroad (Vandalia Line), 34 miles south of South Bend, Ind., 94 miles southeast of Chicago, and 149 miles north of Terre Haute.

The lake is about $2\frac{3}{4}$ miles long and about $1\frac{1}{2}$ miles wide. The total area of the lake is 1854 acres. The greatest depth is 89 feet, and most of the lake is more than 25 feet deep.

The country surrounding the lake lies wholly in the glacial region of Indiana. The topographic features are somewhat varied. There are numerous small hills with gentle slopes, and among them

[1] Published by permission of the Honorable George M. Bowers, United States Commissioner of Fisheries.

are a good many kettle-holes, some of considerable depth, and with more or less water during wet seasons, while others are less deep and usually dry. These kettle holes usually support a more or less rank growth of vegetation consisting of grasses, sedges, bushes and small trees, forming thickets very attractive to certain mammals. The highest land anywhere about the lake is on the east side where it rises 136 feet above the lake surface. There is about the lake a good deal of marsh land; the most considerable areas being that about Norris Inlet at the south end and that on the west side surrounding Lost Lake and extending southward from it along its outlet. Lost Lake is a small lake a few rods west of Lake Maxinkuckee; it is in fact an expansion of the Maxinkuckee outlet. Between the two lakes and bordering the outlet is Green's marsh which consists of several acres of wet land. Just south of this is Green's woods, an open woodland with little underbrush, where certain animals are apt to be found. On the west side of the railroad and facing it at the southwest corner of the lake is a large gravel pit and with high bank on the west which is a favorite place for the striped gophers. Southwest of this, a short distance, is Walley's woods the largest and most virgin forest near the lake. At the south end of the lake is Farrar's woods, smaller and less dense, but with heavy underbrush. East of the north end of the lake is a considerable acreage of open forest of large trees where raccoons, squirrels and other arboreal species occur.

In the following list of species we have followed the nomenclature and sequence of Dr Hahn's recent paper on mammals of Indiana.[1]

List of Species.

1. Didelphis virginiana Kerr.

Common Opossum.

According to old settlers the Opossum used to be common as far north as northern Indiana, but disappeared from there many years ago. In recent years they have been returning northward

[1] The Mammals of Indiana, 33d Annual Report, Department of Geology and Natural History of Indiana, 1908, pp. 417–663.

and are now tolerably common throughout the northern part of the state. About 1887 an old trapper near Fort Wayne caught one and reported that it was the first he had seen for 20 years. No more were seen in that region until about 1900, when they began to be captured occasionally. In October, 1903, three were captured in Walley's woods southwest of Lake Maxinkuckee and three others were trapped at Norris Inlet. It was not seen by us at the lake until the summer of 1906, when on August 5, an adult example was found dead on the lake shore just north of the Outlet. On October 30, 1906, another was seen in the possession of a boy at Culver, who reported the capture of 3 on the previous night. One is reported to have stayed under the Barr Cottage on Long Point during the winter of 1906–7. About September 3, 1907, boys living in Culver got an old Opossum with a number of young in her pouch. They did not count the young, but let her go.

The northward movement of the Opossum seems to have been general over the state. They are occasionally taken in Marshall and adjoining counties. They are frequently seen at Fort Wayne, Indiana, a few being captured every winter. Mr. J. J. Hildebrandt, of Logansport, reported that some one had brought him about October 1, 1904, an old Opossum and 12 young, the latter about two-thirds as large as rats. The first night she killed 9 of them. He kept the other three and the mother for about 3 weeks, when he took them to the woods and turned them loose.

Devouring its young in captivity seems to be a common habit of the Opossum, and almost everyone who has tried to keep them together has had the young destroyed by the mother.

The Opossum is usually caught in this region for its fur. The prices now obtained by the trappers are 15 to 25 cents. The pelts are becoming more valuable every year, the prices brought in the London market in 1910 for prime skins ranging from 45 cents to $1.

The food of the Opossum is chiefly insects, though they are also fond of pawpaws. They also feed to some extent upon the mussels which they find in the lake. They are an innocent, harmless animal and should be protected.

2. Cervus canadensis (Erxleben).
Elk.

Remains of the Elk, especially the horns, are still occasionally found in the peaty bogs in Marshall county, and attest the former presence of this animal in the vicinity of the lake. They evidently disappeared sometime before the deer. The antiseptic nature of the peat has preserved these remains much longer than elsewhere, so that the evidence of the animal's former occurrence remains much longer in regions where there are peat-bogs than in other places. Mr. S. S. Chadwick has in his possession part of an elk-horn 3 inches across at the base and 22 inches long, found in low ground a few miles southeast of the lake about 1904.

3. Odocoileus virginianus (Boddært).
Virginia Deer.

Formerly Deer were common throughout Indiana but none has been seen in recent years. Occasionally a deer is reported from the Kankakee region west of Maxinkuckee but none of these reports has been authenticated. It is said that one was killed in Jasper county in 1890 and one seen in Newton county in 1891.[1]

4. Sciurus carolinensis leucotis Gapper.
Gray Squirrel.

Formerly the Gray Squirrel was very abundant throughout Indiana and southern Michigan. Forty to fifty years ago squirrel hunting was an avocation in which nearly every farmer and farmer's son, as well as many of those who dwelt in the villages and towns engaged, and a poor marksman indeed was he who did not return from a morning in the woods with the old muzzle-loader and anywhere from 6 to 20 squirrels. To be regarded as a real expert shot, however, it was necessary to be able to "bark" the squirrel, that is, to kill it simply by shooting through the bark of the limb on

[1] Butler, Proc. Ind. Acad. Sci. 1894, p. 83.

which the squirrel happened to be sitting without actually hitting the squirrel. There were in every community a number of such expert squirrel hunters. In southern Michigan a large proportion of the Gray Squirrels were *black!* while in middle Indiana a black squirrel was not often seen. In the Maxinkuckee region this squirrel is now a very rare species. Mr. Chadwick says he knows of only 2 or 3 having been killed near the lake in the last 6 or 7 years. The only one ever seen by us in that region was observed May 9, 1901.

5. Sciurus niger rufiventer E. Geoffroy.

Fox Squirrel.

Although formerly quite common in central and northern Indiana, the Fox Squirrel was never so abundant as was the Gray Squirrel when the country was new. But as the forests were cleared away, farms opened up, and open woodlands and pasture lots became more and more common features of the country, the Gray Squirrel became practically extinct while the Fox Squirrel was more nearly able to hold its own, albeit, even this species is far from being as abundant as formerly. In the region with which the present paper deals the Fox Squirrel was very rare until recently. None was seen or heard of in 1899. In 1900 one was seen in Walley's woods on September 28, and one near Delong the next day. The first of these was killed by some one in October. Several were killed by a local hunter in the fall of 1902. In 1904, Fox Squirrels were occasionally seen. Two were killed November 29; one was seen in the Assembly Grounds; on December 15 a large oak on Long Point was cut down and was found to contain 2 Fox Squirrels, probably young of the year, but fully grown. In the fall of 1905 3 or 4 were seen on Long Point. In 1906 two were killed south of the lake September 12, two days later one was seen in Farrar's woods, and on September 17 another was noted on the east side of the lake. In the autumn of 1907 one or more were observed in Green's woods. Doubtless it is no less frequent in the open woods east of the lake.

The Fox Squirrel prefers the open woods and is rarely seen in heavy, dense forests. Wherever there are a few large old trees with

hollow limbs or trunks on the borders of cornfields there these squirrels are apt to take up their homes if there be any in the neighborhood. Unless disturbed the same pair will occupy the same tree for several years, probably until they die or are killed.

These squirrels feed upon all sorts of nuts and are very destructive to the farmer's corn. In January, 1908, Mr. A. M. Evermann observed Fox Squirrels near Burlington (56 miles south of Maxinkuckee) feeding upon the seeds of the cocklebur, *Xanthium strumarium*. The squirrels would strip the burs from the plants and carry them to a nearby log on which they would sit on their haunches while they gnawed the burs and removed the seeds. At the time the ground was covered with snow.

So far as we have been able to learn this habit of the Fox Squirrel had not been previously observed.

6. Sciurus hudsonius loquax Bangs.

Red Squirrel.

The Red Squirrel, Pine Squirrel, Chickaree or Boomer, as it is variously called, is a northern species which is gradually extending its range southward in Indiana. Until within the last decade it was rare or wholly unknown in most parts of the state south of Logansport, though it was not uncommon in the more northern counties. On December 24, 1889, one was shot near Kewanna which is about 12 miles south of Maxinkuckee. It was regarded as a rarity in that region. About 1900 one was seen near Frankfort, about 70 miles south of Maxinkuckee, the first ever noted in that county. We have learned from Mr. Sidney T. Sterling of Flora, Carroll County, that it has recently appeared in that county.

When we began our investigations at Lake Maxinkuckee, the Red Squirrel was not common. In 1899 only one was seen, in September, near Lake Manitou. On September 24, 1900, a young one, just able to crawl about, was found on the ground in Farrar's woods. It had probably fallen from the nest. It was taken home and fed and soon became quite tame. It was not caged by us but was permitted to run about the room, and soon became quite playful and mischievous. One of its favorite positions was a seat on one's shoulder where it soon called attention to itself by a gentle

nipping of the ear of the person on whose shoulder it was sitting. One or more were seen October 1, 14, 19, and 30. In 1904, they were more numerous; several were noted October 19 and 27 and at various times thereafter until January 3, 1905, when we left the lake, until August, 1906, from which month until October 31, several were seen.

On September 13, 1907, and at various times thereafter until the middle of November, one or more were seen on any day when we cared to look for them. According to Mr. S.S. Chadwick they have continued to increase up to the present time. Their favorite haunts about Lake Maxinkuckee are the heavier woodlands at the south end of the lake, Walley's woods, the timbered areas on the east side and the groves north and east of the Academy grounds. Only rarely have we seen it on Long Point, while on several occasions we have observed it on the Tippecanoe River near Delong.

While the Red Squirrel is a merry playful little animal, there is little else to commend it to one's favor. While its principal food consists of nuts and seeds of various kinds it is very destructive to birds' eggs and even young birds. It is also popularly thought to drive the fox squirrel out of regions which it formerly occupied, and there is probably a basis of fact in this belief. On account of its small size it is not much hunted for food, although it makes a very delicious stew.

7. Tamias striatus (Linnæus).
Ground Squirrel.

The Ground Squirrel or Chipmunk is an interesting and familiar little animal in all suitable situations in Indiana. Every farmer's boy in the state knows it well. Wherever there are open woods or pastures and old decaying trees, rocky ledges overgrown with vines, fallen timber and brush piles, and Virginia rail fences that have not been well kept, there the Chipmunk is quite sure to be found. Though still abundant in most parts of Indiana they are less so than formerly. At one time they were so numerous as to be regarded as a serious pest and bounties were paid for their scalps.

About Maxinkuckee they are still rather common and may be seen almost anywhere about the lake and on adjoining farms.

Nearly all portions of the lake shore are favorable. Wherever there are old trees on the north, east and south sides, there you may find Chipmunk families. The old oaks at the southwest corner of the lake and those on Long Point have never, since our acquaintance with the lake, been without their Ground Squirrels. The open woods between the two lakes and Walley's woods are also favorite situations. A visit to any of these regions would almost certainly be rewarded by a glimpse of a pair or more of these merry creatures.

On Long Point several pairs usually have their homes, and from May or June until late in October they may be seen chasing each other along the fences or sitting at the root of some hollow old oak where they often remain chirping hours at a time. During the winter of 1900–1901, one had its home under the cottage in which we lived. During the fall it was seen daily gathering nuts, seeds, and grain which it stored for winter use. On bright sunny days it worked persistently from early morning until evening, usually stopping in the middle of the forenoon and again about two o'clock in the afternoon to sit on the south steps of the cottage or at the root of a gnarled old oak near by, where it would keep up an almost incessant chirping for an hour or more. Toward evening it generally disappeared, not to be seen again until 7 or 8 o'clock next morning. On dark and gloomy days it sometimes failed to appear. On November 27 it went into winter quarters and was not seen again until the twentieth of March following when it was seen scurrying about as lively as ever. From that date on it and others were noted occasionally on bright sunny days until warm weather, when they might be seen every day, usually near the edge of their burrows or other safe refuge into which they would scamper, on the slightest alarm, with a rapid succession of sharp chipping noises. During the summer and early fall they are ever in evidence and are not easily frightened. As fall comes on and seeds and nuts mature, these interesting little animals become more active and very busy laying up their winter stores, stopping now and then to bask in the sun, their crammed cheek-pouches giving them a comical, mump-like appearance. At this time of the year they have a call or note quite different from the sharp chipping noise usually heard in the summer, it being a succession of hollow clucking sounds, most interesting when heard at some distance through the autumn

woods. A little later, toward the last of October, when frosts are frequent and the days are chill, they may be seen only on those days that are bright and sunny, usually sitting in the sun on the root of some old hollow tree, chipping merrily. Still later, as cold days become the rule, only the brightest days tempt them out; then they sit quietly where the sun shines warmest, chipping not at all or only now and then very mildly.

Following are some of our notebook records:

1899.—October 3, still out and busy gathering food. 1900.—October 18 and 19, noisy about and under our cottage; October 22, noted; 24th, one seen going under cottage; 25th, the one belonging to our cottage was quite noisy for a while; 26th, 27th and 30th, still out and noisy; November 3, 5, and 6, seen; 27th, seen for last time. 1901.—March 20, the one under our cottage came out today and scurried about as lively as ever. October 19–21, very common on Long Point. At least 20 between our cottage and the end of Long Point, all very busy garnering their winter stores, but mixing a good deal of play with their work. 1902.—June 19, two seen on Long Point; 22d, one at tip of Point and several elsewhere. 1904.—October 18, several seen; 19th, on early morning trip around the lake saw only one; November 5, one seen. 1906.—September 17, several seen on east side; October 5, a few seen; 14th, a great many seen on east side, all chipping merrily; 25th, caught one in trap on Long Point; 30th, a very bright colored one seen. 1907.—September 26, one heard and another seen on east side; 29th, one heard at Walley's birch swamp; October 4, one seen on Long Point filling its pouches with ragweed seeds which it skillfully gleaned from the standing weeds; 10th, one seen on Arlington coal bin, and another with very full pouches basking on a rock near the Duenweg cottage. Loud gun shots fired at coots near by did not frighten it; 14th, one heard chucking near the birch swamp.

In some sections of its habitat the Chipmunk is said to be migratory, but our observations lead us to believe it to be non-migratory in Indiana.

The Chipmunk feeds chiefly upon nuts and seeds of various kinds. In regions where beech trees are found their delicious nuts constitute its principal food. Hickory nuts, particularly the thinner shelled species, hazelnuts, acorns and corn are also highly prized.

In the spring they may do some damage to the corn fields by digging up the newly planted grains; but this is infrequent and apt to occur only when the field borders an open woods. As already recorded, on October 4, we observed a Chipmunk going from one ragweed to another, stripping off the seeds and cramming his pouches with them; from which it appears that they are of some value as weed-seed destroyers.

On the whole, the Chipmunk is a harmless and very cheery little creature which, in moderate numbers, does little or no harm and adds much to the attractiveness of any region.

8. Citellus tridecemlineatus (Mitchill).

Striped Gopher.

This gopher is an intrusion from the prairie fauna to the westward of Maxinkuckee. It appears to be gradually extending its range eastward. Thirty years ago it was very rare or entirely unknown in Indiana except in the prairie counties along the western border of the state. During 1883–1885 the senior writer of this report had exceptional opportunities to become quite familiar with all parts of Carroll County, which lies some 50 to 80 miles south and a few miles west of Maxinkuckee, and in those years he saw a total of only 3 or 4 pairs of Striped Gophers within its borders and they were all in the extreme western part of the county where the land is largely prairie. During many years of almost continuous residence in that county (1858 to 1885) the species was never seen east of the Wabash River, but recently it is said to have appeared there. In Vigo County it was common from 1886 to 1891 and has so increased in abundance since then as to have become a serious pest.

In 1899 when our field work began at Lake Maxinkuckee the Striped Gopher was rare in that region; in fact, only one or two pairs were seen during that season. They had their home at the gravel pit and were observed most frequently in August. In 1900 they were more numerous. Besides the colony at the gravel pit, one or more were seen occasionally further south along the railroad, several about the sandy hills southeast of the lake, and now and then one was noted on Long Point. In 1904 they had still further increased.

On July 3 one was found dead on the railroad near Murray's where it had evidently been killed by a passing train. One or more were seen on Long Point, and in the autumn of 1906 several were observed there. In 1907, soon after corn-planting, these little rodents were found to have increased greatly in numbers about the gravel pit. They became very destructive to the young corn in a field nearby. They would pull up and eat the young plants. One individual was seen to pull up 20 stalks. The owner of the field shot 20 of them in May and early June. Many of them were old ones while others were small and apparently young of the year. The gophers of this colony had their holes or burrows in and about the gravel pit. The colonies on the sandy farms south and southeast of the lake had also increased considerably in numbers, as had also that on Long Point. One was caught by a cat on Long Point in June of that year. In 1910 it was learned that they were becoming more and more abundant every year. Several were seen on Long Point. On the farms south, southwest and southeast of the lake they are getting to be a pest. They are probably now found west, north and east of the lake in suitable situations, but we have not observed them there, as our field work has not recently extended into those regions.

The Striped Gopher feeds upon young corn, wheat, oats, grass and other tender plants, also upon grain and other seeds of various kinds. It is very prolific and, once it has secured a foothold in any locality, it is quite certain to become a serious pest sooner or later unless drastic measures are taken to hold its numbers in check.

9. Marmota monax (Linnæus).

Groundhog.

The Woodchuck, Marmot or Groundhog as it is usually called in Indiana, is fairly common in most parts of the state. It most delights in the more hilly districts covered with open forests or grassy meadows, particularly those near fields of red clover. It is not rare about Maxinkuckee. One or more pairs can usually be found on the hillsides about Lost Lake, others in or at the edges of the fields along the Outlet, several north and east of the lake, and a few in most other suitable situations. In 1900 one had its

home in a burrow under one of the buildings on Long Point. In the fall of 1904 some burrows were observed in the middle of a level field, the holes going vertically downward several feet. This is rather unusual, as the Groundhog almost invariably selects a hillside or bank in which to dig its burrow.

In May and early June, 1901, five were shot in Green's field near the gravel pit, 2 of which were old females, and 3 were young. About the last of June, 1901, a half-grown young was caught near Lost Lake. When pursued it ran until overtaken, when it turned and showed fight. August 25, 1906, several were noted in fields near the railroad south of the lake. They sat up erect and watched us go by. September 13, 1906, one was killed near Lost Lake. September 22, 1907, several burrows, evidently of this animal, were seen along fences between the lake and the tamarack swamp.

In the early spring, soon after the first warm days have come and the only remaining reminders of the passing winter are a few snow banks in protected places or occasional little flurries of snow, and when the first green blades of grass are just peeping through the matted dead grass of the previous year on warm hillsides and along fence-rows, the first Groundhog of the season is apt to be seen. He will most likely be found out in the open in some old meadow, preferably a clover-field, and near his den. Here he appears early in the afternoon when the sun shines warm on the hillside. He comes out not only to feed upon the young and tender stems and leaves of the clover and other early spring plants, but he also delights to lie in the warm sunshine or to sit upright near his burrow looking about over the fields and renewing his acquaintance with the scenes which have remained only as a memory since he went into winter-quarters the previous fall. Later in the spring and in summer and fall, if you should be abroad in the early morning when the sun is just showing and the dew still hangs heavy and sparkling on the tender new grass, you will almost certainly be rewarded by seeing one or more Woodchucks in any cloverfield you chance to pass. Then they come out for their morning repast of red clover stems and leaves, and the tender shoots of windflower and cinnamon fern. At this time they will be quite busy. When done feeding they return to their burrows where they probably sleep until one or two o'clock when they reappear, not so much for feeding as

to bask in the warm sun or to look about over the country. Again late in the evening, between sundown and dusk, they come out again to feed. Then they usually remain out until nearly dark when they are apt to retire to their burrows. They are, however, to some extent nocturnal and may remain abroad well into the night.

The Groundhog is a pretty strict vegetarian, his food consisting chiefly of red clover and the tender stems of grasses and other plants. He will sometimes do damage to the young corn plants and will, on occasion, feed upon the leaves of pumpkin, squash and bean vines. They will sometimes visit the kitchen garden and do more or less damage to the cabbage heads and celery. They have also been known to visit apple orchards near their burrows and feed upon such fruit as they could find on the ground. The only real damage they do that is serious is that done to the clover-field; all the rest is only occasional and may be regarded as negligible, except perhaps the inconvenience caused by the holes they make in the meadows and fields.

Dr. Merriam has observed[1] that in the fall the Woodchucks tend to leave the burrows in the open fields and go to those in the woods in which they spend the period of hibernation, and our observations lead us to the same conclusion. Certain burrows in Walley's and other woods which appeared to be deserted during the summer showed evidences of being used early in the fall and those in the fields had the appearance of having been abandoned in September or early October.

On May 3, one was observed sitting at the mouth of his burrow which was under a large stump. One of us slipped up from the opposite side, and, looking over the stump, watched him for sometime at very close range. He was very quiet and seemed to be looking out across the field. When a small object was dropped upon his nose he quickly turned his head sidewise and looked up with an expression of curiosity, if not astonishment, on his face. Not until the observer moved did he become frightened, when he quickly disappeared in the burrow.

The Woodchuck produces 3 to 6 young in a litter, usually about the last of April. We have some evidence indicating that two

[1] Mammals of the Adirondacks, p. 241.

litters may be produced in one season. On September 10 a young Woodchuck not more than one-third grown was seen on an open hillside where it was feeding on fresh grass. When chased it ran quite swiftly. When overtaken it would change its course from time to time. Finally when tired out it crouched down in the grass, apparently attempting to hide from its pursuers. Its small size suggested that it was born not earlier than the middle of July or later.

The Groundhog as yet possesses little or no economic value. Its pelage is coarse and contains little fur. The hide is tough and ought to make a good quality of leather. The flesh is abundant in quantity, sweet, palatable and very nutritious; it ought to be more extensively utilized as an article of food.

10. Sciuropterus volans (Linnæus).

Flying Squirrel.

Wherever there are, about the lake, large old trees with hollow trunks or limbs, one or more pairs of Flying Squirrels are likely to be found. Striking such trees with an axe or maul will often induce the squirrels to come out, especially if the tree is of proper size and springy enough to vibrate well in response to blows. When striking the tree is stopped, the squirrels usually return quickly to their nest. By such devices as this, one is apt to discover that the Flying Squirrel is a much more common animal in the neighborhood than the number seen otherwise would indicate. On account of its quiet, unobtrusive ways and its nocturnal habits it is not often seen except by those who know its ways.

These squirrels usually make their nests in holes in old dead or decaying trees; they may utilize a hollow limb, a decayed and hollowed-out portion of the trunk or a deserted woodpecker hole. Late in the fall, after the cottagers have left the lake and the cottages have been closed for the winter, these resourceful little animals sometimes take up their residence in the loft, cupboard or some suitable box in the cottages. There they build their nests and dwell cosily until the warm days of returning spring tempt them to return to a hole in some scraggy old oak near-by, where they will spend the summer.

Occasionally, in the evening twilight or on moonlight nights, a Flying Squirrel may be seen sailing in a gentle downward curve from one tree to another, the start being made from well toward the top of one tree and the place of alighting at a much lower point on the other. There is something ghost-like in this gliding flight; it is so unlike that of any other of our native creatures; there is not only an entire absence of fluttering wings, but perfect silence.

While in their nests these squirrels do more or less squeaking. On the night of September 21, 1903, one or more were heard in trees in the Arlington hotel grounds. On November 27, 1904, the accidental burning of two cottages on Long Point ignited some of the surrounding trees, one of which contained a family of Flying Squirrels. They did not leave their nest until fatally burned when they leaped to the ground. On August 19, 1906, while riding along a road west of the lake a squeaking sound attracted attention to the base of a small scrub oak at the roadside. On examining the place four young Flying Squirrels were discovered. They were quite small and wholly naked. A storm had probably blown them from their nest which was a large, globular affair, made of fibrous material, situated in a crotch of the tree. While we were only a few feet away, one of the parent squirrels, presumably the mother, came down the tree and, taking the young in her mouth, carried them, one at a time, back to the nest.

On April 16, 1890, one of us found a nest containing two young Flying Squirrels, south of Terre Haute. The nest was in a woodpecker's hole about 20 feet from the ground in a maple. Upon striking the tree the mother squirrel came out of the hole and flew to another tree near-by, where she remained watching. Breaking the snag at the hole the two young were removed and placed on the ground. After a little time the old squirrel flew back to the snag and seemed much disturbed by the changed appearance of things. She looked all about and, finally discovering the young on the ground, she came down, and taking one in her mouth, carried it to the top of the snag from which she then flew with the young in her mouth to another tree about 30 feet away. She ran up that tree to a height of about 50 feet where she found a knot-hole in which she placed the little one. In a moment she reappeared and flew back to the snag for the other. In the meantime I had stationed myself

near the young. After several advances and retreats she finally came and seized the young in her mouth when I caught her in my hand. When released she returned to the knot-hole with the young squirrel. These dates (April 16 and August 19), are of interest in showing so wide a range in the breeding season of the Flying Squirrel.

On December 16, 1890, a family of six Flying Squirrels was found by Mr. J. M. Beck near Burlington. They were all full-grown. On Thanksgiving day, several years ago, Prof. U. O. Cox, then of Farmland, Indiana, found 15 Flying Squirrels in a small rotten stump a little higher than a man's head.

It is remarkable the number of Flying Squirrels that can be discovered in any wood by knocking on the old dead snags or trees, particularly in the spring. We have found them in old oaks, beeches, maples, ash, willows, sycamores and hickories, as well as in various old buildings. They seem to breed chiefly early in the spring, about sugar-making time. A second or third litter may be produced later in the season.

Flying Squirrels make very interesting pets. Several years ago one of us had two which were kept as pets for several weeks. They had the freedom of one room in the house. During the day they lay curled up in a box provided and made comfortable for that purpose. At night, particularly before midnight, they would come out to play about the room and to accept the nuts and other food offered them. One night a drawer containing a number of bird-skins was inadvertently left open. One of the squirrels got into it, ate one of the skins and as a result died of arsenic poisoning.

11. Castor canadensis carolinensis Rhoads.

Beaver.

The Beaver was at one time pretty common in the northern part of Indiana. There still exist vestiges of one or more beaver-dams in the outlet between Lost Lake and the Tippecanoe River.

12. Peromyscus leucopus noveboracensis (Fischer).
Common White-footed Mouse; Deer Mouse.

This is the common wild mouse of Indiana. At Maxinkuckee it is abundant not only in the fields and woods but also about the cottages around the lake. Any old pile of wood, boards, logs or brush, stack of straw or hay, or shock of fodder, is almost sure to contain at least one family of these beautiful and interesting little animals. They may also be found in almost any old dead tree whether in open woods or dense forest, in which there are natural hollows or deserted woodpecker holes.

Several examples were trapped in July at the cottage occupied by us on Long Point. A male was captured October 20, 1906, at the pond below Farrar's woods.

These mice feed largely upon beechnuts of which they often store up considerable quantities for winter use. We have on various occasions found more than a pint of beechnuts stored in a hole in some old tree, evidently by these mice. They do not hibernate, but remain quite active during even the most severe winters. Their tracks may be seen in abundance on the snow. They also feed on small snails and other small, delicate mollusks such as Physa, Limnæa and Sphærium. We have frequently found shells, with the apex bitten off, in and about the nests of these mice.

They breed probably several times each season, as we have seen young as early as March and as late as November. The number of young produced in a litter ranges from four to six. We have frequently caught old females with the young hanging to the teats and carried them many rods before the young dropped off.

On two occasions when one of us put a shrew (*Blarina brevicauda*) in a box with a Deer Mouse the shrew killed and ate the mouse.

The Deer Mouse is readily distinguished from related species. It attains a length of 6.5 inches including the tail which is 3 to 3.25 inches long. In color it is yellowish brown, grayish, or fawn-color; belly and feet pure white; tail less distinctly bicolor than in the Michigan White-footed Mouse.

13. Peromyscus maniculatus bairdi (Hoy & Kennicott).

Michigan White-footed Mouse.

This species is not as abundant as the Common White-footed Mouse. It does not appear to venture into woodlands or swamps, but seems to prefer dry, open situations such as the edges of fields and grassy pastures. Its general distribution is more northern than that of its near relative, *P. leucopus noveboracensis*. It is very abundant in the sand dunes that border Lake Michigan. At Maxinkuckee it is probably not uncommon, though we have seen only 3 examples. One was found dead on the railroad track November 3, 1904. Another captured at the gravel pit October 29, 1906, gave the following measurements: Length 118 mm.; tail 48; hind foot 9; ear 10; girth 55. A third example was captured November 3, 1906, in a cornfield east of the lake.

The young of this mouse differ from the adult in being drab in color instead of yellowish-brown. On one occasion when trapping these mice for specimens it was observed that they were quite seriously infested by fleas. The examples thus afflicted could usually be recognized at once by their having the hair gnawed or scratched out from about the root of the tail.

This mouse can be distinguished from its more common relative (the Common White-footed Mouse) by its smaller size, smaller ears and feet, and shorter tail, the tail being more thickly hairy and more sharply bicolor. The adult is yellowish-brown, with a sooty dorsal band; belly white; feet not quite white; tail bicolor. Length $4\frac{1}{3}$ inches, tail $1\frac{1}{2}$ inches.

14. Microtus pennsylvanicus (Ord).

Field Mouse; Meadow Mouse; Vole.

The Meadow Mouse is abundant in all suitable situations about the lake. The extensive areas of semi-marshy grassy land supply an ideal habitat for this noxious but interesting little animal. Wherever there are meadows or marsh ground covered with grasses there these mice will be found, their labyrinthine runways forming an intricate network under the dead grass where their nests are numerous and usually quite conspicuous. These runways are very

common in the low marshy meadows such as are usually submerged during the winter and spring, during which time the mice must retreat to higher ground. They do not hibernate but continue very active throughout the winter. In the spring when the snow melts away their runways that were under it become quite conspicuous.

This species is very destructive to grasses and other cultivated crops. When the corn is cut and left in shocks in the field these mice establish themselves in nearly every shock, building a nest near the center and feeding destructively upon the corn. The amount of damage done in this way to the average field of corn is very considerable and far in excess of that done to the poultry yard by the hawks which, if not destroyed by the farmer, would do much to hold the Field Mice in check. The Marsh Hawk, Sparrow Hawk, Pigeon Hawk and Cooper's Hawk, as well as the various owls all prey on these mice.

On October 24, 1904, a Meadow Mouse was found on the lake shore, beheaded, possibly by some bird of prey. November 1, 1904, a cat was seen with one. December 11, 1904, one was seen near a muskrat house in Norris Inlet marsh.

15. Fiber zibethicus (Linnæus).

Muskrat.

The Muskrat is a familiar and well-known animal throughout North America wherever there are marshes, ponds or streams. Among the hundreds of small lakes and smaller ponds in northern Indiana there is probably not one that is not the home of one to several pairs of these interesting rodents. At and about Lake Maxinkuckee it is quite common, albeit not often seen except by the few elect who know when and where to look for it. In the autumn and early winter, especially in the evening and early morning, they may be seen swimming about or heard splashing among the weeds near shore. It is at this time that they begin to build their houses, and day by day those who pass along the shores of the lakes or about the ponds and marshes may notice the increase in size of the piles of Chara and rushes of which they build their winter homes. These homes or houses are built almost anywhere along the shore in shallow water or even well out in small

shallow ponds wherever there is suitable building material conveniently at hand. Every Scirpus patch is likely to contain one or more of these houses. On the west side of the lake we usually found one in a small pond by the side of the railroad just north of the Assembly grounds, two or three in the edge of the lake between there and Culver, one near the Winfield cottage, one or more in Outlet Bay, two or three between Long Point and Murray's, six or more from Murray's to Norris Inlet, a score or more about Norris Inlet, several along Aubeenaubee Creek and perhaps a dozen in the northeast corner of the lake and along Culver Creek. A great many are seen each year about Lost Lake and along the Outlet throughout its entire length, even to Tippecanoe River. Each of the marshes and ponds west of the lake has its share of nests and each old kettle hole that is not too dry will have one or more.

While these are the usual places where the muskrats build their houses, now and then a house is found in some quite unusual and unexpected place. Among these are the cross-timbers under the piers at the cottages about the lake. December 24, 1900, a completed nest was found resting cosily on cross-timbers under the pier at the Lakeview Hotel. Though not large this nest was compactly built. It was composed almost wholly of Chara and was a foot or more above the surface of the water. November 2, 1904, another nest was found in a similar situaton on cross-timbers at the distal end of the Culver depot pier. This nest was quite large and composed chiefly of Chara. When disturbed the owners of these nests would drop quietly into the water and swim away.

Toward the last of October, 1904, a nest was found on the seat of an abandoned boat near Murray's. This nest was newly built and consisted chiefly of Chara and Scirpus stems. Later, when the lake froze over it was deserted. Still another nest was found on the top of a tree that had fallen into the lake, and yet another on the boughs of a broken tree that extended into the water.

The most interesting and unique situation selected by a muskrat for its house ever seen by us was a large dry-goods box which a duck-hunter had anchored in Outlet Bay for use as a blind from which to shoot ducks. The box was anchored some distance from shore with the open side toward the shore. Bushes with leaves still on were stuck in the lake about the box to aid in concealing

the gunner and his boat, a half-inch manila rope being used to hold the box at anchor. On visiting the blind one morning in October more than a peck of fresh wet Chara was found in the box. The amount was increased each night for the next few days until it consisted of more than a bushel of material, almost wholly Chara. One morning the box was missing and the next day it was found on the east side of the lake where it had evidently been drifted by the wind. An examination of the anchor rope disclosed the fact that it had been gnawed in two by the Muskrat itself which thus set its own home adrift.

The materials which the Muskrat uses in constructing its winter houses are chiefly various aquatic plants such as Chara, water lilies (both white and yellow), Potamogeton, Myriophyllum, Ceratophyllum, Scirpus, Typha, Iris, and the like, and our observations lead us to believe that they utilize at least some of this material as food. Along with these various plants will often be found stems and sticks of various sizes. In Lost Lake some of the houses contain a considerable proportion of mud.

During the summer the muskrats appear to subsist almost wholly on vegetable matter. In the early fall they sometimes make foraging trips to nearby gardens where they commit depredations on the carrots, parsnips, beets, turnips and other succulent vegetables. They also eat the seeds as well as the stems and roots of the yellow and the white pond lilies. They gnaw the bark from the roots and stems of Swamp Loosestrife (*Decodon verticillatus*) and the Buttonbush (*Cephalanthus occidentalis*). Later in the fall and during the winter animal food enters more largely into their menu. We have found them feeding on dead coots and ducks that had drifted ashore or which, wounded by some gunner, had escaped among the weeds and sedges fringing the lake. They also feed on turtles of various species which they find dead or which they themselves may kill. On several occasions we have found partly devoured turtles under circumstances which left no doubt as to what had been feeding on them. December 11, 1904, several dead painted turtles and a few musk turtles were found near Norris Inlet lying on their backs on the snow or ice, with the flesh wholly or partly devoured, and Muskrat tracks leading to and from them and all about. The most important element of the winter food of

the Muskrat, however, is the freshwater mussels or Unionidæ. At various places along the shore, wherever an object projects out into the water, such as a log or pier, or fallen tree-top, there will be found in autumn or early winter a pile of mussel shells where muskrats have been feeding. These piles are frequently of considerable size, containing sometimes a bushel or more of shells. September 24, 1907, one of these piles on Long Point was examined. It was off shore several feet and in water 18 inches deep. About one-half of the shells were examined critically and counted. There were 532 shells, representing 4 species as follows: *Lampsilis luteolus*, 358; *Unio gibbosus*, 167; *L. iris* 6; and *L. multiradiatus*, 1.

During the fall these operations are probably confined to mussels which they find in shallow water near shore. In winter, however, when ice-cracks form and extend well across the lake, the Muskrats go far out on the ice, dive through the cracks and bring up mussels which they eat sitting on the ice. At such times they get mussels at considerable distances from shore. In the first days of January, 1905, a broad crack formed in the ice from Long Point to the Norris boat-house. On January 4, a Muskrat was seen at the edge of this crack about 1000 feet from shore eating mussels. It would dive through the crack and after a little while reappear with a mussel. Sometimes it dived 5 or 6 times before securing one. It would then sit up on its haunches, holding the mussel in its paws and, by much clawing and chewing, finally succeed in opening the shell and removing the meat, which it usually licked out quite clean. In some cases the muskrat failed to get the shell open. Usually the shells are but little or not at all broken; even the hinge still holds and the shells are scarcely injured. It is our observation that the Muskrat, by inserting its claws or teeth between the valves succeeds in cutting or tearing loose the adductor muscles so as to permit the valves to spring open. Another Muskrat was observed further out on the same crack, a long distance from shore, and the ice along the crack between the two was pretty thickly strewn with shells. The Muskrats apparently do not care so much for mussel gills filled with eggs or glochidia, as these were usually rejected. The stomach of a Muskrat examined at Washington, D. C., late in the spring was found well-filled with mussel remains. Muskrats also feed to a considerable extent on fish, crawfish and frogs. We

have on more than one occasion found partly devoured fish at their feeding stations, and remains of fish, frogs and crustaceans in their kitchenmiddens. We have never seen a Muskrat catch a live fish, but have no doubt they do so. They certainly pick up freshly dead fish which they chance to find.

At Lake Maxinkuckee the Muskrats raise at least two litters, and probably three, each season. About the middle of June, 1901, young muskrats about half-grown were seen swimming about or sitting on their haunches on shore eating bits of lily roots. These were probably of the first litter. On June 15, 1903, a nest with 5 young was found in a pile of brush on marshy ground on Long Point. The young were evidently not more than a few days old, as their eyes were not yet open. On May 31, 1901, we caught one about one-third or one-half grown on south shore of lake. September 5, 1906, saw 2 young not more than half grown. On another occasion, a young one was seen on the shore near the Culver depot pier and was almost caught before it took alarm. On another occasion, a young one was seen to dive in shallow water south of Green's pier. Upon wading out to where it dived a hole was seen in the bottom, out of which the Muskrat soon came and was captured. From these data it is evident that at least 2 litters per season are raised in this vicinity.

In the early winter, after ice has formed some distance out from shore, Muskrats are often seen swimming under the ice. They move along quite rapidly, and present a peculiar appearance, a bubble of air at each nostril expanding and contracting as they breathe, and a number of small bubbles on the fur giving them a silvery color. Apparently the Muskrat before diving fills its lungs with air, portions of which it exhales and rebreathes again. During the time it remains as a bubble at each nostril it is purified through its contact with the water and rendered fit for breathing again. This peculiar habit would seem to account for the ability of the Muskrat to remain under water so long. On one occasion (in December, 1904) when standing on the ice a peculiar sound was heard beneath our feet. Upon investigation it was found to be caused by a Muskrat gnawing at the under side of the ice. The sound was like that made by a rat gnawing under a floor.

At times the Muskrats make various noises. September 5, 1906, two half-grown young were observed chasing each other and singing a long, shivering note, followed by mewings and squeakings and other noises or calls. The shivering, singing noise was heard on other occasions.

The Muskrat is the most valuable fur-bearing animal in the Maxinkuckee region; indeed, it is the most valuable in the state. Considerable numbers are trapped each year about the lake, the best grounds being Norris Inlet and Lost Lake together with the Outlet. We have been unable to obtain complete figures of the catch, but have enough to show that it is important. In the winter of 1896–1897 one trapper secured between 60 and 70 skins. One who trapped only at Norris Inlet in the fall of 1900 had secured 30 pelts by November 9, and another at Lost Lake had 50 by the same date. Up to November first, 1903, two men trapping chiefly at Norris Inlet had secured 103 pelts. They got 28 one night. Their entire catch for the winter was 264 Muskrats, 4 Mink and 3 Opossums. The Muskrat pelts brought them 10 to 15 cents each. The prices now are much higher, ranging from 30 to 50 cents. Black pelts, which constitute a small proportion of the catch, bring much higher prices.

It has long been suspected that the Muskrat is the intermediate host of certain parasites which are concerned in the production of pearls in the Unionidæ or freshwater mussels. The Muskrat stomachs and intestines examined by us at Lake Maxinkuckee did not enable us to demonstrate the truth of this theory. One stomach examined contained no parasites of any kind. Another examined at Washington, D. C., contained a few parasites but none that could be identified with the distomid which induces pearl-formation. A species of parasite, *Monostomum affine* Leidy, closely related to the distomids was described from the gall-bladder of the Muskrat. It is the intention to examine a considerable number of stomachs at the first opportunity with a view to determining the facts in this matter.

16. Zapus hudsonius (Zimmermann).
Jumping Mouse.

This is another northern animal whose range southward reaches northern Indiana. It is frequently reported from this part of the state, particularly from the vicinity of Yellow River. It is also said to be seen occasionally about Rochester a few miles southeast of the lake. Our only definite record for the lake is of one found dead near the ice houses on the west side of the lake August 26, 1906. This example gave the following measurements: length of body, 80 mm.; tail 108 mm.; ear 5 mm.; hind foot 28 mm.

Erethizon dorsatum (Linnæus).
Porcupine.

According to accounts given by old settlers in Indiana, the Porcupine was at one time not rare throughout the northern part of the state. It was not uncommon for the inquisitive cow or the dog to come home with its nose full of spines of the Porcupine. It was the custom to hold the afflicted animal and pull out the spines with pincers, as they stuck very tightly, while the suffering creature announced to the neighborhood the discovery it had made that day. Troubles like this caused the settlers to wage a war of extermination on the Porcupine, with the result that it is now rarely or never seen. We have only one record of its recent occurrence in this vicinity. According to Mr. S. S. Chadwick one was killed a short distance west of Culver in the fall of 1887.

18. Sylvilagus floridanus mearnsi (Allen).
Rabbit.

The Rabbit or Cottontail is an abundant and well known animal of the Maxinkuckee region. The large areas of uncultivated swampland, abounding in tall grasses, sedges and small brushy shrubs, the tamarack and other swamps, and the considerable tracts of timber, often with heavy undergrowth, give a wide choice of location and refuge. In all these Rabbits are usually quite abundant. Although apt to be found almost anywhere, there are choice places where it

is particularly common. Among these are the thickets, fields, and Farrar's woods at the south end of the lake; the shores of Lost Lake and the woods and fields from Green's to Walley's and beyond; the fields, swamps and prairie westward to Manitou and Houghton lakes, including the tamarack swamp; and the low ground along Aubeenaubee Creek on the east side.

The following records made by us serve to indicate to some extent the abundance of Rabbits in this region. They are by no means complete, but simply show the observations of one or two persons for portions of each of several years. During the fall of 1899 up to January 21, one man who hunted only occasionally and only in the immediate vicinity of the lake, killed 76 Rabbits. In 1901 they were said to be plentiful in February and on December 10, one hunter shot 19. On January 2, 1903, hunters obtained 21 in the vicinity of Mud Lake near the head of Aubeenaubee Creek; December 14, 4 hunters got 20 and on December 30, one got 8. In 1904, 7 were killed December 8, 24 on December 13, and 2 on December 22. In 1905 two were gotton November 27. In 1906, two on January 22, one seen July 21 and 29, and October 9, several on October 31 on the east side, 2 on November 13, one on the 14th and 4 gotten on the 20th. In 1907, a half-grown young was seen September 11 and another September 20; another not more than one-third grown was seen September 22.

In this region the Rabbit is hunted rather persistently every fall and winter from October to February and the total number killed is great; nevertheless the animals are so prolific that the supply usually keeps up pretty well. During some years it is less abundant. The season of 1908–9 was a period of scarcity. Generally these periods last only for a single season, and the next season is one of usual abundance. They are in best condition in November to January and these are the principal months when they are hunted. Unfortunately a few local pothunters have been using ferrets, a method which affords no sport, is entirely unsportsmanlike, gives the Rabbit no chance, and which cannot be too severely condemned.

In this region the Rabbit breeds at least twice each season. The first litter is produced early in the spring, usually in May, and the young are half or two-thirds grown by the first or middle of July. The second litter is probably produced in July or even as late as

September, as we have seen half-grown and one-third-grown young September 11 and 22. Heavy rains in the spring frequently flood the breeding grounds with the result that many of the first litters are drowned. This was particularly the case in 1902 when there were unusually heavy rains in May and June, flooding all the lowlands. That many young Rabbits were drowned is evidenced by their scarcity in the fall and winter following.

Here, as elsewhere, the Rabbit causes some damage to young fruit trees by gnawing the bark. The damage is greatest during the winters of heavy and long-continued snows which cover up other vegetation on which they would feed. The Lake Maxinkuckee region, however, is not much given to orchards or horticulture and the injury wrought by Rabbits is therefore not serious.

The Rabbit as an article of food is becoming more highly appreciated in recent years and there is also an increasing market for its fur. With proper laws providing adequate protection a large and valuable catch could be made every year.

19. Lynx ruffus (Gueldenstaedt).

Wild Cat.

The Wild Cat or Lynx was probably not uncommon in this county up to about 1850. They are now rarely seen. We have unauthenticated accounts of their occurrence west of Lake Maxinkuckee as late as 1870, or later. Dr. Hahn records the killing of one near Oxford, Benton County, in 1905.

20. Vulpes fulvus (Desmarest).

Red Fox.

Formerly common throughout the state but now not often seen. A few burrows believed to be those of Foxes were observed in Walley's woods and near the outlet, southwest of the lake. The only Foxes actually seen by us about the lake were a family of 3 young and their mother found April 18, 1901, in a den in Green's field southwest of the lake. The old one was shot, and the three young taken as pets. One of them promptly escaped, but the other two were kept for several weeks when a second one escaped. The

remaining one for some unknown reason became paralyzed in its hind legs. It was permitted to go about as best it could, and finally took up its residence among the bushes in Green's marsh. Here the dog would occasionally go to tease it, but the young fox was always able to keep the dog off. Late in the summer it disappeared and was not seen again.

21. Canis occidentalis Richardson.
Timber Wolf.

The Timber Wolf or Big Gray Wolf was doubtless very abundant throughout the wooded portion of Indiana in the early days. It still occurs in some numbers in the more wild regions. Mr. Anton Meyer tells us that he got a few pelts each winter up to 1905–6, from the region northwest of Plymouth toward the Kankakee marshes. During a visit to Starke County in 1906 we heard statements to the effect that large wolves are occasionally seen and heard in the vicinity of Knox. Dr. Hahn in his Mammals of the Kankakee Valley states that the reports of the occurrence of the Timber Wolf in that region are conflicting and that it may be that only the Prairie Wolf is found there. Mr. Meyer, however, states positively that he gets pelts of two different species, a "large gray timber wolf" and a "smaller prairie wolf."

22. Canis latrans Say.
Prairie Wolf.

The Prairie Wolf, or Coyote as it is more commonly known in the west where it is abundant, is not known to occur in the immediate vicinity of Lake Maxinkuckee. It is a species of the prairies, occurring in some abundance in the prairie counties in the northwest corner of the state, particularly in Benton, Lake, Newton, Jasper and Starke counties. Dr. Hahn[1] records a large number from these counties. He also states that a pack of moderate size was seen near Leesburg, Kosciusko County, in the winter of 1906–7.

[1] The Mammals of Indiana, 33d Annual Report Dept. Geology and Natural History of Indiana, 1908, pp. 562–565.

Mr. Anton Meyer of Plymouth, Indiana, already quoted, informs us that he usually gets a few small prairie wolf pelts each winter, chiefly from Starke and Jasper counties. As the prairie of this portion of the state reaches Lake Maxinkuckee it is quite probable that this wolf occurs there. Dr. Hahn expresses the belief that the Coyote has doubtless increased greatly in numbers in recent years in the northwestern portion of the state and that its range is gradually extending eastward.

23. Lutra canadensis lataxina F. Cuvier.
Otter.

The Otter was formerly not uncommon in this region, but it is now very rare. One was caught on the Tippecanoe River just below Delong about 1895. Mr. Anton Meyer, a fur buyer of Plymouth, Ind., tells us that he gets 10 or 12 Otter skins each year, chiefly from the Tippecanoe and Yellow rivers.

24. Mephitis mesomelas avia Bangs.
Skunk.

The Skunk or Pole Cat is not common in this region but it is apparently becoming more frequent. We saw none in 1899 and 1900, but that the country was not wholly deprived of this interesting animal was on several occasions made evident by the presence of the well-known diagnostic odor.

On September 16, 1906, the mangled remains of one were found on the railroad track near the gravel pit; it had evidently been run over by a passing train. On September 20, 1907, a freshly skinned skunk was seen in the possession of a hunter at Culver. The skin was 22 inches long, and the tail 10 inches. The roots of the hairs show through the skin so that the skin looks black under the black parts and white under the white dorsal stripe.

The price of prime skunk pelts in this region has ranged from $1.00 to $1.75 during the last few years.

25. Taxidea americana (Boddært).

Badger.

Never more than very rare in Indiana and now probably extinct in this part of the state. In 1893, Mr. S. D. Steininger, then of La Grange County, reported that the Badger has been found in Elkhart, La Grange, Steuben, De Kalb, Noble and Kosciusko counties; that four had been caught in La Grange County within the last 10 years, the last in 1887; that 3 were caught in the northeast part of Elkhart County in 1888, and a black one in Noble County in 1880. Various old residents say that it was formerly found in Marshall County.

26. Lutreola vison lutreocephalus (Harlan).

Mink.

The Mink is not common in the immediate vicinity of Lake Maxinkuckee, but it is said to be more plentiful a few miles to the westward and along Yellow and Tippecanoe rivers. One was killed in February, 1898, near the Winfield cottage; others were obtained about the lake December 18, 1899, January 19, 1900, and November 9, 1900. On April 5, 1901, a skull of a female mink was picked up near Lost Lake. A few were trapped in the winter of 1903–4; 3 at Norris Inlet in October, and one at the ice-houses December 14. On December 17, 1901, a mink dragged 3 ducks from the ice on the lake to a hole under a stone wall on Long Point.

In the winter of 1906–7, a mink track was observed on the shore at the Shady Point cottage. The mink had gone south toward Murray's until opposite the gravel pit when it went out on the ice several rods to an open place where it evidently fed for a time, after which it returned on the ice to the shore and then followed on south along the lake shore nearly to Murray's where it was found under the edge of the ice and killed. It was in some respects an abnormal mink, the head and shoulders being unusually heavy, the body short and thick like that of a coon, and the color jet black. The pelt sold for $3.50.

On September 7, 1907, a very large mink was seen in Outlet Bay between Chadwick's Hotel and the north end of the icehouses. It was watched for some time and was evidently feeding. It would

dive and remain under a few seconds, then come up not far from where it went under. After remaining at the surface a minute or two, swimming and turning about in a narrow area, apparently eating what it had brought up, it would dive again. Often the entire length from nose to tip of tail could be seen just above the water surface. When it dived it humped its back, going under head first, the entire length of the tail (except the tip) which seemed to be quite long, often coming entirely out of the water.

After feeding for more than 20 minutes it swam to its burrow on shore near the steamer slip. What it was feeding on was not determined.

In July, 1907, Dr. J. T. Scovell found a family of young minks on the Tippecanoe River, below Delong. They were on a mass of drift in the stream. They were moving about on the drift from one part to another. As the boat approached, the two old minks swam out toward it, and as the boat floated by they made a wheezy noise which they continued until the boat was some distance below them when they returned to the drift, into which the young had disappeared.

27. Putorius noveboracensis Emmons.

Weasel.

The Weasel is generally common throughout Indiana. It is not rare about Lake Maxinkuckee, although it is not often seen.

August 3, 1899, one was found freshly dead at the edge of the lake near Green's pier. An adult male was killed August 19, 1901, on Long Point, where it had taken up a temporary residence under the floor of a tent. Another fine large example was found dead near the railroad, south of the lake, in December, 1904.

About July 15, 1902, Mr. S. S. Chadwick saw a weasel chasing a rabbit. The rabbit came out upon the road on Long Point, turned back toward the lake, and then ran south. Just then a Weasel came along on the rabbit's trail. When it reached the road and saw that it was being watched it stopped a moment, then, not at all frightened, started on after the rabbit. Losing the trail it came back and hunted about until it was recovered, then again followed it by scent just as a dog would. The rabbit appeared greatly frightened, its eyes popped and shining. The Weasel was very quick and alert.

28. Procyon lotor (Linnæus).

Raccoon.

The Raccoon appears to be somewhat common, especially in the large stretch of heavy woodland east of the lake. It also occurs west of the lake as well as north and south of it, as evidenced by its depredations in the cornfields at roasting-ear time, and, later in the year, by the piles of shells it leaves from its feasts on freshwater mussels, a habit it shares with the muskrat. In the spring of 1901 they were often heard at night,—a shivering call not unlike that of the screech-owl. In January, 1904, one was caught near Monterey and another was taken east of the lake in November. In 1906 one was seen on east side, October 30. On September 7, 1907, five young Coons about two-thirds grown were got from a tree on the east side. The old ones escaped. Five days later 3 others were caught.

Mr. S. S. Chadwick says that the largest coon he ever saw weighed 18 pounds; this was in Pennsylvania.

In the Delphi Journal was recently noted the capture of a coon near Russiaville, Howard County, Indiana, which weighed 34 pounds.

29. Blarina brevicauda (Say).

Mole Shrew.

On account of its nocturnal and underground habits the Mole Shrew is not often seen and is therefore not very well or generally known even to those living in localities in which it is really common. It is probably not uncommon about Lake Maxinkuckee. We have records of 12 specimens, of which 9 were found dead as follows: one in road south of Arlington, in August, 1899; one on lake shore October 20, 1900; one near Fort Wayne, October 1, 1906; one near Winona, October 2, 1906; one south of Arlington, October 9, 1906; one at icehouses, October 22, 1906; one on Long Point, October 29, 1906; one on Long Point, September 25, 1907; one in road on Long Point, October 13, 1907. One was caught in a trap on west side of lake, November 1, and another on Long Point, October 22, 1906. One was caught by a cat, October 3, 1906.

Special search would no doubt have enabled us to find many more specimens of this curious little creature.

The stomach of the one caught October 22, contained many parasites resembling tapeworms. The one found October 29, was lying at the edge of the water and was covered with leeches.

Why these little creatures are so often found dead is not well understood. It has been suggested that the fetid odor of this animal, particularly the male, causes it to be rejected by animals which would otherwise prey upon it, and that those found dead are individuals which have been caught by hawks or owls and dropped after discovering the disagreeable odor possessed by the little animal which the hawk or owl at first thought would prove a delicious titbit.

The carnivorous, bloodthirsty nature of the Mole Shrew has been noted by many observers. On two different occasions we put a Mole Shrew in a box with a white-footed mouse and in each case the shrew killed and ate the mouse. Others have recorded similar experiences. One observer records the fact that a Mole Shrew ate three times its own weight of meadow mice in 24 hours.

30. Scalops aquaticus machrinus (Rafinesque).

Common Mole.

The Mole is very common about this lake. Its burrows may be seen in all suitable places. The loose, sandy soil is particularly well adapted to their habits. They are usually abundant on Long Point, also along the railroad, in the fields and open woodlands about the lake, in the Academy grounds, and in fact in all situations in the country where the conditions are favorable. Their burrows are often seen along the railroad, and frequently they are seen to pass from one side of the track to the other, passing under the rails between the ties.

Several were caught during our stay at the lake. When a captive mole is released it does not attempt to escape by running away but at once begins to dig or burrow, and in an incredibly short time it has sunk into the ground and entirely disappeared.

The popular prejudice against the mole based on the belief that it is injurious to vegetation is entirely unjustified. Moles are insectivorous in their habits and do not eat garden plants or vegetables at all. The only possible harm they cause is the slight injury

they sometimes do to lawns by their burrows. This, however, is infinitesimal in comparison with the great good done by ridding the fields, gardens and lawns of noxious worms, insects and larvae.

31. Myotis lucifugus (Le Conte).
Little Brown Bat.

The Little Brown Bat is quite common about the lake. They first appear early in April and remain out at least until November. We have definite records of April 10, June 23, September 17, October 9, and November 1.

On still evenings from May to October, just as the twilight deepens and objects at a distance become indistinct, these little creatures come out from their hiding places and may be seen circling in and out among the cottages and trees, and now and then out over the lake in their search for food. Rarely are they seen before sundown, but on moonlit nights we have seen them out over the lake as late as eleven o'clock.


MAP
OF A PORTION OF
STAUNTON, VA.
SHOWING RELATION OF CAVED
AREA TO THE STRIKE AND
DIP OF LIMESTONES
BY
E. M. KINDLE AND P. V. ROUNDY
SCALE
0 100 200 300 400 500 FEET
N
DIP
VERTICAL
40°
75°
48°
45°
50°
85°
SCHOOL HOUSE
ENGINE HOUSE
2
1
BALDWIN ST.
BICKLE ALLEY
3
TODD HOUSE
4
P.O.
AVENUE
STREET
FREDERICK STREET
STREET
CENTRAL
AUGUSTA
MAIN STREET
LEWIS
JOHNSON STREET
Creek
45°
Lewis
45°
30°

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THE COLLAPSE OF RECENT BEDS AT STAUNTON, VIRGINIA[1]

BY EDWARD M. KINDLE
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During the month of August, 1910, a series of cavernous openings in the ground was developed in the central part of the city of Staunton, Va. These have been widely described in the daily press as the "Staunton cave-in" (Pls. II–V). The first three openings to appear have been described by Mr. F. B. Van Horn,[2] of the U. S. Geological Survey. Since the publication of Mr. Van Horn's paper additional caving, and the completion of a series of drill holes by the city engineer to determine the limits of the solid bed rock, have shown more fully some of the essential facts relating to the character and direction of the underground channel responsible for the caving. Some record and discussion of these additional data and of the writer's geological observations made during a visit to the scene of the caving seems desirable. The underground stream involved in the "cave-in" illustrates in its direction and development certain controlling factors to which attention will be invited in the course of the discussion, which are absent in the case of most of the underground streams familiar to the writer.

The city of Staunton is situated in a limestone region, being underlaid by the Shenandoah limestone of Cambro-Ordovician age. This

[1] Published by permission of the Director of the U. S. Geological Survey.

[2] Engineering News, Sept. 1, 1910.

limestone has a thickness of not less than fifteen hundred feet,[3] and owing to inclination of its strata probably extends several times that depth below the surface at Staunton. In this, as in most other limestone regions, subterranean streams play an important rôle in the drainage system. In the Carboniferous limestone region of Kentucky the location of hundreds of sub-surface stream channels is marked by caves mouths and sink holes. "In three counties in the vicinity of Mammoth Cave, over five hundred caves are known to exist."[4] In considerable areas with which the writer is familiar in the limestone region of southern Indiana, more than 90 per cent of the rainfall is carried off by underground streams. Such streams collect the surface waters largely through the agency of irregular hopper-shaped depressions called limestone sinks or sink holes. In the earliest stage of the development of a sink hole the rainwater seeps through a crevice or joint in the limestone to a lower level. Gradually the passage way thus begun increases in size. At the same time the corrosion of the limestone goes on at the surface rather more rapidly in the immediate vicinity of the crevice than elsewhere. This solvent action of the surface waters, either alone or in conjunction with the breaking down of cavern roofs, in time develops the inverted cone-shaped depressions so characteristic of most limestone regions. The limestone sinks, though apt to be irregular in shape, generally approach more or less closely a circular outline at the top. In the Shenandoah valley these depressions generally attain a depth of from 20 to 80 feet and a width of from 60 to 300 feet.

It happens not infrequently that the outlets connecting the bottom of the sink hole with the subterranean stream become choked up and the sink becomes a pond or small lake. Nearly all ponds in limestone regions have had this origin. Such a pond, if the outlet at the bottom remains closed for a sufficiently long period, eventually becomes silted up or filled with marl and is transformed into a marsh, and sometimes even into dry land, through the complete filling of the depression and the reëstablishment of surface drainage. Such a cycle is liable to be interrupted at any time through adven-

[3] Folio U. S. Geol. Surv., No. 14.

[4] Caves and cave formations of the Mitchell limestone; F. C. Greene, Proc. Ind. Acad. Sci., 1908, p. 176.

titious reopening of the outlet. In such a case the limestone sink resumes its original function of catch-basin for surface waters.

It happens that a small portion of the central part of the town of Staunton is located on a tract of land which has passed through the geologic cycle outlined above. The reopening and enlargement of the original outlets of the limestone sink which was the forerunner of the marl bed underlying this part of Staunton, led to the caving of the soft marl and gave to the residents of the city their first knowledge of the presence of this subterranean stream. The caved area lies near the lower end of a small valley traversed by one of the minor tributaries of Lewis Creek. This stream has been confined to a conduit of masonry throughout most of the lower part of its course in the city. At, and above the caved pits (Pl. I), the valley has a very low grade for half a mile or more and is nearly flat in cross-section for a width of three to five hundred feet. On both sides of this comparatively flat area the land rises one hundred feet or more in gentle hill slopes, showing frequent outcrops of the underlying limestone. In the bottom of the valley the limestone is buried nearly everywhere by several feet of superficial deposits of clay and marl. A short distance below the caved holes the grade of the valley is very much steeper than above. In fact the abrupt change of grade here would probably justify the use of the term "hanging valley" for the small valley near the lower end of which the superficial beds collapsed. Previous to the accumulation of the marl beds it had evidently been a closed valley. The abrupt change in the grade of the valley is undoubtedly due to the diversion of the water of the valley stream to a subterranean stream prior to the accumulation of the twenty to sixty feet of clay and marl which now forms the bottom above the abrupt grade. This diversion must have been through limestone sinks which developed in the vicinity of the holes recently caved in the marl beds. At some remote period outlets to the limestone sinks were closed and a large pond occupied the portion of the valley above Frederick street. The great numbers of freshwater shells in the marl beds afford indisputable evidence of the pond conditions under which the marls accumulated. It was during this stage in the history of the valley that the soft marl and clay beds were deposited above the temporarily closed subterranean channel, a superposition which brought

disaster to a portion of the town which was eventually built upon them.

In company with Mr. P. V. Roundy the writer visited Staunton about one week after the crater-shaped openings began to develop. The following account of the development of the first three is based upon information furnished by Mr. C. E. Ashburner, City Engineer, and the account published by the Staunton *Spectator*. The facts regarding the last of the series to develop were furnished by Mr. J. Yost on whose property it occurred.

The initial caving occurred on the morning of August 11. The occupants of a building on the south side of Baldwin street "heard a crash as if under their feet and suddenly the building shook and the pavement sank about 4 feet." The photograph (Pl. II, fig. 1), shows this hole in this first stage of development. After its sudden beginning this first break progressed gradually. "The sinking of the ground continued constantly and in less than an hour it had sunk 10 feet and the radius of the cave-in was 30 feet. Every now and then the dust would rise, showing that fresh caving was going on." Near the center of the ground included in the first break stood a tree 25 feet in height. "In less than two hours this tree had entirely disappeared." A few hours later the lateral enlargement of this first break carried down a two-story house about 25 by 35 feet in dimensions. Like the tree, this house passed out of sight in the cavernous opening. This building is shown in Pl. II, fig. 1. About two hours after the first break a second occurred on the opposite side of Baldwin street and diagonally across from it (Pl. I). It is described as a sudden break which was accompanied by a loud report. It was at first a hole about 4 feet square in the pavement directly in front of the fire engine house. This increased by lateral caving at irregular intervals until it reached nearly across the street in one direction and under the fire engine house in the other, resulting in the ultimate destruction of the building. This second hole is shown in the foreground of Pl. II, fig. 2.

A few hours after the first break appeared, the third and largest of the holes began to develop about 75 feet to the southwest of the first Baldwin street hole. Its dimensions at the top were about 60 by 90 feet. This third slip of the ground carried with it three trees and a portion of a dwelling. The top of one of these trees

which later completely disappeared is seen in Pl. III. The major part of one of the foundation walls of a house occupied by Mr. Todd went down with this break. Pl. V shows the character of the crevice in the limestone into which the engulfed materials disappeared as seen under the Todd house. For a short time after the caving began no water could be seen in the chasm but it rose gradually until, at the time of the writer's visit, it stood within 23 feet of the surface of ground, or almost at the top of the limestone channel seen in Pl. IV. The rate of inflow into this and the adjacent "cave-ins" (Pl. I), Nos. 1 and 2, is estimated at 40 gallons per minute by Hon. J. Yost. The depth of the cavern into which the superficial deposits have slumped has been shown by sounding to be at one point at least 150 feet.

With the development of the third chasm caving ceased, save for occasional slumping of the walls, for more than two weeks. On August 27, however, a fourth opening appeared on the opposite side of Lewis street from the third hole, on the grounds of Mr. Yost. This hole was cistern-shaped, from 10 to 12 feet in diameter and 18 deep. Still later an artificial excavation about 20 feet in width was made by the city across Lewis street over the line of the crevice opening into the cavern below for the purpose of arching it. Except for the slumping of one of the sides of this excavation in which a workman lost his life, no caving has occurred since that of August 27.

The openings in the streets have been filled in after arching the walls of the limestone crevice leading to the cavern below with concrete. On the property of Mr. Yost a cement arch was extended the entire length of the area disturbed by the caving. The work on the Yost property was accomplished without any surface excavation, it being carried out by tunneling over the line of the limestone crevice from the base of a shaft. This was sunk on the inner side of the "cave-in" on the Yost property to a depth of 44 feet. The excavation showed the limestone walls to be separated by an average width of 3 to 4 feet, the space narrowing downwards. This space was filled by tough, red clay. The width of the open interval between the limestone walls in hole No. 3 (Pl. I) is evidently much greater than this if we judge from the size of the trees and house which were engulfed. The only "cave-in" which still remains open

is hole No. 3 on the Wilson property. On account of the attempt which was made to save the Todd house, which stands partly over this hole, by building a cement pillar foundation on the limestone below the marl beds, the water was prevented by pumping from rising to its normal level till recently. Since pumping has ceased the water has risen to within 6 feet of the surface in this hole.

The section exposed by the slumping of the soft beds into the cavernous limestone shows at the top 1 to 4 feet of dark brownish earth and clay. Below this is a bed which is mainly an ash-gray marl containing great numbers of minute fresh water shells. Some beds of yellow clay are interstratified with the marl. These marly beds have a thickness of from 20 to 50 feet. The well at the ice plant is reported to have passed through about 12 feet of marl underlain by 14 feet of clay. The shaft on the Yost property is reported to have penetrated only clay. Previous to caving the soft marl appears to have been prevented from slumping into the limestone channel by a tightly packed tough limestone clay. A small collection of shells was obtained from the marl beds by the writer. These have been determined by Dr. Paul Bartsch who has furnished the following list of the species represented:

Bythinella nickliniana Lea
Planorbis bicorinatus Say
Planorbis parvus Say
Pisidium sp.?

These all represent living species which are common to the streams and ponds of the southeastern states, thus indicating the post-Plistocene or recent age of the beds.

A question of primary geologic as well as practical interest in connection with the caving is the direction followed under the town by the underground stream or cavern which is responsible for the caving. A brief examination of the bed rock stratigraphy in the vicinity of the caved area suggests that the underground course of this stream or cavern may be determined from stratigraphic data within the probable limits of future caving. The basis of this deduction will appear from a brief statement of the general factors controlling underground erosion in limestones and the particular factors which are chiefly effective in this case. It is a familiar fact that "the primary cause of motion in underground waters is gravi-

tation." In a limestone region the movement of underground waters following the line of least resistance, is controlled almost entirely by joint planes and bedding planes. Where the rocks are tilted only moderately, or not at all, the joint planes generally exercise by far the greater influence on the movement of the underground waters and consequently upon the direction of subterranean channels. If, however, the beds are highly inclined or vertical, the surface waters have a strong tendency to descend along bedding planes, and joints have less influence in directing their movement. The efficiency of bedding planes in controlling the movement of underground waters is clearly stated as follows by Bain: "Bedding planes between strata are natural division planes and under the slightest stress or the action of solutions they afford openings of even greater extent than fault planes."[5]

When the joints intersect at various angles, as is frequently the case, the courses of the underground streams controlled by them will be irregular. Where the joints are uniform in direction the underground streams are likely to show a corresponding uniformity. This is illustrated by the caves in the Mitchell limestone in Indiana and Kentucky according to Mr. F. C. Greene. In this formation the joints have a general east and west and north and south direction. "Thus young caves and many which are older follow approximately straight north and south and east and west lines and have right-angled turns."[6]

When, however, the direction of the movement of underground waters is controlled by nearly vertical bedding planes the horizontal flow will follow the direction of strike, and the resulting subterranean channels will necessarily follow in the main the strike of the beds. The subterranean channel disclosed by the caving marl and clay beds at Staunton illustrates this type of stream. Examination of the strike and dip of the rocks in all directions within a radius of a few hundred yards from the caved area showed the beds to be inclined everywhere at a high angle, usually 75° to 90.° (Pl. I.) The strike within the limits of the city has a uniform direct-

[5] Preliminary Report on the lead and zinc deposits of the Ozark region; H. F. Bain, C. R. Van Hise and G. J. Adams; 22nd Ann. Rept. U. S. Geol. Surv., Pt. II, 1901, p. 97.

[6] Proc. Ind. Acad. Sci., 1908, p. 178.

ion, being almost due northwest and southeast. The well marked and highly inclined bedding planes and the absence of any very prominent system of joints afford the factors which, without any knowledge from observation, might be used to predict the probable direction of any underground stream or cavern. It was not surprising therefore, to find that the direction of the subterranean channel as exposed by the "cave-ins" coincided with the strike of the beds in its vicinity. Moreover, the sides of the limestone channel descended where they could be observed, at an angle and in a direction similar to that of nearby outcrops of the limestone and evidently conform rather closely to bedding planes. (Pl. V.)

At the time of the writer's visit all of the limestone channel which was exposed had a direction of N. 48° W. The close agreement between the direction of the exposed channel and the strike of the rocks, and the evident predominant influence of strike and dip on underground drainage led the writer at the time of his visit to suggest to the city engineer that in all probability any future "cave-ins" would be on or very near the 48° line passing through the first series of "cave-ins." This prediction seems to be verified by the alignment of a test drill hole which failed to reach bedrock, in Lewis street at the southwestern end of the earlier series of cavings, and by the last of the "cave-ins." Both of these were reported to be exactly on the 48° line by the city engineer.[7] As already stated the crevice thus located in Lewis street was uncovered by excavating and arched with concrete across the width of the street in order to forestall any possible further caving. Through the series of holes caved in the marl and the drill records we have definite knowledge of the position and direction of the subterranean channel for a distance of nearly 400 feet in a perfectly straight line (Pl. I). A large number of test drillings has been made on both sides of this line by the city engineer and the post-office authorities. All of these have struck bed rock between 20 and 50 feet below the surface except as noted above. These records, together with the fact that the exposed portions of the limestone crevice into which the clay and marl beds have slumped have in no case been outside the 48° line, seem to demonstrate that the course of the underground

[7] Letter of Aug. 31, 1910.

stream coincides with the direction of the strike and is determined by it.

While the primary factors which lead up to the caving, or made it possible, are those which have been outlined it is less easy to state definitely what was the immediate cause of the caving. Various causes may lead to the reopening of the outlets of a silted-up limestone sink. Among these may be mentioned the burrowing of rodents or crawfish. A very small opening through the clay plug at the bottom of a closed sink hole might enlarge rapidly by the downward rush of ponded water. The gradual enlargement of the underground channel by solution of its walls and roof and the consequent breaking down of parts of its roof is in continuous though exceedingly slow operation in all caverns occupied by streams. The influence of a flooded condition of the underground channel, causing it to soften and erode rapidly any clay fillings in its roof might, in some cases, be effective in causing collapse of superficial beds. Another factor known to be effective in producing collapse in some regions is the general lowering of the ground water level. In the zinc district of southwestern Missouri, where limestone sinks, both filled and unfilled, are a characteristic feature of the topography, Mr. C. E. Siebenthal informs me that extensive pumping in connection with mining operations is a generally recognized cause of the collapsing of caves as well as caving in of silted-up sink holes.

Having in mind some of the factors which may produce collapse as outlined above we may consider which, if any, has probably been the cause of caving at Staunton. One of the causes which has been suggested as the effective agency in producing the caving is the very heavy rain which occurred at Staunton shortly before the development of the caved holes. A flooded condition of the underground stream would tend undoubtedly to soften the clay filling of the limestone crevice as well as increase its weight. But this factor must have been active at intervals for centuries at least without producing caving, and probably can hardly be regarded as more than a minor contributory cause at most. As an accessory to whatever may have been the primary cause of the initiation of caving there has been also the constantly present factor of vibration resulting from street traffic and the operation of a street car line across the line of caving.

The small surface stream which flows through the caved valley and very near the "cave-in" which was first to develop has been suspected of being the cause of the trouble by some of the local students of the problem. The hypothetical manner in which the stream may be supposed to have accomplished the caving was by partial discharge of its water through some originally small adventitious outlet into the portion of the limestone cavern under Baldwin street. This flow, gradually increasing from a slight seepage at first to a discharge sufficient to have considerable erosive power on the marl, gradually undermined the street till the collapse resulted. The result of this first "cave-in," which may be considered to comprise the nearly adjacent holes Nos. 1 and 2 (Pl. I) was to block or dam the subterranean stream till it rose to the level of the marl and clay beds above the limestone. The water thus dammed may be supposed to have softened the superficial beds brought in contact with it and have lead to the successive development of holes Nos. 3 and 4. The numbering of these holes on the map (Pl. I) corresponds to the order in which they developed. This hypothesis calls for a stream in the cavern flowing northeast. We are without definite information regarding the direction or the movement of water in the cavern, a current guage having failed to register any current. If this explanation of the caving were correct, careful examination of the artificial conduit of the stream in the vicinity of the caving should indicate the supposed diversion of water. A close examination of the conduit for this purpose by the city engineer, however, failed to show any such divergence. This hypothesis, therefore, appears to be supported by no ascertained facts, and it affords no explanation of the very suggestive sequence of events represented by the beginning of caving shortly after the starting of a high power pump nearby.

Another theory of the cause of the caving which requires consideration has been proposed by Hon. J. Yost. The well at the Smith ice-plant which is located about 150 feet from the line of caving, according to this theory, served to connect the strong stream near the bottom of the 800-foot well with the cavern under the "cave-ins" which previously had been empty or only partially filled with water. During the month which passed between the completion of the well and the installation of the 100-gallon pump, this cavern

was filled from this new source through channels connected up by the well. As a result the clay and superficial beds over the limestone crevice leading to this newly filled reservoir were softened and weakened. As a consequence of this softening collapse resulted when the 100-gallon pump was started and the buoyant support of the water removed. The detailed evidence on which this explanation rests is best stated in Mr. Yost's words. In a letter to the writer December 12, 1910, Mr. Yost says:

"He (Mr. Smith, owner of ice-plant well) states that at 125 feet he struck a stream of 5 gallons per minute, and the water rose in his well to within 24 feet of the surface. He then drilled down to 793 feet where a 15 inch crevice was encountered and a stream. He continued his drilling to 801 feet. The water rose to within 15 feet of the surface, or 9 feet higher than it had been before. The pump with the apparatus with which he drilled would only lift about 35 gallons. He installed another pump of between 50 and 65 gallon capacity, and with this, in 36 hours, reduced the water to 59 feet from the surface. For one month, pending the arrival of his new pump, the water was undisturbed and again rose to within 15 feet of the surface. The new pump had a capacity of 100 gallons. This was operated for 108 hours and reduced the water in the well to 100 feet from the surface. The first water drawn with the new pump was murky and continued so until the evening before the "cave-in," when it became clear. The next morning, when he noticed it, it was muddy, and about 9 o'clock, the first cave-in occurred. He was ordered to stop pumping and did so. Two days later, he tried to pump, but could not. A month later, the Superintendent of City Water undertook to clear out the well. He lowered a $\frac{3}{8}$ inch pipe to the 800 foot level and turned the city water (pressure about 70 pounds) into it. The discharge into the pipe was 3 gallons per minute. At the same time, Smith operated his pump and drew out about 8 gallons per minute—the 5 gallons from the 125 feet opening plus the inflow of the city water. Apparently, the well at the 800 foot level was closed.

Smith then tried by the aid of air pressure and the pressure of the city water to open his well, but failed.

This record of the Smith well tends, in my mind, to substantiate the theory outlined in my letter to you on Monday. (That the stream encountered by Smith at the 800 foot level was diverted into the crevice under the Todd house). It shows that Smith never had 100 gallons as supposed. What has bothered me, heretofore, has been to account for the supposed one hundred gallons from the well, when the flow from the Todd hole was scarcely one-third of that quantity. This explains it. The stream he struck at the 800 foot level could not have been more than 35 or 40 gallons. For more than a month after he struck this stream it probably emptied into the Todd hole. Thence it rose in the adjacent cavity and gradually saturated the roof to within 15 feet of the surface.

The roof, thus weakened, gradually dropped down. This would account for the rumblings and mysterious noises noticed by the tenants of the Todd house for some time before the cave-in. Then, with his large pump, Smith drew that water off suddenly, and the roof gave away. Since that time the 35 gallons has been running into the Todd hole and this inflow and sudden evacuation caused the trouble.

I have endeavored to recall all of the circumstances and incidents connected with the trouble and nothing presents itself to me which negatives this theory, except one possible incident:

At the Clem Ice Factory, in the Valley 600 or 800 feet north of the school house, there are four shallow wells, ranging from 16 feet to 20 feet in depth. On the night following the slump, the pump in the deepest well failed to catch the water for an hour or one and a half hours. The same thing occurred the following night. Mr. Clem does not know whether or not any of the other walls were affected. I cannot attach great importance to this incident. The water was low for only 1½ hours at most and that may have been because he was drawing harder at that particular point. The fact that he dug four wells and uses them all tends to show that one of them could easily be temporarily exhausted."

As previously pointed out by Van Horn[8] the data given by Mr. Yost seem to establish clearly the fact of direct connection between the stream tapped at 790 feet by the deep well and the water in the cavern under the "cave-in."

But the vital question in any interpretation of this relationship in explaining the caving is, did the water enter a previously empty cavern through the agency of the 800-foot well, as Mr. Yost supposes, or did pumping the well empty the cavern which was previously full and which had never before been drained? It is the writer's view that the latter supposition is much the more probable. This probability is indicated by the fact that when the pumping ceased, which was utilized to lower the water in the "cave-ins" during the process of arching with cement the openings in the streets, and at the Todd house the water rose nearly to the surface in hole No. 3. The rise was very rapid, 3 to 4 feet per hour, or about 35 gallons per minute, till it stood within 10 feet of the surface. Above this point the rise was very much slower, about 5 to 6 feet per day, until it reached within 5 or 6 feet of the surface. "It was still rising at about this rate when pumping was resumed, and has since continued." (Letter from J. Yost, April 22.) If this water had entered the "cave-in" through the deep

[8] Mining and Engineering News; Sept. 1, 1910.

well, as supposed by Mr. Yost, there should have been no such difficulty as is reported in pumping from the well after the caving ceased. This rise of water in the "cave-in" doubtless represents the original level of ground water previous to the caving. If this is true it follows that the roof of the cavern received a certain amount of support from the water which filled it previous to the caving. If we suppose the normal development of the cavern to have reached the point where the strength of the materials comprising its roof made them barely self-sustaining, the withdrawal of this hydrostatic support, however slight it may have been, combined with the rapid subsurface erosion of the marl which may have resulted, would have served as a trigger to start the collapse of the roof. Caving as a probable result of the withdrawal of such support is not only a theoretic but an observed fact in some mining districts, as will be seen from the following quotation from Smith and Siebenthal.[9]

"Where caverns are below the ground-water level and full of water the water helps support the weight of the roof. Where the balance is nicely adjusted and the roof is only just self-sustaining, if the water be withdrawn the cave will collapse. In a number of cases in the Joplin district such collapsing has followed the lowering of the ground-water level by pumping in the deeper mines. Without doubt many "natural caves" have in the geologic past resulted from the draining of caverns by elevation of the land and other causes, and have developed into closed valleys."

The above statement is substantiated by Bain[10] who cites in the following quotation specific instances where collapse has resulted from the withdrawal of hydrostatic support in the lead and zinc region of southwestern Missouri.

"An interesting phenomenon of the Joplin caves is the fact that in them the weight of the roof is occasionally partly supported by the hydrostatic pressure of the water When the water is pumped out the roof may fall in. This occurred at the Budweiser mine at Tuckahoe. Near the

[9] Smith and Siebenthal; Joplin District Folio Missouri-Kansas; U. S. Geol. Surv., Bull. 148, 1907, p. 8.

[10] Preliminary report on the lead and zinc deposits of the Ozark region, H. F. Bain. With an introduction by C. R. Van Hise and chapters on the physiography and geology by George I. Adams, 22d Ann. Rep. Director U. S. Geol. Surv., Pt. II, 1901, p. 110.

Sand Ridge mine, at Aurora, great cracks similar in appearance to those formed by earthquakes developed in the summer of 1900 as pumping lowered the ground-water level. Near Carl Junction a section of railway track at one time sank, presumably as the result of pumping, in this instance some distance away."

Another example of this kind of collapse is furnished by the following account[11] of a cave-in which occurred at Neck City, Mo., early in January of this year.

"A hole opened under the mill pond and a great elm tree was swallowed into the earth, in a natural cave so large that nothing remained visible of the tree when workmen arrived on the scene at 7 a.m.

"Some time between the night before and 7 o'clock yesterday morning the bottom of the pond went it, presumably as a result of water having been pumped from beneath, though no mine drifts exist beneath the cave.

"A tape line set down into the cave to a distance of 84 feet failed to touch bottom, though the nature of the hour-glass cave prevented a close scrutiny from the top."

From the cases cited above it will be seen that the caving of the roofs of natural caverns is a rather familiar phenomenon in the zinc region of Missouri where there appears to be no question regarding its dependence upon extensive pumping. In the light of these analogous cases it is hardly possible to ignore the suggestiveness of the fact that the caving at Staunton followed five days after the operation of the 100-gallon pump at the ice plant began. That the pumping and caving bear the relation of cause and effect seems to the writer most probable.

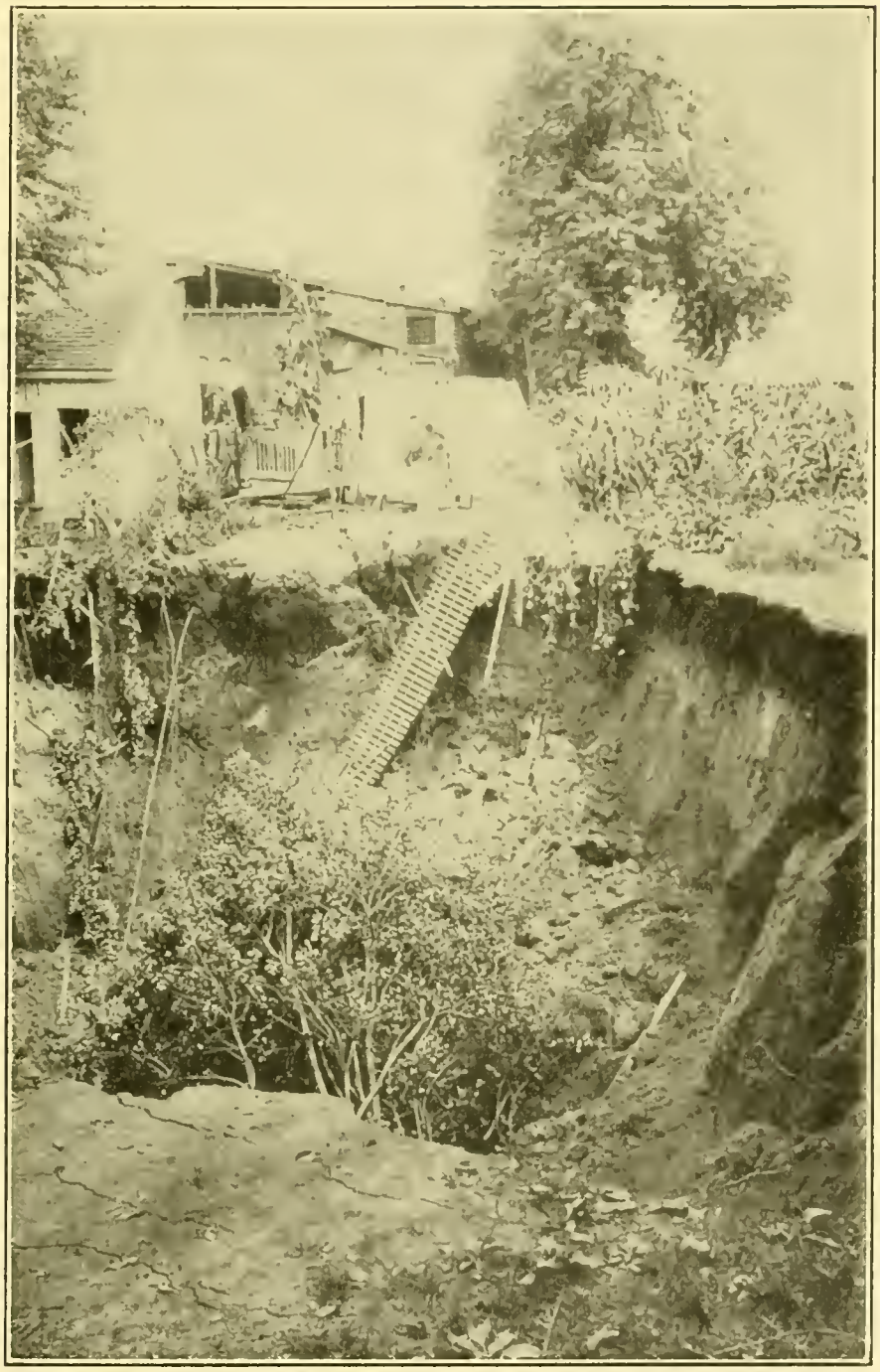
The lowering of the water level in the cavern which resulted from the operation of the ice plant pump it is believed not only removed the buoyant support of the water from the beds forming the roof, but probably initiated strong downward currents through subsurface channels, thus carrying downward soft beds which had partially filled the interstices of the limestone roof and others above it, and which would otherwise have remained undisturbed. The intensified movement of downward trending waters through the marl resulting from the drainage of the limestone cavern below these beds may have developed fair-sized cavities in the marl

[11] Joplin (Mo.) News Herald, Jan. 15, 1911.

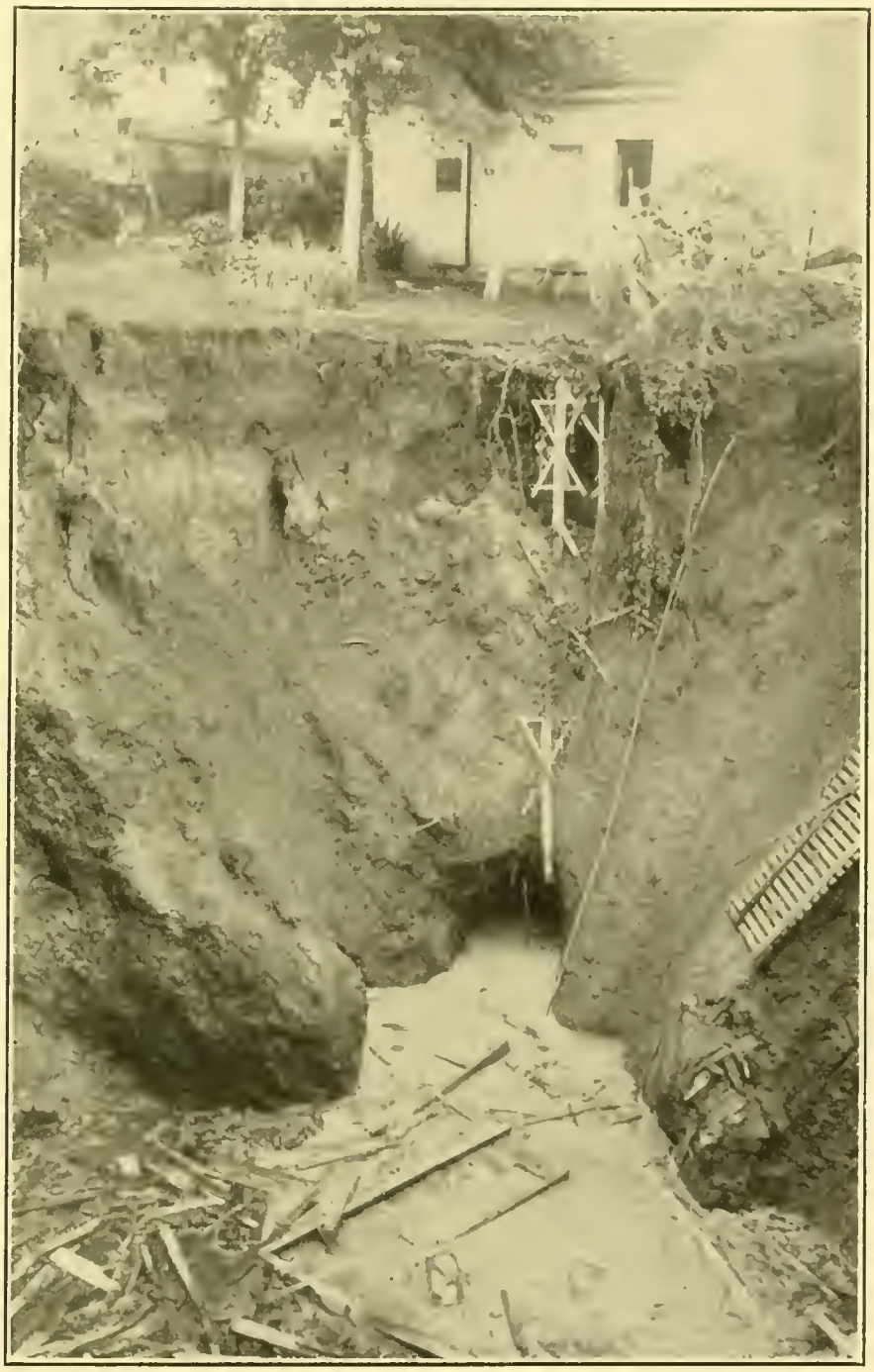
above the limestone roof of the cavern before the larger breaks in the limestone roof occurred. Such a temporary cavity in the marl superimposed upon the limestone cavern might, when it collapsed, precipitate tons of clay and marl with destructive effect upon the limestone roof which, under normal conditions, would have remained stable for ages. That the marl beds held abundant water for such streams, if their development were stimulated and an outlet provided by withdrawing the water from the cavern beneath a portion of the beds, is indicated by the fact that a pump at the Clem ice factory with a capacity of 50 gallons per minute draws its water from these beds. Desication resulting from the lowering of the ground water and the consequent shrinkage of the materials which filled the old outlets of the original sink hole may also have been a factor, though probably a minor one, in starting the caving. Consideration of all the available evidence which has been given appears to point to the lowering of the level of ground water by pumping as the most probable immediate cause of the caving.

Fig. 1 Showing first stage of the caving and a house and tree which were engulfed.

Fig. 2 View of two of the holes in Baldwin Street, taken after the disappearance of the house shown in Fig. 1.



View showing an early stage of "cave-in" No. 3.



View of hole No. 3 after the disappearance of the shade tree seen in fig. 1, plate 2, and the rise of the water.

View showing the crevice opening into the limestone cavern under the Todd house.

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REMARKS ON THE FOSSIL TURTLES ACCREDITED TO THE JUDITH RIVER FORMATION.[1]

BY F. H. KNOWLTON.

In my paper entitled The Stratigraphic Relations and Paleontology of the 'Hell Creek beds,' 'Ceratops beds' and their equivalents, and their reference to the Fort Union Formation,[2] I made, among others, the following statements regarding the turtles of the Judith River formation: "It has recently been confidently asserted on eminent authority that the turtles of the 'Ceratops beds' are very closely related to those of the Judith River formation; in fact that several species are identical, and others so close as to be separated with difficulty. Fortunately the work of Hatcher, published as late as 1905, has left us with a very complete annotated list of the Judith River forms, which makes a valuable basis of comparison of the two faunas. It needs, however, but a cursory examination to show that at least half of the species listed as belonging to the Judith River do not belong to this fauna at all, but come from the Fort Union, Arapahoe, etc., or are so fragmentary as to be unidentifiable. . . . Any comparison of the turtles of the Judith River formation with those of the 'Ceratops beds' as tending to support the Cretaceous age of the latter, does not make a very impressive case."

[1] Published with the permission of the Director of the United States Geological Survey.

[2] Wash. Acad. Sci., Proc., vol. xi, 1909, pp. 235, 236.

Lack of space at that time precluded the full presentation of the data on which the above statements were based. Inasmuch as this mild remonstrance does not appear to have attracted attention, and since the turtles are still being used to "prove" close relationship between the Judith River and Lance ("Ceratops beds") formations, it seems opportune to set forth the facts as they are. In a paper[3] just published Dr. O. P. Hay writes as follows: "My study of the fossil turtles indicates that the species of these animals rarely pass from one epoch to another. If they have ever done so they passed from the Judith River into the Lance Creek epoch. There are five or six species of Judith River turtles which are represented in the Lance Creek and Hell Creek beds by turtles of identical or very closely related species."

In the following pages it is proposed first to take up the species of turtles mentioned by Hatcher[4] as belonging to the Judith River formation, and to indicate the type locality for each species as well as its subsequent distribution so far as this is a matter of published record. Later in this paper the species enumerated by Doctor Hay will be similarly treated, and finally some remarks will be presented on the results of this showing.

Turtles of the Judith River Formation Enumerated by Hatcher.

1. Trionyx foveatus Leidy [Aspideretes foveatus (Leidy) Hay].

Type locality: "Bad Lands of the Judith River, Nebraska Territory." Fragments collected by Doctor Hayden and named and described by Doctor Leidy in 1856[5]. Subsequently Leidy figured two of the type specimens, together with another specimen, identified doubtfully as the same species, from Long Lake below old Fort Clark on the Missouri River, North Dakota, the latter belonging to the Lance formation. On this point Hatcher says: "Considering the difference in the age of these deposits, it is quite

[3] Where do the Lance Creek ("Ceratops") Beds belong, in the Cretaceous or in the Tertiary? Indiana Acad. Sci., Proc., 1909 (issued Oct. 1910), p. 21 (of reprint).

[4] U. S. Geol. Surv., Bull. 257, 1905, pp. 72–80.

[5] Acad. Nat. Sci., Phila., Proc., vol. viii, 1856, p. 73.

probable that had better material been at the disposal of Doctor Leidy he would have found them to be at least specifically distinct." Specimens identified by Cope as *Trionyx foveatus* were collected by Sternberg in the Judith River area in 1876; it does not appear to have been found by Stanton and Hatcher when they visited the area in 1905. This species was reported by Marsh from the "Ceratops beds" near Denver, Colorado, but according to Hay these specimens "belong probably to *Aspideretes beecheri*" a species from the Lance formation of Converse County, Wyoming. *Trionyx foveatus* has also been identified by Lambe from the Belly River beds of the Red Deer River region in Canada, and by Barnum Brown in the "Hell Creek beds" (= Lance formation) of Montana.

From this review it appears possible that there are two and quite likely three species confused under the name of *Trionyx foveatus*, and hence any conclusion as to which part of the "species" belongs to the Judith River, and which to the Lance formation, must be a matter of more or less doubt.

2. Trionyx vagans Cope [Aspideretes? vagans (Cope) Hay].

Type locality: Bijou Basin (Bijou Creek), 40 miles east of Denver, Colorado, in beds regarded by Cross as probably Arapahoe in age. It was also reported by Cope from near the mouth of the Bighorn River, Montana, and near Long Lake, North Dakota, both localities in beds belonging in all probability to the Lance formation. Apparently on the basis of Lambe's reporting it from the Belly River beds of the Red Deer River in Canada, it was included by Hatcher in his list of Judith River species, though Hatcher himself points out the obvious distinctness between the type specimens and the specimens so identified by Lambe. Hay has referred Lambe's specimens to another species, and hence all pretense of *Trionyx vagans* as a Judith River species disappears.

3. Plastomenus coalescens Cope. [Aspideretes coalescens (Cope) Hay].

Type locality: "Bad Lands south of Woody Mountain, latitude 49°," longitude about 106°, Assiniboia, Canada.

Much confusion has arisen concerning this species, which can only be eliminated by a review of all the earlier references to it in the literature of the subject. It was first mentioned but without description in a list published by Cope in 1875,[6] and was fully described later in the same year in an obscure paper published as an appendix to Dawson's Report on the Geology and Resources of the Region in the vicinity of the Forty-ninth Parallel, etc.[7] Still later in 1875 this description was copied word for word, but without reference to either of the two preceding places of publication in Cope's Vertebrata of the Cretaceous Formations of the West.[8] In the Report where it was first described the locality was given as The Bad Lands south of Woody Mountain, latitude 49°, a locality confirmed by Dawson in his description of the geology of the region.[9] Dawson also mentions other vertebrate remains with which it was found associated, as well as several species of plants, and refers the beds to the "Lignite Tertiary," and in the latest published geological map of Canada,[10] the area is still colored as "Laramie," which in the writer's opinion is the approximate equivalent of the Fort Union of the United States.

The confusion dates from the moment when Cope transferred the original description to his "Vertebrata of the Cretaceous Formations of the West," where as regards the locality he says: "This species is found . . . . near the Milk River in British America," where it was "collected by George M. Dawson . . . . near Woody Mount." As a matter of fact Woody Mountain (or Woody Mount) is *more than 150 miles east* of the valley of Milk River where it crosses the international boundary, and there is not the slightest evidence that it came from Milk River. But because it was supposed by subsequent writers that Woody Mountain was in the Milk River Valley, it was assumed that the age must be Judith River! Thus Hatcher,[11] who was apparently in ignorance of the original place of publication says: "This species is founded on fragments . . . .

[6] Acad. Nat. Sci., Phila., Proc., 1875, p. 9.
[7] Brit. N. A. Bound. Com., Montreal, 1875. Appendix B, p. 337.
[8] Rept. U. S. Geol. Surv. Terr., vol. 2, 1875, p. 92.
[9] Brit. N. A. Bound. Com., Montreal, 1875, p. 105.
[10] Western Sheet, 1901.
[11] U. S. Geol. Surv., Bull. 257, p. 74.

collected by George M. Dawson near Milk River in Canada, from beds referred by Cope to the 'Transition series, probably the Fort Union or Lignite epoch,' but now known to belong to the Judith River." This error is also perpetuated by Hay in his Fossil Turtles of North America,[12] who, although obviously familiar with the original place of publication, still gives the locality as "in the basin of Milk River, south of Wood Mountain, Assiniboia, British Columbia."

The above exposition would seem effectively to dispose of the claim for Judith River age of the type material of *Plastomenus coalescens*, though it might possibly be considered to figure as a Judith River species if Doctor Hay's reference to it of a specimen identified by Lambe as *Trionyx vagans* is of valid standing. That is to say Lambe collected a large, finely preserved specimen, which he identified as Cope's *Trionyx vagans*, in the Belly River deposits in the region of the Red Deer River, below Berry Creek, in Alberta. Concerning this Doctor Hay says:[13] "The present writer, regarding Cope's type of *Trionyx vagans* as too small and imperfect a fragment for satisfactory comparison with materials from any region, except the type locality in Eastern Colorado, is compelled to seek for some more probable disposition of Mr. Lambe's fine specimen. Since the plastron of Cope's *Plastomenus coalescens* indicates a large trionychid which lived in approximately the same region and in the same geological period, it appears to be best to refer the Red Deer River carapace to the same species." It appears, then, that the study of these specimens themselves is not sufficient to determine whether Lambe's specimen is really referable to Cope's species, so the burden is placed on stratigraphy!

4. Plastomenus costatus Cope.

Type locality: "Bad Lands south of Woody Mountain, latitude 49°."

This species was found in the same locality and horizon as the last, and the same confusion and compounding of error has resulted. Simply because Woody Mountain was supposed to be in the valley

[12] 1908, p. 489.
[13] Op. cit., p. 489.

of Milk River it followed that the age must be Judith River! Upon this assumption alone rests the claim.

This species has been found by Barnum Brown in the Lance formation ("Hell Creek beds") 12 miles south of the Missouri River, on Hell Creek, Montana. This locality is about 100 miles directly south of the type locality in Canada.

5. Plastomenus punctulatus Cope.

Type locality: Bijou Creek, 40 miles east of Denver, Colorado, in beds that are of Arapahoe age according to Whitman Cross. Cope also states that he had the same species from beds at Long Lake, "Nebraska" (now North Dakota), the age of which is Lance formation.

Hatcher's reason for including this species in the Judith River fauna is interesting. He quotes[14] Cope's statement, evidently from his Vertebrata of the Cretaceous Formations of the West, to the effect that it was "found in association with the preceding species," which, in this book happens to be *Plastomenus costatus*, but in the place where *P. punctulatus* was originally described,[15] the "preceding species" happens to be *Trionyx vagans*, the status of which has already been considered above. As the original description was transcribed without change from the Annual Report into the Monograph the error arose as stated above and as has been pointed out by Doctor Hay. *Plastomenus punctulatus* can, therefore, lay no claim to having been found in the Judith River.

6. Plastomenus insignis Cope.

Type locality: Bijou Creek, 40 miles east of Denver, Colorado.

This species was introduced into the Judith River fauna by Hatcher[16] who, consulting Cope's Vertebrata only, and ignoring the original place of publication, concludes that by "inference" it came from south of Woody Mountain, and if from this locality it was assumed, as in the cases of the several species above considered, that

[14] U. S. Geol. Surv., Bull. 257, p. 74.

[15] U. S. Geol. and Geogr. Surv. Terr., Ann. Rept., 1873 (1874), p. 453.

[16] U. S. Geol. Surv., Bull. 257, p. 75.

it must be of Judith River age. It is clear enough when the original description is consulted that this species came only from Bijou Creek, Colorado, and this is confirmed by Doctor Hay who has examined the type now in the American Museum of Natural History and finds it labeled in Cope's handwriting as "*Plastomenus insignis*. 10–9–1873, Colorado." It is therefore to be excluded from the Judith River fauna, but not for the reasons given by Hatcher.

7. Adocus lineolatus Cope.

Type locality: Bijou Creek, 40 miles east of Denver, Colorado, in beds believed to be Arapahoe in age. Also reported by Cope from the mouth of the Bighorn River, Montana, and it appears in his list of Judith River vertebrates, though according to Hatcher this last reference is probably "due to an oversight." Fragments that have been identified as this species have been found by Lambe in Belly River beds of Red Deer River, Alberta, by Barnum Brown in the Lance formation on Hell Creek, Montana, and by others in the "Ceratops beds" (Lance formation) of Converse County, Wyoming. Hatcher has expressed as his opinion[17] that the reference of Lambe's specimens "may be incorrect" and Doctor Hay[18] says: "It is the writer's opinion that it is unsafe to identify as belonging to *Adocus lineolatus* specimens from the Judith River and Laramie beds before far better materials of the species have been collected from the type locality." He adds: "It is improbable that the same species continued from the Judith River epoch to the Arapahoe epoch," which latter, be it remembered, is the probable age of the type material.

8. Basilemys ogmius (Cope).
Basilemys variolosa (Cope).

Type locality: "From six miles west of the first branch of Milk River, near latitude 49°," in the province of Alberta, British America. Because this locality is in the vicinity of Milk River it has been assumed by Hatcher and others that the age must be Judith River,

[17] U. S. Geol. Surv., Bull. 257, p. 76.
[18] Fossil Turtles of North America, p. 248.

but a careful reading of Dawson's account[19] of the geology of the place where he actually obtained the specimens shows that in all reasonable probability it should be referred to the "Ceratops beds," that is the Lance formation. Dawson considered the beds as "belonging probably to the base of the Lignite Tertiary," and compares them to the beds south of Woody Mountain, adding: "The bones, in the manner of their preservation, much resemble division β of the Bad Lands south of Woody Mountain, which these beds may possibly represent." The lithology is described as similar in the two areas, and associated with the remains of the turtles Dawson reports finding many bones of dinosaurs, and large Unio shells. In any event it seems unsafe to refer these beds to the Judith River merely on geographical position and without corroborative data.

The type specimens of *Basilemys ogmius* are said to be very poor, and Doctor Hay states that: "It is doubtful whether new materials could be identified by means of the type." However this may be, this species has been combined with *Basilemys variolosa* (Cope), which has as its type locality "Bad Lands of the Judith, Montana," and was described a year or more later. Material that has been identified as *Basilemys* (or *Adocus*) *variolosa* has been mentioned by Lambe from the Belly River beds of Red Deer River, Alberta, and by Hatcher in the Judith River formation of Montana. It seems not improbable that there may be two species represented, but in any event it would appear that the undoubted Judith River material has been that identified with "*B. variolosa*," whereas the *B. ogmius*, being very poor, has not been certainly recognized.

The conclusion reached is that that part of the "species" named "*B. ogmius*" came from beds that are not certainly of Judith River age, and has not been subsequently recognized, while the part known as "*B. variolosa*" came from beds of Judith River age, and is the only part of the "species" that has been distinguished by later authors.

9. Basilemys imbricarius (Cope).

Type locality: Judith River Basin, Montana, in beds of the Judith River formation; it has not been found elsewhere. It was founded on very unsatisfactory materials, according to Doctor Hay.

[19] Brit. N. A. Boundary Com., 1875, p. 130 *et seq.*

10. Polythorax missouriensis Cope.

Type locality: Judith River Basin, Montana, in beds of the Judith River formation. It has not been reported from any other locality or horizon.

11. Baëna antiqua Lambe.

Type locality: Red Deer River, Alberta, British America, in beds supposed to be of Belly River age; it has not been obtained elsewhere.

12. Baëna hatcheri Hay.

Type locality: South side of Lance Creek, opposite mouth of Dogie Creek, Converse County, Wyoming, in beds of the Lance formation ("Ceratops beds").

A specimen from the Belly River beds of the Red Deer River, Alberta, was referred to this species by Lambe,[20] and it was upon this ground that it was included by Hatcher[21] in the Judith River fauna. Later, however, Doctor Hay[22] referred Lambe's specimen to a totally different genus and species (*Boremys pulchra*), and hence *Baëna hatcheri* is to be eliminated from the Judith River fauna.

13. Neurankylus eximius Lambe.

Type locality: Red Deer River, Alberta, British America, in beds regarded as of Belly River age; it is monotypic and has not been collected elsewhere.

There is one naïve bit of history connected with this genus that should not be omitted. Doctor Hay in his Fossil Turtles of North America (p. 93) remarks as follows: "Mr. Lambe placed the genus provisionally among the Chelydridae, but as no genera of this family are known from deposits older than the Tertiary and as the type has some resemblance to the Baënidae, which flourish at that time, it seems better to refer Neurankylus to this family until more is known about it."

[20] Cont. Canadian Pal., vol. 3, 1902, pt. ii, p. 43.
[21] U. S. Geol. Surv., Bull. 257, p. 79.
[22] Fossil Turtles of North America, 1908, p. 92.

Turtles Mentioned by Hay as Tending to Show Identity or Close Similarity Between Species of the Judith River and Lance Formations.

Following is the list of six species given by Doctor Hay[23] and of which he says: "I shall take pains to give some details."

1. Compsemys obscura (Leidy).

Type locality: Near Long Lake, on the Missouri River below Fort Clark, North Dakota, in beds regarded as belonging to the Lance formation. It has otherwise been collected only in beds of the Lance formation ("Hell Creek beds") on Hell Creek, Montana.

This species was included by Cope[24] in his list of Judith River vertebrates, but without giving any evidence in support of such reference, and presumably on the authority of Cope's list it is included by Osborn[25] in his list showing the "distribution of the land and fresh-water Cretaceous vertebrates in the west," as occurring in Montana and hence "by inference" in the Judith River fauna. *Compsemys obscura* as well as its companion species, *C. victa*, was excluded from the Judith River fauna by Hatcher, who says, "In no descriptions of either of these species can I find any suggestion that remains of either have been described from Montana." That *C. obscura* is properly excluded from the Judith River is shown by Doctor Hay, who says,[26] "This species is included by Cope in his list of Judith River fossils, but the writer knows of no specimens that confirm the statement." Curiously enough, however, this species is the first one given by Doctor Hay[27] as occurring in both Judith River and Lance formations!

2. Compsemys victa Leidy.

Type locality: Long Lake, on the Missouri River below Fort Clark, North Dakota, in beds regarded as belonging to the Lance formation, that is the same locality and formation as the last.

[23] Proc. Indiana Acad. Sci., 1909, p. (of reprint) 21.
[24] U. S. Geol. and Geogr. Surv. Terr., Bull. vol. 3, 187, p. 573.
[25] Cont. Canadian Paleont., vol. 3, 1902, pt. ii, p. 12.
[26] Fossil Turtles of North America, 1908, p. 236.
[27] Proc. Indiana Acad. Sci., 1909, p. (of reprint) 21.

The history of this species is much the same as that of the last, except that specimens identified under this name have a somewhat wider distribution. It was included by Cope in his list of Judith River vertebrates, but, as stated under the last species, was excluded from this fauna by Hatcher. It is accepted by Doctor Hay[28] as of Judith River age on the ground that it was found in the region about Milk River, Alberta. This occurrence in the "Milk River region" is traceable to Dawson's Report on the Geology and Resources in the Vicinity of the Forty-ninth Parallel, but, as in the case of *Plastomenus coalescens*, a reading of the geological part of the report shows that it came from south of Woody Mountain, and 150 miles east of the Valley of Milk River, in beds of "Lignite Tertiary" age.

This species was reported by Cope from supposed Arapahoe deposits east of Denver, Colorado, and is said to be "very common in the Lance Creek beds," of Converse County, Wyoming. It was also found by Brown in the Lance formation ("Hell Creek beds") on Hell Creek, Montana, and an allied but undescribed species is reported by Doctor Hay from the Fort Union.

From this brief exposition it is clear that *Compsemys victa* must be excluded from the Judith River fauna, and the only horizons in which it is authenticated are Arapahoe and Lance formations. In the treatment of this species in his Fossil Turtles of North America (p. 234), Doctor Hay opines that there is so much difference in age between Judith River, Arapahoe and Denver, and Lance formations that it is "not improbable" that three species are represented instead of one. Again would the responsibility be shifted from paleontology to stratigraphy!

3. Aspideretes foveatus (Leidy) Hay.

The status of this species has been already considered under its synonym, *Trionyx foveatus*, ante, p. 52.

4. Aspideretes beecheri Hay.

Type locality: East side of Lance Creek, Converse County, Wyoming, in beds belonging to the Lance formation. Two cara-

[28] Fossil Turtles of North America, p. 234.

paces from the Judith River of Fish Creek, Montana, have been referred to this species by Doctor Hay, who makes the following statement concerning them: "No characters are observed which serve to distinguish these carapaces from that of the type of *A. beecheri*. It is not improbable, however, that they belong to a distinct species."

5. Adocus lineolatus Cope.

The status of this species has been considered, ante, p. 57.

6. Basilemys variolosa (Cope).

This has already been considered at length under its synonym *Basilemys ogmius*, p. 57.

Discussion of Evidence Regarding "Judith River" Turtles as Brought out in the Foregoing Review.

On combining the lists given by Hatcher and Hay it appears that sixteen species of turtles have been accredited to the Judith River formation. Of these sixteen species it has been demonstrated that only three species have the type specimens from the original Judith River area in Montana, while two additional species have the types from the Belly River (= Judith River?) of the Red Deer River region of Alberta. The three species from Montana are the following:

Trionyx foveatus
Basilemys imbricarius
Polythorax missouriensis

The two Canadian species are:

Baëna antiqua
Neurankylus eximius

Of the remaining species four, as follows, have the types described from Bijou Creek, Colorado, in beds supposed to be of Arapahoe age:

Trionyx vagans
Plastomenus punctulatus
Plastomenu sinsignis
Adocus lineolatus

The types of two species came from south of Woody Mountain, Assiniboia, in beds referred to the "Lignite Tertiary" by Dawson, Cope, and others, but are now considered to belong to the Lance formation. They are:

Plastomenus coalescens
Plastomenus costatus

From Long Lake, North Dakota, in beds of the Lance formation, the following types are supplied:

Compsemys obscura
Compsemys victa

The types of two species were obtained from the Lance formation of Converse County, Wyoming:

Baëna hatcheri
Aspideretes bcccheri

The remaining species is *Basilemys ogmius* which as already shown is of mixed position. Strictly speaking the type came from near Milk River, Alberta, in beds that are probably younger than the Judith River, while *B. variolosa*, the "species" with which it has been combined, came from the Judith River formation near Judith River, Montana.

A further analysis of the evidence adduced indicates that the following species should be excluded from the Judith River fauna on the sufficient ground that they do not occur in beds of this age:

Trionyx vagans
Plastomenus costatus
Plastomenus punctulatus
Plastomenus insignis
Baëna hatcheri
Compsemys obscura
Compsemys victa

To return again to the five species having their type locality in Judith River and Belly River beds, it appears that the four following have never been found outside the Judith River or Belly River horizons.

Basilemys imbricarius
Polythorax missouriensis
Baëna antiqua
Neurankylus eximius

The fifth species—*Trionyx foveatus*—is the only one that appears to be distributed into higher beds, but it will be recalled on referring to the discussion of this species on page 53, that, while it has been reported from Long Lake, North Dakota, Hell Creek, Montana, and near Denver, Colorado, both Hatcher and Hay have expressed the opinion that there may be two and possibly three species confused under this name, each being confined to one of the three horizons involved.

The following forms, although having their types from beds higher than the Judith River formation (Arapahoe, Lance formation etc.), appear on more or less questionable evidence to have ranged downward into the Judith River:

Plastomenus coalescens (*?*)
Adocus lineolatus (*?*)
Aspideretes beecheri (*?*)

The reasons why these are regarded as questionably present in the Judith River formation are set forth in the discussions of these species in the preceding pages. Not a single one has a clear title.

Conclusions.

1. The Judith River fauna has had accredited to it by Hatcher and Hay at least sixteen species of fossil turtles.

2. Of these sixteen species seven are to be excluded on the sufficient ground that they do not occur in beds of Judith River age.

3. Of the nine remaining species that may have a more or less valid claim to membership in the Judith River fauna, five have their type localities in beds of Judith River and Belly River age, and four in horizons above that of the Judith River.

4. Of the five typically Judith River species, four are absolutely confined to these beds, while the remaining one which has an alleged higher range, is shown to be probably a composite species possibly including three species which correspond respectively to the three horizons involved.

5. Of the four species, the types of which came from post-Judith River beds, and which are claimed to range downward into the Judith River, not a single one enjoys a clear title to be so regarded.

6. It is plain, then, that the comparisons that have been made between "Judith River" turtles and those of higher horizons (Lance formation, "Laramie," "Ceratops beds," "Hell Creek beds," "somber beds," etc.), have not been made with species that really belong to the Judith River fauna, but with forms that actually belong to these higher beds. It is not to be wondered at that such a comparison has resulted in showing "identity" and "striking similarity," since it is in accord with the ancient axiom, that "Things equal to the same thing are equal to each other."

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ON THE SYSTEMATIC VALUE OF RANA CHINENSIS OSBECK.

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In an article which I published in "Állattani Kozlemények (3)", I separated as a distinct species *Rana ridibunda* from *Rana esculenta*. After the publication of that paper Professor Dr. Méhely directed my attention to a frog found in China and Japan which is mentioned in literature, according to Boulenger, as a variety of *R. esculenta* (*Rana esculenta chinensis* Osb.), but which, however, as Professor Méhely observed, can be separated with more right from *R. esculenta* than is *R. ridibunda*.

A short time afterward my article appeared in German also (4), and was commended by Wolterstorff who wrote as follows on that subject: "As soon as we acknowledge the right of a species for *Rana ridibunda* we must do the same with more reason still for *Rana chinensis*, a fact also recognized not long ago by Stejneger."

Wolterstorff considers this same question in one of his articles, published in 1906, and there expresses his conviction that *Rana chinensis* is a well-defined subspecies.

Quite recently Leonhard Stejneger, the American herpetologist, described *Rana chinensis* as a distinct species under the name *Rana nigromaculata* Hallowell.

The first author who describes *Rana chinensis* is Osbeck. He mentions as the sole peculiarity distinguishing it from *R. esculenta* the fact of its having six toes of which the sixth is the shortest.

Schlegel finds it quite similar to *R. esculenta*. Maack alludes to it as *R. esculenta var. japonica* Hallowell and describes it under the two names *R. marmorata* and *R. nigromaculata*. Peters and Cope go furthest, placing it in an other genus, the former mentioning

it as *Hoplobatrachus reinhardti*, the latter under the name *Tomopterus porosa*. Lataste calls it *R. esculenta marmorata*. Boulenger refers to it at first as *R. esculenta var. japonica*, then as *var. nigromaculata*, and quite lately as *var. chinensis* Osbeck.

R. chinensis has been mentioned only once in Hungarian literature, Professor von Méhely describing as *R. esculenta var. chinensis* the three specimens collected at Peking by the Zichy expedition.

The great confusion existing in literature upon that question, as well as the statements by Professor von Méhely and Professor Wolterstorff, induced me to study the Chinese frog. My aim is to point out, with especial regard to the osteological marks, the systematic position of *R. chinensis*, and to prove at last that the Chinese frog has nothing to do with *R. esculenta*, and that taking all of its characteristic features into consideration, it can be placed near to *R. ridibunda* Pallas.

I find it necessary to give a detailed description of the species, improved and completed by the result of recent observations made upon specimens from the Hungarian National Museum as well as upon others from China bought at Magdeburg from Wolterstorff. Having pursued my investigations in the Hungarian National Museum, I wish here to express particular thanks to Professor von Méhely for the kind assistance he lent me in my work, allowing me the benefit of the Museum's material as well as giving me most valuable information.

RANA CHINENSIS Osbeck.

Synonymy.[1]

1765. *Rana chinensis* Osbeck, Reise Ostind. China, I, (p. 244); Voy. China (Engl. ed.), I, 1771, p. 299 (Canton, China).

1906. *Rana esculenta* subsp. *chinensis* Wolterstorff, Abhdl. Berichte d. Mus. f. Natur. und Heimatkunde zu Magdeburg, Bd. I, Heft 3, 1906, pp. 135–143.

1907. *Rana nigromaculata*, Stejneger, Herpetology of Japan and adjacent Territory, Bull. U. S. Nat. Mus. No. 58, p. 94, pl. 10, fig. 1.

[1] For complete Synonymy see Stejneger, Herpetology of Japan, cited above.

Description.

Vomerine teeth in two slightly oblique groups between the choanæ very seldom extending to the line joining the posterior border of the choanæ. The male's head is generally narrower, that of the female rather broader than its length. The snout is pointed and projects beyond the mouth; the distance from the anterior corner of the eye is always longer than the eye's horizontal diameter; *canthus rostralis* strongly marked; loreal region slanting, rather sunken; nostrils considerably nearer to the eyes than to the tip of the snout; interorbital space contained about one and a half times in that between the nostrils and about twice in the breadth of the upper eyelid; (these measurements are subject to slight variations.) Tympanum well developed, its horizontal diameter longer than the vertical, equal to two-thirds, at most, to three-quarters of the diameter of the eye.

The fingers of the fore limbs are rather pointed, the first longer than the second; the subarticular tubercles are prominent, and well developed.

The hind limbs being carried forward along side of the body the tibio-tarsal joint reaches the posterior corner of the eye, or at most to between the anterior corner of the eye and the nostril; tibia always much shorter than the fore limb, or the foot measured from the outer meta-tarsal tubercle; when the hind limbs are bent at right angles to axis of body, heels never do meet; toes entirely webbed; the subarticular tubercles small and not very prominent; the inner meta-tarsal tubercle (Plate VI, fig. 1) very large, projecting, compressed, on both sides, hard and sharp, twice as long as high; its length contained 1–1.8 times in length of inner toe and 4.8–7.5 times in that of the tibia; it is most characteristic, that the inner meta-tarsal tubercle is never parallel with the length-axis of the sole but invariably forms a greater or smaller angle with it. It is very characteristic, further, that the inner meta-tarsal tubercle never adheres to the base of the thumb but is attached to it in a mobile way with a web, spreading between it and the thumb. At the root of the fourth (longest) finger there is always a small, roundish outer meta-tarsal tubercle.

The glandular lateral folds are well developed, their width being at least equal to one-third of an upper eyelid, not seldom, however, attaining the entire breadth of it; the distance between the lateral folds,—measured on the scapular region,—is contained $4\frac{1}{4}$–$5\frac{1}{2}$ times in whole length of head and body.

On the back, on both sides of dorsal line, longitudinal dorsal folds, which vary in length but are always sharply projecting; these are generally disposed in six longitudinal rows, on the anterior part of the back, and in eight on the posterior part of it; breadth of one fold amounts to about half of inter-orbital space, greatest length, to twice the length of the upper eyelid, frequently, however, equal to $4\frac{1}{3}$. The back of one of the specimens found at Pingshiang, besides the usual folds, is covered with innumerable small warts, which make it look unusually warty.

Chin, throat and fore part of belly smooth; sides of body and lower hind part of thighs alone somewhat granulated, the hind part of belly crosswise slightly wrinkled.

Color (taken from spirit-specimens): Back brownish olive, sprinkled with black spots; the latter present three main types: either unequally rounded as in our *R. esculenta*, or lengthwise extended (specimens from Japan) or again are they of such a shape as we never meet with in our *R. esculenta* viz. in most of the Chinese specimens the black spots widen horizontally.

The vertebral line is pale blue and varies in breadth; the dorso-lateral folds of same color; on the *canthus-rostralis*, beginning at the end of snout, passing across the eye, above the tympanum and at the back of it, runs the black stripe which reaches down behind the angle of the mouth; along the outer side of the dorso-lateral folds, the black spots most frequently melt into a single black stripe; on sides of body large, irregular black spots are to be seen, which often unite into a large black stripe between the articulation of the two extremities; the upper edge of the stripe is undulating and from the lower one, following close upon each other, several branches extend towards the belly. The dark spots on the edge of the upper lip never unite into a single dark stripe.

Upper surface of limbs, tibias, and feet crossed by dark bars. In Japanese specimens we find the dark crossbars of the upper

limbs and tibias invariably detached into blotches.[2] The hind part of the thighs is whitish-grey with dark marblings; belly uniform white, border of lower jaw, however, together with throat region, breast, both sides of belly and thighs, slightly marbled with a darker tint. The vocal sacs are blackish-grey.

Osteological characters. The skull (Plate VI, fig. 2) presents partly the characteristic marks of *esculenta* and partly those of *R. ridibunda*, general form narrow and longish; becoming (gradually) narrower and pointed in front, always narrower than it is long; the *cranium cerebrale* is comparatively higher than in *R. esculenta*. The *pars facialis* of the maxillary much higher than with the *esculenta*. Nasals narrow and meeting at a sharp angle in the middle line, joining each other in a broad ridge, contrarily to the arrangement in *R. esculenta* in which they are broad, meeting at a blunt angle and generally not in contact on the middle line.

The two borders of the fronto-parietals are—in old examples—quite parallel, in younger ones slightly converging forwards; breadth of their inter-orbital space—measured in the middle—is contained 3–3.5 times in its length; posterior border almost straight; upper surface very slightly sunken, *sutura-sagittalis* always entirely ossified.

With *R. esculenta* the fronto-parietals' two outer borders are never parallel, becoming conspicuously narrower towards the front. Their breadth between the orbits, measured in the middle is but 2.5–3 times contained in their length; their back edge is always undulating; their upper surface is deeply sunken; *sutura-sagittalis* open from *os ethmoideum* until about the middle.

Tectum synoticum always triangular, whilst in *R. esculenta* it is invariably quadrangular.

Prooticum always shorter and broader than in *R. esculenta*. The *tympanicum* presents in its formation such differences as separate most markedly the skull of *R. chinensis* from that of *R. esculenta*. The forepart of the *tympanicum*, the zygomatic process, is straight, narrow and long, just reaching the half of the longitudinal diameter of the orbit, sometimes even extending rather beyond it; never curved inwards, being on the contrary, always expanded in front, its

[2] Stejneger (p. 98) mentions specimens from the collection of Dr. Smith and Owston, from Shikoku Islands and Mount Fuji in which the dark blotches on the hind limbs melt into quite distinct crossbars.

Measurements

MEASUREMENTS IN MM.	PEKING		PINGSHIANG				KIUKIANG		JAPAN	
	♂	♀	♂	♀	♂	♀	♀	♀	♂	♀
From snout to vent	66	66	69	69	59	67	90	92	54	52.5
Length of head	22.5	21.5	24.5	23	20.5	22.5	29.5	29	18.5	18.5
Width of head	21.5	22.5	23.5	22	21	22.5	30.5	29.5	17.5	17.5
Diameter of eye	7.5	7	7.5	7.5	7.5	8.5	10.5	10	6.5	7
Interorbital width	3	3	3	2.5	2.5	2.5	4	3.5	2.5	2
From eye to nostril	4.5	5	5	5	4	5	6	6.5	4.5	4.5
From eye to end of snout	10.5	10.5	11.5	10.5	10	10	14	14.5	9	9.5
Diameter of tympanum	5	4.5	6.5	5	5	5	6.5	6.5	4	4.5
Fore limb	35	33	38.5	35.5	32	36	48	45	29.5	28
Hind limb	101.5	98	106.5	110	91	108.5	138	137	87.5	85
Tibia	29.5	29	30	34	29	32	42	44	25.5	25
Length of foot	36	35	37	36.5	33	38	42	46.5	31	28.5
Inner toe (from tubercle)	6	6	6.5	6.5	7	7	8.5	9	6.5	5.5
Inner metatarsal-tubercle	6	6	5	4.5	4.5	4.5	7	6.5	3.5	3.5

foremost end, consequently, never extending into the orbit. This is also the reason why the posterior corner of the inner branch of *tympanicum* forms a still blunter angle than in *R. esculenta*. The back branch of the *tympanicum* is still shorter than in *R. esculenta*, so that the straight line connecting the articulations of the two jaws invariably crosses the *condylus*. The plate of the inner branch of the *tympanicum* is always shorter than in *R. esculenta*.

The intermaxillary's (fig. 3) inner border never sinks so deep as it does in *R. esculenta*.

The vomerine teeth lie between the *choanæ* in two small, semicircular groups inclining towards each other at a very slight angle; the group of teeth are always separated by a larger space than is the case with *R. esculenta* in which the inner edges of the teeth groups sometimes almost meet—and never attain the straight line connecting the posterior border of the *choanæ*.

The palatines differ from those of *R. esculenta* in as much as they bear on their exterior side a rough, prominent bony crest.

Median branch of *os parabasale* is in general narrower and more rounded than in *R. esculenta*. *Foramen occipitale magnum* in old individuals, oval, in very young ones, round.

If we survey (fig. 4) the skull from the back joining the tympanicum's two posterior corners by a line, it will just about cut across the middle of *foramen magnum*. In *R. esculenta* in 90 per cent of the cases this line touches the upper border of the foramen magnum; with *R. ridibunda* the mentioned line invariably crosses the upper third of the foramen magnum.

The vertebral column (excepting the length of the urostylus) is as long as the skull. Characteristic differences are to be found on the second, third and eighth vertebræ. Whilst, with *R. esculenta* the diapophysis of second vertebra presents a cylindric shape (fig. 5), with only a few unimportant protuberances towards the center of the front border, the diapophysis of second vertebra of *R. chinensis* is flat and presents a well developed bony crest on its anterior border (fig. 6). This bony crest is to be found in *R. ridibunda* also. The outer half of the diapophysis of the third vertebra is carved out, shovel-like (fig. 7). On the median side of its posterior edge a projecting bone ridge extends to the base of the diapophysis. This bone ridge is to be found neither in *R. esculenta* nor in *R. ridibunda*.

The diapophysis of the eighth vertebra (fig. 8) generally curves backwards, median side also expanding wing-like backwards.

It is worth mentioning that the *processi spinosi* of the vertebræ are longer on *R. chinensis* than on either *R. esculenta* or *R. ridibunda*. If we join, by a straight line, the back borders of the *processi obliqui* on the second, third and fourth vertebræ we shall find that the *processi spinosi* invariably extend beyond this line. On *R. esculenta* and *R. ridibunda* the *processi spinosi* generally touch that line, sometimes ending a good deal before it.

The urostylus is as long as the vertebral column.

If we examine the pelvis (fig. 9) so that the symmetric plane passing through the symphysis is parallel with the base we will find the following peculiarities: pelvis 1.2–1.3 times as long as the vertebral column; ilium in its general form straight, the extremities touching the sacral vertebra, being alone slightly curved downwards; upper ridge of the ilium's crest straight and the angle of it which declines towards the acetabulum forms only just a somewhat larger angle than a rectangle. This declining angle is smooth, or presents a hardly visible distended margin; if we draw on the ridge of the ilium crest a line parallel to the base of the *pelvis*, this line will just be reached by the upper corner of the *crista ischio-pubica*.

In *R. esculenta* (fig. 10) the pelvis is 1.06–1.2 times as long as the vertebral column; the ilium is curved, the upper ridge of its crest is rounded and the corner declining towards the acetabulum forms a very blunt angle. This declining corner presents a strongly distended margin and consequently under this margin at the base of the ilium we find a somewhat deep cavity; if we draw on the ridge of the ilium crest, a line parallel to the base of the pelvis, we shall notice that the upper corner of the *crista ischio-pubica* remains far under that line.

The most interesting of the tarsus bones is the so-called præhallux (fig. 11) which is a large, flat spade-like bony plate, growing rather thick towards its base; its outer surface somewhat convex, whilst the inner one is very slightly concave; its greatest breadth equal to two-thirds of its length, the latter to two-thirds to three-fourths of the length of first meta-tarsal bone. In *R. esculenta* the præhallux (fig. 12) is a flat, thin bone plate; greatest breadth half its length, length half that of the first meta-tarsal bone.

In both species we find the præhallux joined to the *tibiale* by an intercalated bone, the *tibiale* being formed by the following principal elements: *tarsale præhallucis*, *centrale* and *tarsale I.*

Under the second and third meta-tarsal bones we find the *tarsale II.* and *III.;* the fourth and fifth meta-tarsal bones are joined to the fibulare by the so-called *ligamentum tarsi suppleus.*

Measurements of skeleton in mm.

MEASUREMENTS IN MM.	KIUKIANG ♀	PINGSHIANG ♂	PINGSHIANG ♀
Length of skull	28	24	21
Breadth of skull	27.5	21	20
Interorbital space	4	3	3
Columna vertebralis	29	23.5	20.5
Urostylus	29.5	22	20
Humerus	23.5	18	16
Radius-ulna	15	11.5	10.5
Manus	18	15.5	14
Pelvis	38	28.5	26
Femur	38.5	29	31
Tibia	39	29	31
Tarsus	18	14	13.5
Pes	41.5	35	35.5

Rana chinensis **Osb.**	*Rana ridibunda* **Pall.**	*Rana esculenta* **Linn.**
1. Head narrow, long and very pointed at the end.	1. Head broad, short and tip of snout bluntly rounded.	1. Head comparately narrow, tip of snout ending in blunt point.
2. Inter-orbital space equal to half the breadth of upper eye-lid.	2. Inter-orbital space equal to one third the breadth of upper eye-lid.	2. Inter-orbital space equal to half or frequently to three quarters the breadth of upper eye-lid.
3. Heels never meet when hind limbs are bent at right angles to axis of body.	3. Heels always overlap when hind limbs are bent at right angles to axis of body.	3. Heels never meet when hind limbs are bent at right angles to axis of body.
4. Bending the hind limbs forward along the side of body the tibio-tarsal joint reaches the posterior corner of eye or can prolong itself beyond to space between the anterior corner and nostrils.	4. Bending the hind limbs forward along side of body, the tibio-tarsal joint reaches with the female, the back corner of eye, with male the end of snout.	4. Bending the hind limbs forward along side of body the tibio-tarsal joint reaches, on the female the space between the tympanum and posterior corner of eye, on the male,—at the utmost—space between the anterior corner and nostrils.

5. The inner meta-tarsal tubercle is very large, projecting, compressed on both sides, hard and sharp; always a good deal longer than the distance between the subarticular tubercle of first toe and inner meta-tarsal tubercle, frequently equal to length of first toe.	5. Inner meta-tarsal tubercle small, of a flattened cylindrical form not very projecting, always shorter than space between the sub-articular tubercle of first toe and inner meta-tarsal tubercle.	5. Inner meta-tarsal tubercle large, compressed on both sides, projecting; always longer than distance between the subarticular tubercle of first toe and inner meta-tarsal tubercle.
6. The subarticular tubercles on toes of hind limbs small and only slightly projecting.	6. The subarticular tubercles on toes of hind limbs larger and more projecting.	6. The subarticular tubercles on toes of hind limbs are largest and strongly projecting.
7. The vocal sacs are blackish grey.	7. Vocal sacs blackish grey.	7. Vocal sacs milky white.
8. The spaces between the dusky marbling on the back surface of thighs is filled (according to Boulenger) by a yellow color.	8. Spaces between dark marbling on back surface of thighs is never filled with a sulphuric color.	8. Spaces between dark marbling on back surface of thighs always filled with sulphur colored spots.
9. The dark spots of back,—on Chinese specimens—expand horizontally.	9. It is rare that the dark spots of back expand horizontally and that happens only in a small degree.	9. The dark spots on back never expand horizontally.
10. Fold on the back, between the two dorso-lateral folds in 6–8 longitudinal rows, varying in length.	10. No glandular dorsal folds on back.	10. No glandular dorsal folds on back.
11. Skull invariably narrower than long, very pointed at the end.	11. Skull invariably broader than it is long, in front gradually narrowing.	11. Skull generally as broad as long, front part forms a sudden point.
12. Vomerine teeth never meet the line joining posterior border of *choanæ*.	12. Vomerine teeth extend slightly behind the level of *choanæ*.	12. Vomerine teeth generally touch the line joining the posterior border of *choanæ*.
13. The nasals form a sharp angle towards each other and meet in a broad ridge on middle line.	13. The nasals form a rectangle or a somewhat blunt angle and meet in a broad ridge on the middle line.	13. The nasals form a blunt angle and do not meet on the middle line.
14. Side borders of fronto-parietals parallel with upper surface slightly sunken in.	14. Side borders of fronto-parietals converging forwards, upper surface deeply hollowed.	14. Side borders of fronto-parietals converge conspicuously forwards, upper surface deeply hollowed.
15. *Tectum synoticum* triangular.	15. *Tectum synoticum* triangular.	15. *Tectum synoticum* quadrangular.

16. Foramen magnum oval.

17. The *processus zygomaticus* of *tympanicum* expand forwards, just reach to half the length of orbit.

18. Back corner of inner branch of *tympanicum* forms very blunt angle.

19. Back branch of *tympanicum* very short so that the *condylus* always extends beyond line joining the articulation of jaws.

20. If we join by a line the posterior corners of inner branch of *tympanicum*, this line invariably crosses *foramen magnum* in the middle.

21. *Diapophysis* of second vertebra flat, outer side of front border presents a prominent long crest.

22. Outer side of *diapophysis* of third vertebra is carved out shovel-like and on median side of back border a strong, projecting bone ridge extends to the base of the *diapophysis*.

23. *Diapophysis* of eighth vertebra generally curved backwards median side expanding wing-like, backwards.

24. *Processi spinosi* of vertebrae longer.

25. If we draw on pelvis on the upper border of ilium crest a line parallel to base of pelvis, this line will just be attained by upper corner of *crista ischio pubica*.

16. Foramen magnum oval.

17. The *processus zygomaticus* of *tympanicum* curved inwards invariably extends beyond half the length of orbit.

18. Back corner of inner branch of *tympanicum* frequently forms a sharp angle, rather projecting backwards.

19. Back branch of *tympanicum* long, so that the line joining the articulation of jaws remains far behind the *condylus*.

20. If we join by a line the posterior corners of inner branch of *tympanicum* this line generally crosses *foramen magnum* in its upper third.

21. *Diapophysis* of second vertebra cylindrical, outer side of front border presents a slight bony crest.

22. Outer side of *diapophysis* of third vertebra shovel-like carved out.

23. *Diapophysis* of eighth vertebra expanding backwards in the form of a wing.

24. *Processi spinosi* of vertebrae shorter.

25. If we draw on pelvis on the upper border of ilium crest, a line parallel to base of pelvis, the upper corner of *crista ischio pubica* will remain much below this line.

16. Foramen magnum of a somewhat circular form.

17. *Processus zygomaticus* of *tympanicum* curved inwards, does not even reach the half of length of orbit.

18. Back corner of inner branch of *tympanicum* forms a blunt angle.

19. Back branch of *tympanicum* shorter, consequently the line joining the articulation of jaws just meets the back border of *condylus*.

20. If we join by a line the posterior corners of inner branch of *tympanicum* this line just touches the upper border of *foramen magnum*.

21. *Diapophysis* of second vertebra cylindrical, towards middle of outer side we notice a slight protuberance.

22. Outer side of *diapophysis* simply flattened.

23. *Diapophysis* of eighth vertebra of a cylindrical form.

24. *Processi spinosi* of vertebrae shorter.

25. If we draw on pelvis on the upper ridge of ilium crest, a line parallel to base of pelvis, the upper corner of *crista ischio pubica* will remain much below this line.

If we look back on the above tables as well as on the osteological characteristics and description of the Chinese frog we shall find that, owing to all its distinctive features *R. chinensis* can be placed near to *R. ridibunda* Pall, and that neither *R. esculenta* nor *var. lessonæ* seems designated for a closer comparison with it.

Up to now, the glandular folds on the back were alone considered as easily distinguishable characteristic marks; I find, however, that the most important amongst the outer distinctive features are: the general shape of the head, color of vocal sacs, shape of spots on the back and, finally, the formation of inner meta-tarsal tubercle. The head is comparatively very narrow and the snout ends in a very marked point.

My experience is that we never meet with *R. esculenta* having a similarly narrow head or pointed snout. Needless to say that in that respect the Chinese frog differs still more from *Rana ridibunda.* The vocal sacs are of a dusky grey and in that feature it quite resembles *R. ridibunda.*

As regards the spots on the back it differs very markedly from *esculenta,* as already mentioned the spots on the back—on some of the specimens from China—broaden in horizontal direction, giving the back the appearance of being horizontally striped. On other specimens from China the spots are entirely similar in form and disposition, to those of our *esculenta.* The spots on the specimens from Japan present quite a different shape, extending, generally lengthwise on the back, the cross-bars dividing into spots on thigh and tibia, in opposition to the Chinese specimens on which these cross-bars invariably form an uninterrupted dark line. The Chinese frog therefore, as regards the shape of its spots, could be said to somewhat approach the typical *R. ridibunda* in which the spots of the back frequently broaden horizontally.

Finally, I consider the most important mark to be the inner meta-tarsal tubercle—not meaning thereby its proportions as do Boulenger and his adherents—but most especially taking into consideration the differences manifested in its formation and its biological rôle. These differences separate insuperably *Rana chinensis* from the group of either *esculenta* or *ridibunda.* As I already remarked in the above description, the chief difference between the meta-tarsal tubercle of *Rana chinensis* and that of *esculenta* and

var. lessonæ, lies in the fact that it is *never parallel to the length axis of sole, but invariably closes on it at a larger or smaller angle, and that it never stands vertically on the surface of sole but always so to say leans against it.* The most striking difference, however, is—as also Wolterstorff already recorded—the fact of the meta-tarsal tubercle *not adhering to the base of thumb, being independently movable and that of a web extending between it and the thumb.* The above also justifies Osbeck's statement of the Chinese water-frog having six toes as in this case the meta-tarsal tubercle can truly be considered as a sixth toe transformed into a burrowing implement. The edge of the meta-tarsal tubercle is very sharp on the Peking and Tsingtau specimens and quite resembles the meta-tarsal tubercle of *Pelobates fuscus*. This edge is never as sharp on the Pingshiang, Kiukiang and Japan specimens.

The dimensions of the meta-tarsal tubercle frequently vary on specimens from Peking and Tsingtau; it attains the length of the thumb; on specimens collected at other places it is a good deal shorter, but it is never contained twice in the length of the thumb. As regards its rôle in biology, this peculiarity is in itself reason enough for *R. chinensis* to be separated as an independent species.

Once their pools dried up, our *esculenta* and *ridibunda* generally wander further on in search of new waters. Not so with *R. chinensis* which *burrows* itself in the ground as soon as water is wanting. Dr. Kreyenberg (17, p. 136) at Tsingtau, found frogs burrowed under the ground and he writes further on about the Chinese frog digging itself under the earth on the rice fields once the water there has dried up.

It is interesting to notice here that these frogs do not bury themselves thus in exceptional cases, but do this *regularly* with the beginning of the dry season; this being recorded from the surroundings of Peking and Tsingtau most likely happens elsewhere also and seems sufficient explanation of the fact that the meta-tarsal tubercle on the specimens from the above named places is so particularly well developed and so excellent a burrowing implement. It is not improbable that in some parts of those countries this burrowing is only exceptional (the specimens of Kiukiang and Pingshiang do not present so sharp a meta-tarsal tubercle) and it is most likely

that in some parts *R. chinensis* lives an exactly similar life to that of our *R. esculenta* (Kilung, Masempho).

In Wolterstorff's already mentioned article (17, p. 140) we read that the meta-tarsal tubercle of *ridibunda*, *esculenta*, and *var. lessonæ* stands in contrary proportion to the length of the tibia, that is to say, that the larger the meta-tarsal tubercle, the shorter the tibia and reciprocally. He explains this occurrence by the law of correlation; according to his opinion the *R. ridibunda's* leaping faculties are increased through the tibias' length, whilst those of *esculenta* and *var. lessonæ* are augmented by the larger size of the meta-tarsal tubercle. He then continues saying: "If the *R. chinensis* also belonged directly to this series of development, then—considering the size of the meta-tarsal tubercle—the tibia ought to be shorter still, yet just the contrary is stated as it is longer." Wolterstorff further remarks that when hind limbs are bent at right angles to axis of body the heels meet or even rather extend beyond each other. This is stated by Boulenger also (6).

On the specimens examined I found that the *heels never meet.* The reason of this can easily be explained by the Chinese frog's peculiar mode of life. As its burrowing faculties gave it the possibility of remaining in its accustomed place in spite of the water drying up, there was no necessity for wandering, thus its leaping faculties did not particularly develop whilst it possesses the burrowing-faculty's requisites, viz.: thickly set, strong hind limbs. I shall refer later on to the great modification, which wandering may cause in the length of the hind limbs.

After this I am not astonished, that Bedriaga's (17, p. 140) Ordos' specimen was found similar in the length of the hind limbs to *var. lessonæ* of Norfolk.

Referring to the explanation given on the skeleton's distinctive features, I must here again insist upon the fact that they are—according to my opinion—the most important, as the skeletons which I prepared all present the above mentioned characteristic marks, although they belonged to frogs originating from different places. The particularities most worthy of attention are on the skull: the position of nasals, the shape and dimensions of the zygomatic process as well as the fact of the condylus always extending beyond the line joining the articulation of the jaws, finally the shape

and position of the vomerine teeth group. The bony ridge visible on the diapophysis of the third vertebra of the vertebral column, as well as the characteristics in connection with the pelvis, are also exceedingly important marks.

I cannot, after these results, accept Wolterstorff's opinion (17, p. 139) that the Chinese frog is a now-arising, not yet fully expressed species, whose characteristics in the formation of the legs have not yet quite developed in each specimen. With regard to the metatarsal tubercle, my conviction is that it has reached its full development, but that, owing to climatic conditions and natural surroundings it varies in formation according to countries.

If we look back upon what has been said above, it becomes immediately clear to us that the Chinese frog bears the mixed characteristics of *R. ridibunda* and *R. esculenta*, and it is just this mixture of distinctive features which proves that we have to do with independent species. This is also confirmed by its geographic distribution. The Chinese frog is to be found—as is reported—from Vladivostok in the North down to Bangkok in the South, and from Japan westwards to the 105–110° eastern longitude. In opposition to this *Rana esculenta*, respectively the *var. lessonæ*, is to be found until the 30° eastern longitude, whilst *ridibunda* is met with as far as Persia. The fact of its geographic distribution being confined within such definite limits, seems to be a proof more, that *R. chinensis* belongs to an independent species as it were difficult to suppose that alone one variety of *esculenta* lived on such an immense territory, within so great a distance of the circle limiting the typical form's natural boundaries. If *R. chinensis* meets with any western species it can only be with *Rana ridibunda*. Boulenger supplies us in his work "The Tailless Batrachians of Europe," with a map (p. 263) marking the *esculenta* group's geographic distribution. Wolterstorff remarks (17, p. 142) that on this map he finds the limits of *Rana chinensis*' geographic distribution rather far extended westwards. My opinion is that the distance between these two species is not even as great as that, but that they most likely directly meet somewhere. This question could only be solved by a minute investigation in the regions of Asia Minor and Tien-san.

My studies on the Chinese frog have led me to the conclusion that it is not the Chinese frog which originates from *R. esculenta* or *R.*

ridibunda, but on the contrary both *R. esculenta* and *R. ridibunda* from *Rana chinensis*.

I wish to support this supposition by the inner meta-tarsal tubercle. As is already known the inner meta-tarsal tubercle of frogs has developed from the ancestral thumb, the former sixth toe. If during the development of the body any part of it is arrested in its growth and decays, it regenerates no more. This is the fact on which I found my explanation. In the above description I have already pointed out the fact that the meta-tarsal tubercle of the Chinese frog is truly no meta-tarsal tubercle at all, but a real finger connected by a web to the present thumb. The Chinese frog, influenced by surroundings and climatic conditions, adapted itself to the already mentioned peculiar mode of life and its ancestral thumb just only transformed itself so far as to become its burrowing implement.

In opposition to this it is quite evident that the meta-tarsal tubercle of *Rana ridibunda* and *Rana esculenta* has quite degenerated inasmuch as through adaptation to new conditions, it increases its dexterity in leaping. On account of this, therefore, it would be impossible to suppose that the Chinese frog's meta-tarsal tubercle together with the web between it and the first toe is a new acquisition.

I found on *Bufo viridis* Laur. a most convincing proof of the change in the hind limbs caused by wandering. In one of my articles (p. 166) whilst comparing the *Bufo viridis* of county Gömör (Hungary) to *Bufo viridis* of Konia (Asia Minor) I pointed out the fact of the specimens from Asia Minor having comparatively a good deal longer hind limbs than those from the county Gömör. After the publication of that article my friend Mr. D. v. Földváry who undertook a journey in Asia Minor in the year 1906, informed me having repeatedly met in the deserts with *Bufo viridis*, wandering in search of new pools after their former resorts had dried up.

It seems likely therefore, that the hind limbs of the specimens from Asia Minor were thus developed in consequence of this frequent wandering, and it is to be presumed that Hungarian specimens have shorter hind limbs, because they never wander. Taking these above facts into consideration it will seem more probable still that *Rana ridibunda* and *Rana esculenta* were derived from the Chinese frog whilst this latter was extending westwards; the in-

fluence of surroundings and climatic conditions then co-operated in the formation of the longer hind limb and with it the greater facility to leap. This opinion of mine differs very essentially from Wolterstorff's (17, p. 139) who wishes to prove by the Chinese frog's example the way in which a former leaping-frog gradually transformed itself into a burrowing-frog. He mentions as an example the *Pelobates* genus, which he believes to have originated in that same manner.

This seems refuted according to my opinion by the very fact of such frogs, as bearing the ancestral characteristic features—(as the *Pelobates* for instance)—being none of them agile leapers in opposition to the undoubtedly younger race of *Ranae fuscae*, of which every representative is most dexterous in leaping.

LITERATURE

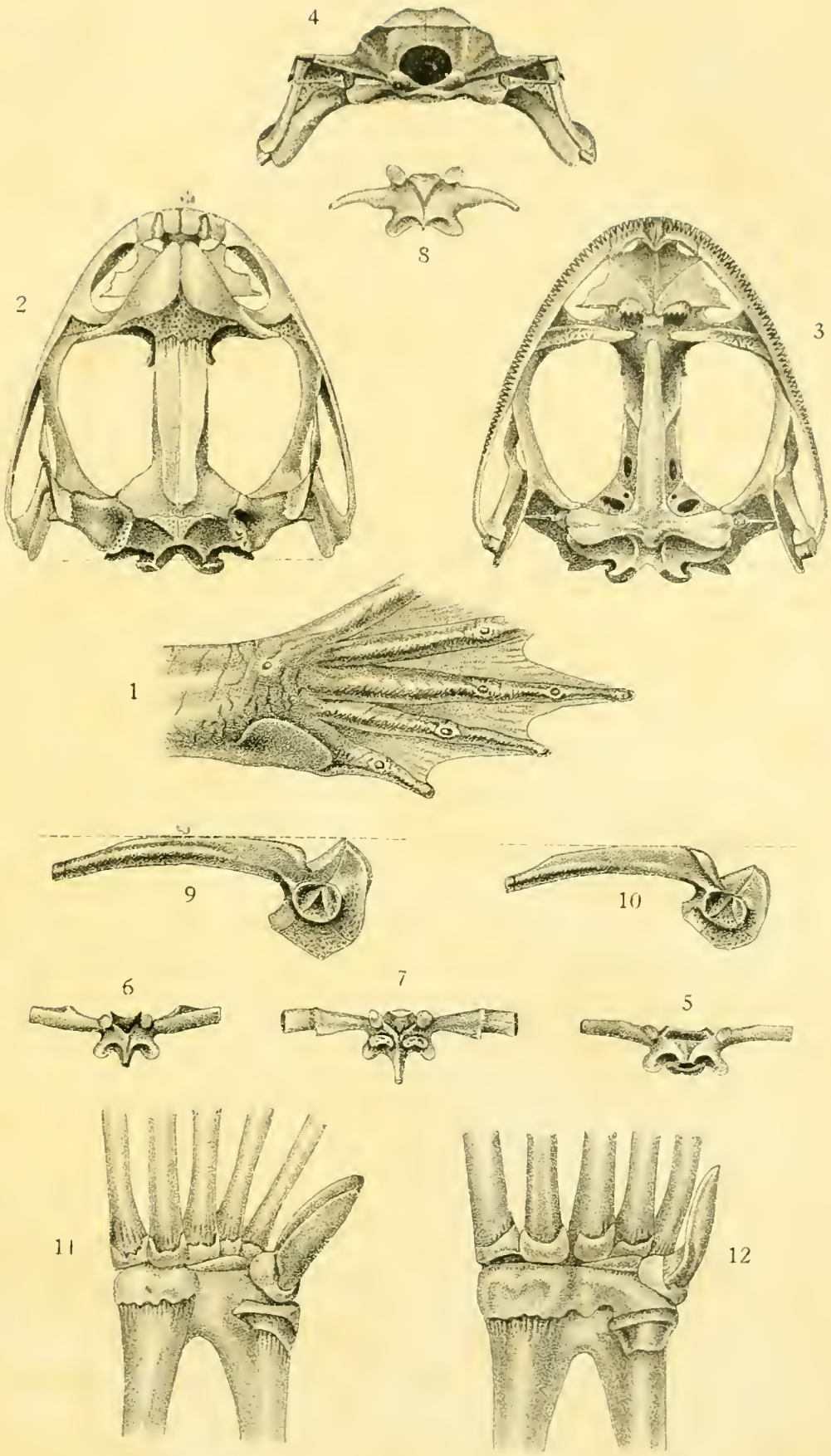
1. Bedriaga, J. V.
   1898. Wisseuschaftliche Resultate der von **Przewalski** nach Central-Asien unter nommenen Reisen.—III. Bd. 1. Abth., Amphibien u. Reptilien, Lief. 1. St. Petersburg.
2. Bolkay, S.
   1907. Adatok Göniör-Kishont vármzye herpetolo-ziajshoz—Allattain Kozlemények, VI.
3. 1907. A tair béka (Rana ridibunda **Pall.**) faji jogosultsojs. Allattain Kozlenieuyek VI.
4. Bolkay, St. V.
   1908. Über die Artberechtizung des Flussfrosches (Raus ridibunda **Pall.**—)"Lacerta" No. 13. "Wochenschrift," V. Jahrz.
5. Boulenger, G. A.
   1882. Catalogue of the Batrachia Salientia in the collection of the British Museum, London.
6. 1891 A Contribution to the Knowledge of the races of Rana esculenta and their geographical Distribution. Proc. Zool. Soc., London.
7. 1896–1897. The Tailless Batrachians of Europe, I., II., London.
8. Cope.
   1868. Second supplement on some new Raniformia of the Old World. Proc. Phila. Acad. Nat. Sci.
9. Hallowell
   1860. Rep. upon the Rept. of the North Pacific Exploration. Proc. Phila. Acad Nat. Sci.
10. Lataste, F.
    1880. Batrachiens et Reptiles recucillis en chine por **M. V. Collin** de Plancy. Bull. de la Soc. Zool. de France.
11. Maack,
    1859. Voy Amour.

12. Méhely, L. O.
1901. Zichy's Dritte Asiatische Forschungsreise II., p. 62.
13. Osbeck.
1765. Ruse nach Ostindien und China, Rostock.
14. Peters.
1867. Sitzber. Ak. d. Wiss. Berlin.
15. Schlegel.
1836. Fauna japonica, Rept.
16. Stejneger, L.
1907. Herpetology of Japan and adjacent Territory.—Smithsonian Institution, Washington.
17. Wolterstorff, W.
1906. Über die von Herrn **Dr. Kreyenberg** in Ostasien gesane melten Frosch-und Schwanzlurche.—Abhandl. u. Breichte d. Museums f. Natur und Heinistkunde zu Magdeburg, I. Bd., 3 Heft.

18. 1908. Bemerkungen zu **Bolkay**: Über die Artberechtigung des Flussfrosches.—Lacerta No. 14, "Wochenschrift," V. Jahrg.

Explanation of Plate VI.

Fig. 1. First toe of hind limb, with shovel-like inner meta-tarsal tubercle. Peking. × 1.5.
Fig. 2. Skull, upper view. Kiukiang. × 1.5.
Fig. 3. Skull, under view. Kiukiang. × 1.5.
Fig. 4. Skull, back view. Kiukiang. × 1.5.
Fig. 5. Second vertebra of Rana esculenta L. upper view. Bariás, (Hungary). × 2.
Fig. 6. Second vertebra, upper view. Kiukiang. × 1.5.
Fig. 7. Third vertebra, upper view. Kiukiang. × 1.5.
Fig. 8. Eighth vertebra, upper view. Kiukiang. × 1.5.
Fig. 9. Pelvis from side. Kiukiang. Nat. Size.
Fig. 10. Pelvis of Rana esculenta L. from side. Bariás (Hungary). Nat. size.
Fig. 11. Bones of tarsus. Kiukiang. × 3.
Fig. 12. Tarsal bones of Rana esculenta L. Rimanambat. (Hungary.) × 3.



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Osteological characters of Rana chinensis and Rana esculenta.

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