

ART. XIV.—*Nodules with Fishes from the Coal Measures of Kansas*; by W. H. TWENHOFEL and CARL O. DUNBAR.*

THE rarity of vertebrate remains in rocks of Pennsylvanian age makes each new discovery of great interest. The American localities where vertebrate fossils of this period occur in sufficient completeness to be of value are so few that they may almost be counted on the fingers of one's hand, while in Kansas such have been among the rarest of fossils. Two noted localities are Mazon Creek, Illinois, and the mines about Linton, Ohio. The former locality has long been famous because of the excellent preservation of its plants, crustacea and insects, and the fossils possess an added interest because of their occurrence in nodules.

Kansas Nodule Horizons.

Fossil-bearing nodules have also been collected in the Kansas Coal Measures. The Labette shales, near Sherman City, carry many, of which great numbers contain the brachiopod, *Orbiculoidea nitida* (Phillips). This fossil also occurs abundantly in the nodules of the Cherokee shale. The LeRoy shales have nodules which are fossiliferous and others are also quite common in the Vilas shales, but of the many from the latter horizon which have been broken open by the writers, not one has contained anything of value. At Twin Mound, about ten miles southwest of Lawrence, what appear to be the Kanwaka shales carry great numbers of nodules. Doctor R. L. Moodie has broken open hundreds from that locality and in only a few was anything discovered. Local collectors, however, have obtained one or two specimens of *Prestwichia danae*.

A New Nodule Horizon.

To the localities and horizons noted above, another must be added, which is of exceptional interest by reason of the remarkable abundance and splendid preservation of the fish remains. The discovery was accidentally made by the junior writer while searching for Pennsylvanian invertebrates. An oblong gray nodule, which he carelessly cracked, contained a complete and well-preserved skull. Naturally, invertebrates were neglected and careful search was made for nodules. The first afternoon's collecting netted three fish skulls and over a dozen other bones. Since then the place has been repeatedly visited and skulls have been found each time.

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Locality.—The outcrop from which the fossils were obtained is almost within the city of Lawrence, at a small quarry and pond near the southeast corner of Oak Hill cemetery. The outcrop has been in existence for some years; but the nodules have not previously been noted, due to the fact that they are not of the ordinary form, but have more the appearance of weathered pebbles. At the time of discovery there were several hundred lying upon the surface of the ground.

Manner of Occurrence and Stratigraphic Position.—The nodules occur in a thin bed of yellowish-gray shale which lies immediately above the Kickapoo limestone, the thickness of the shale not exceeding two inches. The surface of the limestone is irregular, the elevations rising practically to the upper surface of the nodule-bearing shale. The irregularities are due to differential deposition, however, and not to any action of surface weathering. The Kickapoo is one of the many thin, persistent bands of limestone of the Kansas Coal Measures. These bands outcrop in a northeast-southwest direction and apparently extend entirely across the state. The Kickapoo is stated to have been traced for a distance of two hundred miles, and its thickness varies from four to fifteen feet. At the nodule locality the thickness does not exceed four feet, and while there seems to be a slight thickening eastward, the amount is apparently not significant. As a rule the limestone is not well exposed, since the thick, overlying Lawrence shale weathers very readily and keeps it covered. Its position, however, can easily be located by the terrace which it has determined.

Beginning at the surface, the section at the quarry is as follows:

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| 1. Shale, oxidized or gray, to the grass roots | 3 to 5 feet |
| 2. Limonite nodule layer | 1½ inches |
| 3. Gray and blue shale | 8 “ |
| 4. Brown and yellow shaly sandstone. This layer
is somewhat calcareous and quite soft | 2 “ |
| 5. Brown and yellow sandy fossiliferous shale | 2 “ |
| 6. Nodule layer. Gray and grayish gray shale | ½ “ |
| 7. Kickapoo limestone. Gray and blue limestone,
öolitic near the top | 4 feet |

The same sequence is present at Blue Mound, about five miles east of Lawrence. There are, however, fewer nodules, and they are also smaller, and vertebrate remains, while present, are of little value. The limonite nodules also occur and are like those of the little quarry. About fourteen miles south of Lawrence, near Baldwin, the same sequence, in so far as it relates to the Kickapoo, the limonite nodule layer

and the other shale, likewise obtains. At this locality a single nodule like those which contain the vertebrates at Lawrence, was found. It was about one-half inch in diameter and contained nothing. The same sequence was found near the village of Vinland, about ten miles south of Lawrence, but no vertebrate nodules appear to be present. At this locality there is a thin bed of coal a few feet above the limonite nodule band. Traced northeastward, the sequence is the same near the village of Tonganoxie and three nodules were found in the thin shale just above the limestone. None, however, contained anything.

Description of the Nodules.—The nodules are generally of a gray color, with a granular surface, similar to that which they would have, were they made of lime and sand. In shape they vary from spherical to oblong, and are generally of regular proportions; but some are quite irregular. A few are slender elongate. The spherical shape is the most common, but the oblong ones carry the better fossils. They appear to have silica as their chief component, but a considerable percentage of lime is also present.

Some of the oblong nodules are as much as two inches in length, while a few of the round ones are not more than one-half an inch long. The diameters of the average nodules vary from three-fourths to one and one-fourth inches. The outside usually affords no indication of the contents; but a few have been collected with the fossils protruding, one having a piece of petrified wood projecting for fully one-half inch. That the shape to a large extent was determined by the inclosed bone is indicated by the fact that slender nodules contain long bones, while skulls are usually inclosed in those which are oblong.

About one foot above the vertebrate zone is another layer in which the nodules have an elongated, lenticular shape, and are composed of impure limonite. They vary in length from one to four inches, are frequently hollow, and contain no fossils.

Abundance of Nodules.—In order to determine the abundance and distribution of the nodules, a space with an area of fifty-six square feet was cleared and the nodules carefully collected. From this space were obtained two hundred and thirty-five, sixty of which contained vertebrate remains. The nodules are unequally distributed, and appear to be most abundant in the depressions of the limestone. From one square foot as many as a dozen have been collected, while from another area of equal size not one has been obtained. Unequal distribution of fossils also occurs, the greatest number of those having any value having been collected in one part of the outcrop.

Fossil Content of the Nodules and Inclosing Shales.—The fossils of the nodules are chiefly vertebrates. Those collected consist of skulls, bones, and spines of fishes, a crustacean (*Palaeocarid*, probably new), one specimen of *Nautilus* cf. *planovolvis*, and eight pieces of wood, one of which shows a great development of the medullary rays and another the vascular bundles. There are no leaves, such as occur so abundantly at the Mazon Creek locality, while invertebrates are rare in the nodules, although quite common in the inclosing shales. It was at first thought that some of the remains were amphibian, but this view appears to be erroneous. About eight hundred nodules have been broken open, and from these more than one hundred and fifty vertebrate fossils of value have been obtained. Many of the nodules carry what are thought to be coprolites, some of them contain unidentifiable fragments of bone, and a still greater number are apparently barren. These figures show that the locality is far more fossiliferous than that of Mazon Creek, where Doctor Moodie estimates that there is one vertebrate fossil to every thousand nodules.*

The vertebrates were submitted to Doctor Moodie, and his identifications are as follows:—tooth of *Cladodus*, teeth of *Cochliodonts*, two teeth of *Diplodus*, spine of *Ctenacanthus*, dermal tubercles of fishes, fish coprolites, and eighteen skulls of small fishes, whose systematic position has not been determined. Three of the skulls contain remarkably well-preserved casts of the brain—a feature of preservation which Doctor Moodie states, “is unique in the history of vertebrate paleontology.” †

The fossils of the inclosing shales are of a totally different character. There are no vertebrates, nor any wood. The invertebrates are not uniformly distributed, but are in patches. They consist of small forms, forms with a more or less spherical shape, or forms with air chambers. All are of marine origin. Those which have been identified are *Axophyllum rude* (?) (rare), *Meekella striatocostata* (r), *Orbiculoidea nitida* (r), *Productus nebraskensis* (r), *Pugnax utah* (common), *Bellerophon stevensanus* (r), *Trepostira sphaerulata* (r), *Edmondia* like *nebraskensis* (but with finer concentric striae) (r), *Nautilus planovolvis* (r), *Orthoceras* sp., crinoid stems, and several additional species of unidentifiable gastropods and pelecypods.

In the brown shale above the nodule bed, there are also fossils and nodules, the latter of lenticular shape, brown in color, generally hollow, and altogether without fossils. The biologic facies must have been quite different, since the fauna is mollus-

* Moodie, this Journal, vol. xxxiv, p. 279, 1912.

† Moodie, personal communication.

can. No brachiopods appear to be present. The fossils which have been identified are *Aviculopecten occidentalis*, *Astartella* sp., *Edmondia* cf. *nebraskensis*, *E.* sp., *Macrodon tenuistriatus*, *M.* sp., *Nucula bellistriata*, *N.* cf. *beyrichia*, *N. ventricosa*, *Bellerophon* cf. *crassus*, *Euphemus carbonarius*, *Trepostira sphaerulata*, *Metacoceras sangamonense*, *Phillipsia major*, and quite a number of additional pelecypods which have not been determined.

The underlying Kickapoo limestone contains sixty-two species, eighteen of which are brachiopods, while no fossils have been reported from the Lawrence outcrops of the overlying Lawrence shale, and, except for *Prestwichia danæ*, none have been discovered elsewhere. In this respect they resemble the Bandera, LeRoy (fossil insects excepted), and Tecumseh shales, while several others of the Kansas shale zones contain only a few species.

Conditions of Deposition.—The Kansas Coal Measures consist of a series of alternations of more or less barren shales and thin fossiliferous limestones, of which many of the latter can be traced as escarpments or terraces from the northern side of the state to the southern, and, in addition, several of them have been traced into Nebraska, Missouri and Oklahoma. The shale zones are generally not highly calcareous, and most of them locally contain thin bands of coal, or highly carbonaceous shale, a thin bed of the former outcropping on the campus of the State University. The limestones are of marine origin, and such is also true of many of the shales, but it is certainly equally true that some of the latter are to be considered as deposits of freshwater origin. The absence of thick zones of coarse sandstone permits the inference that the land was not of great relief, and was probably characterized by sluggish, meandering streams which spread layers of mud over their flood plains and deltas. During times of relative stability the delta extended into the sea, which the typical marine deposits indicate was at no time of great depth. The shore is probably to be conceived as a wide mud flat with small shore lakes and swamps, over which the tide swept for greater or less distances. Intermittent submergence would from time to time bring portions of the mud beneath the sea and initiate the deposition of limestone, thus giving rise to an interfingering of marine and continental deposits—a type of sedimentary structure characteristic of delta deposits which have been laid down in shallow seas.*

The Kickapoo limestone represents an incursion of the sea, while the Lawrence shale indicates the possible driving back

* Barrell, Jour. Geol., vol. xlv, p. 354, 1906.

of the marine waters and the deposition of mud under non-marine conditions. It is inferred that the beds immediately succeeding Kickapoo limestone deposition record the struggle for supremacy of the two rival deposits. The almost coexistent marine organisms and thin coal beds indicate the critical line between land and water and probably the tidal zone.

A peculiar fact in connection with the fossils of the nodule bed is that the nodules contain almost wholly vertebrates, while none have been found in the inclosing shales. This could readily be explained on the assumption that the nodules were pebbles and transported to the invertebrates—an assumption, however, which is disproved by the fact that the nodules show no evidence of ever having undergone transportation.

As has been noted above, the invertebrates in the shales are either small, spherical, or contain air chambers. Shells of this character are readily transported for long distances by currents of little velocity, the cephalopods and small shells being floated and the large spherical ones rolled. Hence it may be that the invertebrates were transported to the nodules.

Many modern shores are characterized by lakes and swamps in which live animals and plants that are quite different from those of the adjacent shore. Many of the lakes are fresh, while others are salty. Into the latter the sea effects an entrance twice daily, while at some time or other many of the freshwater lakes are likely to be reached by waves and tides of unusual height. Into the lakes in this way are brought empty shells which are irregularly distributed over the bottom, thus producing the co-occurrence of animals of different habitats. Elsewhere the senior author has shown that into the modern peat deposits of Anticosti Island such typical marine animals as echinoderms are carried by the waves.*

It is possible that a similar state of affairs obtained at the time of the deposition of the nodule bed. After the death of the fishes, their decaying bodies would have precipitated the matter composing the nodules. The empty shells, however, would have been incapable of doing this. It would frequently have been the case that a few shells would have retained small amounts of organic matter and hence been able to become the centers of nodules. In this way, the irregular distribution of the invertebrates in the shales and their great scarcity in the nodules admit of ready explanation.

The fossiliferous bed just above the nodule layer probably indicates a slight ingression of the sea. The fossils are uniformly distributed and quite different from those below. The animals appear to have lived where their shells are found.

* Twenhofel, this Journal, vol. xxx, p. 67, 1910.

Zonal Assignment of the Nodule Bed.—Whether the Lawrence shales shall still continue to be regarded as unfossiliferous will depend on the disposition made of the beds described above. They record the beginning of the end of marine sedimentation and are followed by non-marine deposits. Lithically they belong to the Lawrence shales. Faunally they are related to the Kickapoo limestone; but since lithology is the chief basis for the division of the Pennsylvanian of Kansas it would seem that their reference to the shale formation would be the more logical, and such an assignment is made.

University of Kansas, June, 1914.