THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XLVII.—*The Ordovician and Silurian Formations in Alexander County, Illinois*;* by T. E. SAVAGE.

Location and Earlier Work.

ROCKS of Ordovician and Silurian age are exposed in southwest Illinois only over a narrow belt, less than four miles in maximum width, bordering the Mississippi river. The line of outcrop of these strata extends along the west side of Alexander county, and continues north about two miles into the southwest corner of Union.

For almost forty years practically no work was done on these horizons in this portion of the state. In 1866, Worthen† described a bed of massive, light gray, semi-crystalline limestone, outcropping near Thebes, as the lowest strata exposed in this part of Illinois, and correctly referred it to the Trenton (=Mohawkian) series. Concerning the Cincinnatian strata in this region he says:‡

"They consist of about 100 feet in thickness of brown, sandy shales and regularly bedded, brown sandstone (Thebes sandstone and shale) which forms the lower portion of the group; overlain by about forty feet of thin-bedded, compact, fine-grained limestone—which breaks with smooth, conchoidal fracture" (Cape Girardeau limestone).

Under the name Clear Creek limestone§ he described a group of siliceous limestones in this region which immediately succeed the Girardeau. These he interpreted as occupying the same stratigraphic position as the Niagara dolomites in the northern part of the state.

* Published by permission of the Director of the Illinois Geological Survey.
† Worthen: Geol. Surv. Ill., vol. i, p. 148.
‡ Ibid., p. 139. § Ibid., p. 126.

In 1868 there was published a detailed report on the geology of Union and Alexander counties,* based on the studies of A. H. Worthen and Henry Englemann. In this work the divisions of the Ordovician remain unchanged, but the term "Clear Creek limestone" is restricted to only that part of the siliceous limestones which is correlated with the Oriskany series of the Devonian. To the Silurian there is referred the lower 250 feet of these deposits under the name Lower Helderberg limestone.

In this report Worthen referred the so-called Lower Helderberg limestone to a horizon higher than that of the Niagara dolomites in northern Illinois. In 1870 he reverted to his earlier views and correlated these limestones with the Niagara dolomites farther north,† explaining the difference in the specific character of the fossils in the respective deposits as "entirely due to the difference in the oceanic conditions under which they were laid down and not to the different ages of the sediments themselves."

Since 1870 no careful study of the above mentioned beds has been made until detailed work was taken up by the writer during a part of the summers of 1907 and 1908. In the collection of fossils the exposed ledges were worked by layers, or arbitrarily divided into zones from six inches to a very few feet in thickness. The fossils from each of these layers or zones were kept separate in order to determine the vertical range and the relative abundance of the different species. This detailed manner of work has revealed the presence of a surprising number of unconformities, some of which would not have been detected by any marked change in lithology, or by a less careful method of study. In a preliminary statement of the results of this work, a general section of the deposits has been given.‡

Conditions of Deposition.

The strata under consideration were laid down in an arm of the sea which had connection southward with the Mexican gulf region along a depression now occupied by the lower course of the Mississippi river. Up this embayment the sea pulsated backward and forward. Through the southward connection the successive faunas reached the part of the basin under consideration and spread towards the north, east and west, to a greater or less distance, with increasing or decreasing depth of the water. A short distance to the west of

* Worthen: Geol. Surv. Ill., vol. iii, p. 20 et seq.

† Worthen: Proc. Am. Assoc. Adv. Sci., vol. xix, pp. 172–175.

‡ Savage, this Journal, vol. xxv, pp. 431–443, 1908; also, Ill. State Geol. Surv., Bull. No. 8, pp. 103–117, 1908.

this area the embayment was bordered by the Ozarkian land mass. On account of the proximity of the shore, the sea was generally shallow, so that even minor movements were registered in the deposits. As a consequence of these conditions there occur here a surprising number of breaks in sedimentation, recording a remarkable number of oscillations of level during the Ordovician and Silurian periods; and during the interval, generally represented by land conditions, between the deposition of the uppermost Richmond beds and the basal deposits of the Clinton.

Succession of Strata.

The relations of the various formations representing the Ordovician and the Silurian Systems in this region are shown in tabular form below:

Silurian	Clinton	Sexton Creek limestone, 16–70 feet
	Alexandrian	Edgewood limestone, 0–12·5 feet
		Girardeau limestone, 18–33 feet
Ordovician	Cincinnatian	Orchard Creek shale, 17–22 feet
	Mohawkian	Thebes sandstone, 75 feet
		Fernvale limestone, 0–3·5 feet
		Kimmswick limestone, 70–82 feet

ORDOVICIAN SYSTEM—MOHAWKIAN SERIES.

Kimmswick Limestone.

The name Kimmswick was applied by Ulrich* to a bed of gray, thick-bedded, subcrystalline limestone exposed in the vicinity of Kimmswick, in Jefferson county, Missouri. These beds correspond in their lithology and fauna with those appearing in the railroad cut and river bank a short distance south of Thebes, which Worthen referred to the Trenton. The above name is retained for these strata in southwest Illinois which contain the fossils *Receptaculites oweni*, *Dalmanella testudinaria rogata*, *Platystrophia biforata*, *Rafinesquina alternata*, *Parastrophia hemiplicata*, *Strophomena trentonensis*, *Rhynchotrema inæquivalve*, *Zygospira recurvirostra*, *Bronteus lunatus*, *Bumastus trentonensis*, *Illænus americanus*, *Isotelus* cf. *maximus*, *Platymetopus cucullus* and *Remopleurides striatulus*.

* Ulrich: Mo. Bur. of Geol. and Mines, vol. ii, 2d series, p. 111, 1904.

The outcrop of this formation is limited to a few small patches in the bank and bed of the river, in the vicinity of Thebes. The Kimmswick beds differ in their lithology and fauna from those of any horizon in the Mohawkian series in the northern portion of the state, with some part of which they were doubtless contemporaneous. A barrier of some kind probably separated the two areas during the time of deposition of the respective beds.

Correlation.—Out of thirty-five species of fossils listed from the Mohawkian strata of Minnesota* which are also found in the Kimmswick limestone of Illinois, nine appear below the Trenton, six of which persist into the lower Trenton beds; twenty occur in the lower division of the Trenton (Clitambonites bed), nine of which continue upward into the overlying division; twenty-four species occur in the middle division (Fusispira bed); while only a single one of these is found in the upper division (Maclurea bed). From these facts the Kimmswick limestone is thought to correspond, in time, with some part of the middle division of the Trenton (Fusispira bed) of the upper Mississippi valley.

The Post-Kimmswick Unconformity.

An erosion interval succeeding the deposition of the Kimmswick limestone is shown in the fact that the thickness of this limestone varies from place to place, and the upper portion of the formation is not a constant horizon. Land conditions are also indicated in the presence, at the top of the formation at Cape Girardeau and other points, of solution channels filled with red colored, residual clay. The time involved in this erosion period was long. Some of the upper part of the Mohawkian and all of the Utica and Lorraine deposits are wanting.

Cincinnatian Series.

The rocks of the Cincinnatian series in Alexander county are all embraced in the Richmond stage. They comprise three distinct formations: 1, the Fernvale limestone at the base; 2, the Thebes sandstone, and 3, the Orchard Creek shale.

The Fernvale Limestone.

Overlying the Kimmswick strata is a thin bed of hard, gray limestone, bearing *Rhynchotrema capax*, *Dinorthis subquadrata* and other fossils characteristic of the lower portion of the Richmond stage. Strata containing similar fossils have

* Geol. and Nat. Hist. Surv. of Minn., vol. iii, pts. 1 and 2.

been described by Ulrich and Hayes,* for which the name Fernvale was proposed, from the town of Fernvale, in Williamson county, Tennessee. From the similarity of the fossils in the two areas this limestone overlying the Kimmswick formation in the vicinity of Thebes is considered the equivalent of the Fernvale beds in Tennessee, and the name of the Tennessee locality has been used to designate this basal Richmond formation in Alexander county.

This horizon is exposed at only two points, at each of which the area of outcrop is very limited in extent. A thin zone may be seen on the top of the Kimmswick blocks in the bed of the river, one-fourth mile north of Thebes. A thickness of three and one-half feet of this limestone occurs immediately underlying the Thebes sandstone† in the south part of the town of Thebes.

Among the fossils found in this limestone are bulbous crinoid segments, *Dinorthis subquadrata*, *Hebertella insculpta*, *H. occidentalis*, *Platystrophia acutilirata*, *Plectorthis whitfieldi*, *Rafinesquina alternata*, *Rhynchotrema capax*, *Strophomena fluctuosa* and *S. planumbona*.

Correlation.—The continuity of the Richmond sea in Illinois and Iowa was apparently broken by a number of low land barriers extending in a general northeast-southwest direction. The sediments of this age in Iowa and northwest Illinois have been called the Maquoketa beds. The sea in which they were laid down was not broadly connected with that in which the Richmond beds in the southern and eastern parts of the state were deposited. For this reason exact correlation of horizons in the two areas is as yet difficult.

In the Maquoketa beds of Fayette county,‡ Iowa, *Rhynchotrema capax* occurs at three successive horizons. It is found first in the lower Maquoketa division, in beds of alternating shale and impure limestone, a short distance above the zone of *Nileus vigilans* (No. 5 of the general section on page 485 of the Fayette County report). The second appearance is in the limestone or dolomite which constitutes the middle division of the Maquoketa beds, while the third occurrence is in the alternating shale and limestone layers near the top of the upper Maquoketa beds. Among the fossils associated with *Rhynchotrema capax* in the lowest horizon are *Dinorthis sub-*

* Ulrich and Hayes: The Columbia Tennessee Folio, No. 95, U. S. G. S., 1903.

† Note: The position of this horizon is immediately below 2a of the general section given in the preliminary statement. (This Journal, vol. xxv, p. 443, 1908.) It was not noted in that paper because its presence had not been detected, nor had it previously been recognized in this portion of the state.

‡ Savage: Iowa Geol. Surv., vol. xv, pp. 484–486.

quadrata, *Hebertella insculpta*, *Plectorthis whitfieldi*, *Strophomena fluctuosa* and *S. planumbona*. Only one of these recurs in either of the higher horizons. From these considerations the Fernvale formation of southern Illinois is thought to correspond, in time, with the lower *Rhynchotrema capax* horizon of the Maquoketa beds in Fayette county, Iowa.

Outside of this region the Fernvale formation is known in Illinois from Monroe county; and it has also recently been recognized by the writer in the vicinity of Millsdale, and again two miles further north, in Will county.

The Post-Fernvale Unconformity.

The presence of an unconformity between the Fernvale limestone and the overlying sandstone is shown in the fact that at some points in adjacent portions of Missouri the Thebes sandstone formation rests upon the weathered surface of the Kimmswick beds, the Fernvale strata being entirely absent. A considerable movement is also indicated in the change from the limestone strata of the Fernvale to the sandstone of the succeeding formation.

The Thebes Sandstone.

The name "Thebes sandstone" was given by Worthen to the chocolate-colored sandstone and sandy shale which is well developed and favorably exposed in the town of Thebes. The formation is separated by its lithology and fauna, and also by an erosional unconformity, from the Fernvale limestone upon which it rests, and from the overlying calcareous shale. In its lower part the strata consist of a few feet of fine, slightly shaly sandstone, above which the beds become more massive and the texture more coarse. In the upper portion the material weathers into thin flakes or flaglike layers, and contains a small admixture of shale. The thickness of the formation is about 75 feet. This sandstone carries a meager fauna. In a narrow zone near the base trilobite fragments are very abundant, but throughout the greater portion of the thickness an occasional shell of *Lingula covingtonensis*, and branches of *Climacograptus putillus* are the only fossils that are encountered.

The Thebes sandstone is exposed over a much larger area in this region than any of the preceding formations. It has also recently been found to have a much wider distribution in the state than was formerly supposed.

The Post-Thebes Unconformity.

Evidence of a break in sedimentation closing the deposition of the Thebes formation appears in the abrupt change in the

lithology, and in the fauna, in passing from the Thebes sandstone to the succeeding deposits. It is shown in a strongly weathered and iron-stained zone at the top of the Thebes formation; and in the fact that in different exposures the succeeding deposits rest upon different levels of the Thebes sandstone.

The Orchard Creek Shale.

The name Orchard Creek shale is here proposed for a bed (=2b of my generalized section of 1908) of calcareous shale exposed in the banks of Orchard creek, about two miles south of Thebes. The formation is embraced between the Thebes sandstone below and the Girardeau limestone above. The material consists of bands of bluish-gray shale, four to six inches thick, alternating with two- to four-inch layers of impure, concretionary limestone. The maximum thickness of the bed is about twenty-two feet.

An exposure of this shale, underlying the Girardeau limestone, may be seen near the mouth of Orchard creek above mentioned. It appears, above the Thebes sandstone, along the bank of the river, and in the cut along the Chicago and Eastern Illinois railroad, between Thebes and the village of Gale.

The more characteristic fossils of this horizon are *Cyclocystoides* cf. *illinoisensis*, *Phylloporina granistriata*, *Dalmanella meeki*, *Leptæna rhomboidalis*, *Rafinesquina alternata*, *Rhynchotrema* cf. *inæquivalve*, *Strophomena* near *incurvata*, *Zygospira recurvirostra*, *Cornulites tenuistriata*, *Conradella*, *imbricata*, *Pterinea thebesensis* and *Isotelus* sp.

More than one-half of the species certainly identified from this formation have not been reported from any other locality. A number of them are recurrent Mohawkian forms. The fauna lacks the characteristic Richmond fossils, but the presence of earlier types is not unusual in the Richmond strata. The position of these beds, above the Fernvale and the Thebes sandstone, refers the horizon certainly to the higher Richmond.

The Post-Orchard Creek Disconformity.

No well marked line of unconformity separates the Orchard Creek shale from the overlying Girardeau limestone. However, such a sedimentary break is indicated by the great difference between the faunas of the two formations. Out of sixteen species collected from the Orchard Creek shale and twenty-seven species from the Girardeau limestone, only three are common to the two horizons. These are *Leptæna rhomboidalis*, *Cornulites tenuistriata* and *Pterinea thebesensis*, all long-ranging species. This almost total change in the fossils, accompanied by no abrupt change in the lithology, is con-

sidered deciding evidence of a land interval between the time of deposition of the respective beds.

Silurian System—Alexandrian Series.

The term Alexandrian Series has been proposed* to include those strata which more or less completely bridge the interval between the uppermost horizon of the Richmond and the basal deposits of the Clinton. They carry faunas intermediate in character between the Richmond and the Clinton, but not distinctively those of either group.

The formations in southern Illinois that contain faunas which cannot properly be referred to the Richmond below, or the Silurian above, but which have affinities in both directions, are: 1, the Girardeau limestone, and 2, the Edgewood formation.

The Girardeau Limestone.

Strata of this age were first described by Shumard,† in 1855, from Missouri under the name Cape Girardeau limestone. Worthen recognized the horizon in southwest Illinois and retained Shumard's name for the formation.

The rocks consist of dark-colored, fine-grained, compact, brittle limestone, in imperfectly separating layers two to five inches thick. Between the layers occur thin lenses of hard, calcareous shale which locally contain numerous fossils. Among the common species are *Glyptocrinus fimbriatus*, *Tanaocrinus* cf. *typus*, *Camarotœchia scobina*, *Dalmanella* near *elegantula*, *Homœospira* sp., *Leptæna rhomboidalis*, *Rafinesquina mesacosta*, *Schuchertella missouriensis*, *Waldheimia* (?) *bicarinata* var., *Cyclonema cancellata*, *Platyostoma niagarensis* var., *Cyrtodonta primogenia*, *Pterinea thebesensis*, *Acidaspis halli*, *Cyphaspis girardeauensis*, *Encrinurus deltoideus* and *Lichas* sp.

The maximum thickness of the formation in Illinois is about thirty-three feet. The strata are well exposed in the banks of a creek two miles south of Thebes, and also along the river one-half mile further south. North of Thebes they outcrop along the Chicago and Eastern Illinois railroad, one-half mile south of Gale.

The Girardeau a transition fauna.—The fauna of the Girardeau limestone, listed above, has a decidedly Silurian aspect. The genera Homœospira, Schuchertella, Waldheimia? and Platyostoma are distinctively Silurian, while not one of the species could be considered a marker of a Richmond horizon. A few of the Ordovician forms persist, but the

* Savage: This Journal, vol. xxv, p. 434, May, 1908.

† Shumard, B. F.: 1st and 2d Ann. Repts. Geol. Surv. Mo., p. 109, 1855.

presence of new Silurian types in the fauna is of much greater significance than the lingering of a few Ordovician species. Hence the formation is thought to represent early Silurian time.

Although the fauna of the Girardeau limestone shows distinctly Silurian characters, it cannot be assigned to any recognized horizon in the Clinton. The Sexton Creek beds, which in this region succeed the Edgewood formation overlying the Girardeau, are thought to represent a Clinton horizon as low as any previously described. Hence it seems most conducive to a clear statement of the facts to refer the Girardeau and the succeeding Edgewood formation to a distinct time interval earlier than the Clinton, called the Alexandrian, by which the post-Richmond and pre-Clinton age of the beds, as shown by their stratigraphic position and by the transitional character of the faunas, is clearly indicated.

The Post-Girardeau Unconformity.

Clear evidence of an erosion interval succeeding the deposit of the Girardeau limestone appears in an exposure in the bank of the river three-fourths mile south of Gale. The strata here which are next younger than the Girardeau limestone rest on the very basal portion of this formation, three feet above the top of the Orchard Creek shale. That a considerable thickness of the Girardeau limestone was originally present here is shown in the fact that at a distance of only twenty rods north a thickness of thirteen feet of this limestone is exposed, and at a less distance to the south a ledge, apparently in place, may be seen in the river bank to a height of five and six feet.

The Edgewood Limestone.

The name Edgewood limestone is here applied to the strata in this region lying above the Girardeau limestone and below the Sexton Creek formation. In my paper of 1908 these are referred to as beds 3b and 3c. The name is taken from the town of Edgewood in Pike county, Missouri, near which place occur strata that have furnished fossils of this horizon in great abundance. In Alexander county the Edgewood beds are exposed in the bank of the river three-fourths mile south of Gale, where they occupy a channel eroded in the Girardeau limestone. A thin band of this limestone may also be seen in an abandoned quarry, one-fourth mile southeast of Gale. At the former locality there is a conglomerate at the base, composed of fragments of Girardeau limestone. This is succeeded by a few feet of fine-grained limestone, and dark, calcareous shale. At the top is a massive layer of hard, gray,

coarsely granular limestone, four feet in thickness, which is locally oolitic in the upper part.

The dark shale member furnished the fossils *Clorinda* sp., *Rafinesquina mesacosta*, coarsely plicate shells of *Schuchertella subplanus*, and *Dalmanites danæ*. The massive upper layer yielded *Clathrodictyon vesiculosum*, *Atrypa putilla*, *Clorinda* sp., *Leptæna rhomboidalis*, *Rhynchotreta thebesensis*, *Schuchertella subplanus*, *Spirifer* cf. *sulcatus*, *Whitfieldella billingsana*, *Pterinea thebesensis*, *Dalmanites* sp., *Prætus determinatus* and *Lichas clintonensis*. The exposure in the abandoned quarry, near Gale, furnished the following additional species: *Calapœcia* sp., *Lyellia thebesensis*, *Atrypa marginalis*, *Plectambonites transversalis* and *Rhynchonella janea*.

The Post-Edgewood Unconformity.

A break in sedimentation between the Edgewood and the succeeding deposits is shown at the abandoned quarry, near Gale, where the Edgewood limestone is separated from the basal portion of the Sexton Creek beds by a two-inch band of red, residual clay.

The Niagaran (Clinton) Series.

Sexton Creek Limestone.

The name Sexton Creek limestone is here proposed for Silurian strata in this region, which represent some portion of the Clinton time. The name is taken from Sexton creek, one and one-half miles north of Gale, in Alexander county, along which stream these beds are well exposed. In my paper of 1908 these beds are referred to as 4a, 4b, and 4c.

Ulrich* has proposed the name Bainbridge limestone for the Silurian strata appearing in the river bluffs for some miles above and below Bainbridge, Missouri. He states that it is nearly the equivalent of the Clifton limestone of Tennessee (later than Clinton), and that it also occurs in the vicinity of Thebes, Illinois. The present studies have shown that the Silurian strata in the vicinity of Thebes are of Clinton age, or earlier, and hence cannot be correlated with beds in Missouri representing the horizon of the Clifton limestone in Tennessee.

The lower part of the Sexton Creek formation consists of hard, gray limestone, in layers four to eight inches thick, which are separated one from another by two- to four-inch bands of

* Ulrich: Mo. Bur. Geol. and Mines, vol. ii, 2d series, p. 110, 1904.

chert. This chert-bearing phase is succeeded by thicker layers of pink or reddish, mottled, subcrystalline limestone.

In the upper part the cherty limestone contains *Favosites favosus*, *Halysites catenulatus*, *Atrypa marginalis*, *Orthis flabellites*, *Plectambonites transversalis*, *Stricklandinia triplesiana*, *Triplecia ortoni* var. and *Illænus* cf. *daytonensis*. The strata are well exposed along Sexton creek, one and one-half miles north of Gale. They appear in the river bluff between Gale and McClure; and they may also be seen in the bank of the river two and one-half miles south of Thebes. The maximum thickness of the formation is about seventy feet. The species of fossils listed above indicate that the Sexton Creek limestone represents the westward extension of the Clinton strata occurring in Indiana and Ohio.

The Post-Sexton Creek Unconformity.

After the deposition of the Sexton Creek beds, land conditions prevailed over this area for the greater portion of the time during which the Niagara limestones in the northern portion of the state were laid down. The strata that occur next above the Sexton Creek beds, in this region, represent the Helderbergian series of the Devonian.

Oscillations of level.—Frequent strand-line movements are clearly recorded in the Coal Measure deposits of Illinois, and elsewhere, where a number of coal seams occur in vertical succession, and separated one from another by marine beds of shale or limestone. The numerous oscillations that are shown to have occurred in southwest Illinois, during the late Ordovician and early Silurian times, would indicate that frequent movements were not peculiar to the Pennsylvanian Period. It seems probable that oscillations of level may not have been uncommon throughout the Paleozoic era. The scarcity of such records may be largely due to the fact that the deposits made in shallow water, near shore, are not present over large areas; and that such deposits would be most likely to be removed during subsequent periods of erosion.

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