ART. LIII.—*The Bethany Limestone at Bethany, Missouri;*
H. FOSTER BAIN.

THE Coal Measures of the Iowa-Missouri coal field are made up of the well-marked series of beds known respectively as the Des Moines and the Missourian. As originally used* these terms were considered to rank as stage names, but as the work of geologic mapping has progressed in the two states it has been found that both the Des Moines and the Missourian formations are really series of quite well-marked beds. Keyes has already proposed† that the terms be considered as serial and many of the minor divisions or stages have been made out in Iowa,‡ Missouri,§ and Kansas.¶

The complete section of the Missourian series has not been published, though individual formations falling within its limits have been made out by Haworth,¶ Prosser,** Keyes and others. Among the minor division the basal member of the Missourian has been often referred to. It is a heavy bed of limestone, or really a group of limestones with their intercalated shale beds, and its outcrops have been mapped, in part in detail and in part by reconnaissance work only, in Iowa, Missouri and Kansas. The limestone is of considerable economic importance, not only because it furnishes stone for building and lime-burning but also because it marks the upper limit of the productive Coal Measures throughout most of the region. It is accordingly particularly important that there should be no mistake in its correlation. There has been some controversy as to the proper name to be applied to the bed,†† but the term Bethany or Bethany Falls seems to have priority. In the present paper it will be shown that it is not the particular limestone which forms the falls which is of significance, but a whole group of limestones, all of which are well shown within the limits of the town of Bethany, Missouri. In view of this fact the suggestion already made, that the latter portion of the name as first used be dropped, seems particularly good.

In the recent work of the Iowa Geological Survey detailed sections of the Bethany limestone have been made out at intervals from the central portion of the state, where it passes beneath the Cretaceous, to the southern border, where it is well

* Keyes: Mon. Rev. Iowa Weather Service, vol. iv, p. 3. 1893.

† Amer. Geol., vol. xviii, pp. 22-28, 1896.

‡ Iowa Geol. Surv., vol. v, pp. 378-398; *ibid.*, vol. vii, 443-450, 509-520, 1897.

§ Missouri Geol. Surv., vol. x, pp. 29-71, 1896.

¶ Univ. Geol. Surv. Kansas, vol. i, pp. 145, 193, 1896.

¶ Loc. cit.

** Jour. Geology, vol. iii, p. 800, 1895.

†† This Journal, IV, vol. ii, pp. 221-225, 1896.

shown on Grand River. Bethany is but a few miles beyond the Iowa border and along Big Creek at this point the same beds, seen first in central Iowa, are well exposed. It was at Bethany that Broadhead* first studied the limestone. As now exposed the beds yield the following sequence, along a small tributary of Big Creek running through the town. The first exposure, which shows the top of the Bethany, is near the railway bridge north of the depot, the top of the limestone being at about 888 A. T.

6. Limestone, fragmental, loosely cemented, with many specimens of *Meekella striatocostata*, *Chonetes verneuilliana*, *Productus costatus*, *Athyris subtilita*, *Productus longispinus*, *Spirifer cameratus* and *Dielasma bovidens* 6
5. Shale, clayey, green to drab with thin bands of limestone... 2
4. Shale, clayey, drab to black 2
3. Limestone, drab blue, two ledges, 9 and 3 inches thick. 1
2. Shale, black 1
1. Shale, black to drab, with irregular nodules and thin layers of impure black limestone carrying large well-formed *Productus cora*, *Productus nebrascensis*, *Athyris subtilita*, *Myalina subquadrata* (?), *Schizodus*, sp.? In the shale itself are *Myalina subquadrata*, *Productus nebrascensis*, *Athyris subtilita*, *Rhombopora lepidodendroides* and plates of *Eupachyrinus verrucosus* 6

Below this exposure for some distance there are no outcrops, but in the western part of town there are some small quarries which show the following beds :

	Feet.	Inches.
6. Shale, clayey, drab		6
5. Shale, calcareous, transition beds, with <i>Spirifer cameratus</i> , <i>Meekella striatocostata</i> , <i>Productus cora</i> , <i>Productus costatus</i> , <i>Productus nebrascensis</i> , <i>Rhombopora lepidodendroides</i> , <i>Fistulipora nodulifera</i> , <i>Myalina subquadrata</i> , <i>Athyris subquadrata</i> , and <i>Derbya crassa</i>	1	6
4. Limestone, heavy ledges, many <i>Fusulina cylindrica</i>	2	10
3. Limestone, thin-bedded with many of the fossils collected above, particularly <i>Athyris subtilita</i> , <i>Productus cora</i> , <i>Productus costatus</i> , <i>Spirifer cameratus</i> , and <i>Meekella striatocostata</i>	10	
2. Unexposed		8
1. Limestone, thin-bedded, with <i>Productus costatus</i> , <i>Productus cora</i> , <i>Productus longispinus</i> , <i>Athyris subtilita</i> , <i>Spirifer lineatus</i> , <i>Spirifer cameratus</i> , <i>Spirifer kentuckensis</i> , <i>Chonetes verneuillianus</i> , <i>Hustedia mormoni</i> , <i>Dielasma bovidens</i> and <i>Fusulina cylindrica</i>	12-15	

*Trans. St. Louis Acad. Sci., vol. ii, pp. 311, 1862; Mo. Geol. Surv. Iron Ore and Coal fields, Pt. II, p. 77 et seq. 1873.

Not far from here is the mouth of the stream which is just above the falls of Big Creek. The rock forming the falls lies probably 6 to 8 feet below the base of the limestone just described. It is about 20 feet thick, the upper 18 feet being made up of a coarse but firmly cemented limestone breccia. It is marked by long dark streaks which suggest corals but which fail to show structure. The only fossil collected from it was *Productus cora*. Below the breccia is about two feet of fine-grained gray limestone, carrying large well-formed *Spirifer cameratus* with *Productus cora*. The brecciated character of the limestone and the absence of marked sedimentation plains has given under water action rounded forms and knob and pot hole surfaces.

The general sequence found here, with the four bodies of limestone separated by shales, is the same as has already been found in central Iowa. The exposures in the latter region were first studied by White* and have been more recently reviewed by the present survey.† In many of the minuter details even, there is a close correspondence between the Bethany section and that of Madison and adjacent counties. The latter may be summarized as follows:

	Feet.
8. Limestone, thick and thin-bedded, characterized by a particular abundance of <i>Fusulina cylindrica</i> , and hence called the Fusulina limestone	15-30
7. Shales, predominantly dark-colored and argillaceous, containing several thin bands of bituminous limestone which are usually quite fossiliferous. About midway of the shales is a horizon which is particularly fossiliferous. The more usual forms, including <i>Athyris</i> , <i>Productus</i> and <i>Spirifer</i> , occur in great abundance and perfection. With these forms are vast numbers of <i>Derbya crassa</i> with <i>Myalina subquadrata</i> , <i>Myalina kansasensis</i> , <i>Myalina swallowi</i> , <i>Aviculopecten occidentalis</i> , <i>Productus nebrascensis</i> , etc. Not far above this horizon is usually a thin band of limestone literally made up of <i>Chonetes verneulianus</i> . The whole thickness of shale is	10-20
6. Limestone earthy, magnesian, easily disintegrating above to medium grained coarse-bedded quarry rock below ..	10-20
5. Shale, usually dark and including a black bituminous horizon	8-12
4. Limestone, well shown near Earlham and hence called the Earlham limestone. It carries an abundant fauna which will be noted later	20

* First and Second Ann. Repts. State Geol., pp. 71-72, 1868; Geol. Iowa, vol. i, pp. 245-250, 1870.

† Trans. Iowa Acad. Sci., vol. i, pt. iii, p. 144, 1895; Iowa Geol. Surv., vol. iii, p. 137, 1895; *ibid.*, vol. vii, pp. 446-451, pp. 491-539, 1897.

3. Shale, with bituminous horizon and at many points a thin black limestone 3-8
2. Shales, sandy, light-colored, very variable thickness ... 2-16
1. Limestone, fragmental, made up of irregular bits of lime rock filled in with calcareous clay. In places the rock can be picked to pieces with the fingers; elsewhere it hardens up into massive thick-bedded layers. Along a small tributary of Deer Creek in Guthrie County it is quite fossiliferous, yielding *Spirifer lineatus*, *Spirifer cameratus*, *Athyris subtilita*, *Hustedia mormoni*, *Productus longispinus*, *Naticopsis altoensis*, *Lopophyllum proliferum*, *Orthis pecosi*, *Bellerophon* sp., *Strapharrollus* sp., *Archæocidaris* sp. 10-15

The Earlham limestone in Madison County is one of the best developed and most easily recognized members of the section. At Robertson quarry, two miles east of Earlham, the following section was noted :

	Feet.	Inches.
11. Bed of soft, yellowish, magnesian, earthy limestone, decomposing readily when exposed to weather	4	
10. Limestone in three heavy ledges at west end of quarry	4	
9. Buff shale with <i>Chonetes verneulianus</i>		4
8. Limestone, like number 4	2	
7. Ashen shale with very few fragments of brachiopod shells		6
6. Earthy limestone, decomposing readily, yellowish, carrying large individuals of <i>Athyris subtilita</i> ..		4
5. Drab shale, with <i>Productus longispinus</i> , <i>P. costatus</i> , crinoid stems and fragments of other fossils ..		6
4. Quarry limestone, in thin layers, irregularly bedded	8	
3. Unexposed	20	
2. Sandstone, in heavy layers	7	
1. Base of sandstone to creek, unexposed	17	

At one point the quarrymen had worked down in the bottom of the quarry and exposed, below number 4, drab and black shales to the depth of three feet, and below the shales a ledge of limestone six inches in thickness.

Distributed through the limestone beds No. 4 are the following :

Lopophyllum proliferum McChesney.
 Stem segments and body plates of crinoids.
 Various species of Bryozoa.
Meekella striatocostata Cox.
Productus punctatus Martin.
P. costatus Sowerby.

P. longispinus Sowerby.

P. cora D'Orbigny = *P. prattenianus* of authors.

Athyris (*Seminula*) *subtilita* Hall.

Hustedia mormoni Marcou.

Spirifer cameratus Morton.

Spiriferina kentuckensis Shum.

Allorisma subcuneatum M. & H.

Chonetes verneulianus N. & P. is somewhat common in No. 9 but is very rare in the other members of the section. *Spirifer cameratus* and *Productus longispinus* are most abundant near the base of No. 4, while *Productus costatus* and *Athyris subtilita* are more common in the upper layers. All the species enumerated, however, with the exception of *Allorisma subcuneatum*, range through all the beds making up No. 4.

The best exposures of the Bethany limestone in southern Iowa are found along Grand River and its tributaries. From the outcrops found there a complete section can be made from the Fragmental limestone at the base up to and above the beds which farther north have been called the Fusulina limestone, but which from their excellent development in that vicinity may now perhaps be best called the De Kalb limestone.

In Union County there is an important bed of limestone which from the fact that it is well shown on Sand Creek, near Westerville, may be called the Westerville limestone. It lies some little distance above the De Kalb horizon. In Jones township section 28, and farther south along the river, the beds are exposed, showing the following section:

5. Limestone, ash gray, fine-grained, thin-bedded, becoming almost shaly at the top, with <i>Productus cora</i> , <i>Productus costatus</i> , <i>Spirifer cameratus</i> , <i>Athyris subtilita</i> , <i>Chonetes verneulianus</i> cf. <i>glabra</i> , <i>Lopophyllum proliferum</i> , <i>Strapharolus subquadratus</i> and Fenestelloid bryozoa	10
4. Shale, gray, calcareous, with thin nodular bands of limestone	4
3. Shale, drab to black	10
2. Limestone, impure nodular in two bands	2½
1. Shale, drab to black, well exposed at Westerville	8

These beds extend into Decatur County, being seen near Westerville on Sand Creek and on Grand River. It seems probable that the shale (No. 1) extends down to the top of the De Kalb or Fusulina limestone, which is exposed near Grand River and was at one time quarried at the old Madarasz quarry (Sec. 36, Tp. 70, W., R. xxvii W.). The best exposures of the latter limestone and the ones which may be taken as typical are found a short distance east of De Kalb station (Sec. 28, Tp. 70 N., R. xxvi W.). The section at this point is given below.

	Feet.	Inches.
5. Limestone, irregularly water-worn		6
4. Shale, hard, drab		6
3. Limestone, irregularly bedded		8
2. Shale, calcareous, becoming in places a poor grade of lime rock	2	
1. Limestone in thick to thin ledges	4	

The limestone is quite fossiliferous, the forms collected including: *Productus costatus*, *Productus longispinus*, *Athyris subtilita*, *Spirifer camerata*, *Spirifer kentuckensis*, *Dielasma bovidens*, *Derbya crassa*, *Lopophyllum proliferum* and *Fusulina cylindrica*. This fauna is more abundant than is usually found in the same beds farther north, though no extensive collections have been made in the latter region and many of the species collected at De Kalb are known to be present, sparingly at least, in the Madison County outcrops. The marked predominance of the *Fusulina cylindrica*, which is so striking a characteristic of these beds in Madison County, is not so noticeable at De Kalb. This is probably due as much to the greater abundance at the latter point of the other forms mentioned as to any real decrease in the numbers of the *Fusulina*. It is nevertheless true that the Decatur County outcrops show much closer relations to the rocks as developed at Bethany than to the Winterset section in the earlier advent, or at least culmination, of *Fusulina*. It is for this reason in part, that the term De Kalb limestone is to be preferred to *Fusulina* limestone, since neither the presence nor the abundance of the latter form is found to be consonant with a constant stratigraphical horizon.

The beds below the De Kalb limestone are well developed and show no important variation from the standard sections already given. A point of interest is the persistence of the *Myalina* horizon, which is found on Grand River west of the town of Decatur only less perfectly developed than at Winterset.* The exposures in and near Davis City show the Earlham and Winterset limestone especially. The Fragmental limestone is shown but is almost non-fossiliferous, as at Bethany. As seen in Clarke County near Osecola it is also unfossiliferous, and the only abundant collections from this horizon were made in the central Iowa counties.

No attempt has been made to follow the subdivisions of the Bethany south of its type locality. Their persistence in Iowa however, with certain hurried observations at Kansan City and a study of the reports of the University Geological Survey of Kansas, indicates that a portion of the section at least may be

* Geology of Decatur County, Iowa Geol. Surv., vol. viii. In press.

looked for in the latter region. The persistence of these minor subdivisions over the territory where they have already been traced for more than one hundred and fifty miles, suggests that the differences are due to widely acting causes and brings into sharp contrast the unsettled and disturbed conditions which apparently prevailed during the deposition of the Des Moines beds.

This manifest change in conditions affords a legitimate basis for making the Bethany the dividing line between the two divisions of the Coal Measures, even though it be recognized that the faunal changes are in the proportion and abundance of the species present rather than in the introduction of new forms. The old fauna adapted itself to the new conditions and there was a change merely in the balance between the species.

The taxonomic rank of the Bethany and its subdivisions is indicated in the following table:

System	Series	Stage	Substage
Carboniferous	Missourian	Undifferentiated	
		Bethany	Westerville ? De Kalb Winterset Earlham Fragmental
	Des Moines		

It is probable that the Westerville limestone will be found to be better included with the next higher division when that shall be studied, but for the present it may be conveniently considered in connection with the Bethany.

Des Moines, Iowa, April 18, 1898.