CRETACEOUS DEPOSITS

OF

Woodbury and Plymouth Counties,

WITH

OBSERVATIONS ON THEIR ECONOMIC USES.

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The Cretaceous deposits of Iowa deserve consideration on account of the important economic uses to which they are certain, in the near future, to be applied. As they now exist in our State, these deposits constitute many detached fragments of a series of formations that once spread continuously from a shore-line passing through the interior of Iowa, westward to the Rocky mountains. Measured in the other direction, the area over which Cretaceous sediments are known extends from central Texas northward to the Arctic ocean. At some time during the Cretaceous period the ancient sea in which the sediments were laid down probably reached, in the latitude of northern Iowa, as far east as the Mississippi; in which event the shore-line traversed our State from its northeastern to its southwestern corner.

Erosion has cut deeply in places into the soft Cretaceous sediments, thus dividing them into isolated masses. For example, the Iowa Cretaceous is separated from that of Nebraska, with which it was originally continuous, by the action of the rivers in cutting out the broad valley between the bluffs at Sioux City and those near Ponca, Nebraska.

In Woodbury and Plymouth counties the Cretaceous exposures are confined almost exclusively to the bluffs facing the Missouri and Big Sioux. The few exceptions observed possess little of scientific or economic interest. As displayed in the region in question the deposits are sharply divisible lithologically into two series. The lower series consists of soft sandstones interstratified with bands of hard, ferruginous, concretionary nodules and variegated, often particolored, clays. So far as these beds are exposed in the counties mentioned, the clays greatly predominate.

Resting on the clays of the lower series, and often separated from them by a very sharp line of demarkation, are beds composed in part of white or yellowish chalk, and in part of more indurated, though still soft, beds of fissile limestone. The indurated beds divide under the hammer or the effects of weathering into thin layers which are usually crowded with valves of an oyster-like shell, the *Inoceramus problematicus* of Schlotheim.

White has called the great complex mass below the chalk the *Woodbury Sandstones and Shales.* While the calcareous beds at the summit of the series he calls the *Inoceramus Beds.* This arrangement of the deposits is satisfactory on lithological grounds, and for all ordinary purposes may be more convenient than any other. If, however, we follow the example of Meek and Hayden, who studied the corresponding deposits in Nebraska with great care, we would draw a line about forty feet below the base of the chalk and so divide the deposits into three parts. The lower division will consist of alternating sandstones and shales, the sandstones occurring in heavy beds near the base, while thicker beds of shale with thin beds of sandstone will be found near the top. This lower divis-

ion is the Dakota group. In its lower members impressions of leaves belonging to species of plants resembling our modern forest trees are common, but remains of animals of any kind are exceedingly scarce. The few molluscan remains that have been found in beds of the Dakota group are related to brackish-water species. They occur only in the lower part of the series where sandsandstones predominate and imply that the beds were laid down in an estuary, or at least in a region where the sea was shallow and large volumes of fresh water were poured into it. The second division consists of about forty feet of dark colored, calcareous shales, rich in crystals of selenite and containing impressions of valves of *Inoceramus* and other true marine mollusks associated with the vertebræ and teeth of bony fishes and the skeletons of marine Saurians. This middle division is the Fort Benton group of Meek and Hayden. It is separated from the underlying Dakota group on both lithological and paleontological grounds. The conditions favoring the deposition of sandstones and the existence of brackish-water mollusks had passed away owing to the gradual deepening of the sea and the shifting of the shore-line farther to the east. True marine mollusks and fishes and reptiles occupied the region and left their skeletons to be buried in the finer mud that characterized the deposits then slowly accumulating in the open sea. The Inoceramus beds of White, comprising the deposits of chalk and shell-bearing limestone represent Meek and Hayden's Niobrara group, the water, by progressive subsidence of the ocean bed, had become deeper than during the Fort Benton epoch. The shore-line of the Cretaceous sea attained its greatest extension to the east, probably reaching as far as the Mississippi in northeastern Iowa. Inoceramus multiplied over the region occupied by Wood-

bury and Plymouth counties, and swarmed over the sea-bottom as oysters, if undisturbed, would crowd a modern oyster bed. Sharks belonging to the genera Otodus, Lamna, Oxyrhina and Ptychodus, disputed possession with bony fishes and marine Saurians. Everything betokens a deep, clear, open sea that spread away from its shore-line in Iowa, over all the intervening plain, to the present site of the Rocky mountains. In the central and western part of the area the Fort Benton epoch merges into the Niobrara without marked change of conditions, and Hayden proposes to unite the deposits of the two epochs under the name of the Colorado Group. Indeed even at Sioux City all three of the epochs blend more or less completely. We have simply a record of gradual and progressive subsidence from the earliest recorded condition of a shallow, land-locked sea into which large volumes of fresh water swept enormous quantities of sand and mud. With the sand and clay came leaves and trunks of forest trees from the adjacent land. A few brackish-water mollusks maintained a precarious existence, and strong currents, probably tidal, swept the sands alternately in one and another direction and produced the peculiar kind of bedding known to all observers as current structure, so well illustrated in a section near Springdale, northeast of Sioux City. From that time on to the close of the Niobrara epoch the sea-bottom subsided more and more, the water became gradually deeper, the shore-line was carried farther and farther east, leaves and trunks from the land ceased to be imbedded in the growing sediments simply because the land was too far away for these objects to reach the region in question; marine forms supplanted those adapted to conditions of brackish water, and the cross-bedded, coarse sands, indicative of proximity to shore, gave place to deposits characteristic of the

clear, open sea. Such is, in brief, the history of the origin of the deposits under consideration.

Recent excavations and cuttings have shed much light on the extent of the Iowa Cretaceous; but the success with which such deposits have been converted elsewhere to economic uses has made it very desirable that the actual thickness and areal distribution of the several beds should be carefully determined. Accordingly, in October, 1892, the writer, in company with Mr. D. H. Talbot, of Sioux City, to whom the Survey is under obligations for valuable gratuitous assistance, undertook a thorough examination of the region about the mouth of the Big Sioux river with the purpose of determining anew the nature of the deposits, the points at which they are most accessible, and the amount of each kind of material the region can be depended upon to afford.

The following sections, taken at different exposures, will help to make clear the relation which the several beds sustain one to the other.

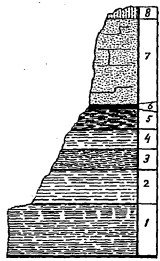

Figure 16. Section at Sargeant Bluffs.

At Sargeant Bluffs, at the Holman brick works, the shales are somewhat irregularly bedded, and no single diagram will represent exactly the succession of strata. The part of the section marked 1 lies below the level of the breast of clay now worked, but, according to Mr. Holman, excavations show it to be the same as number 2. I am indebted also to Mr. Holman for information respecting the quality of the several beds of clay as they have been ascertained by tests in the kilns. The section may be thus described:

		FEET.
8.	Loess: the common deposit of comparatively recent (Pleistocene) origin which covers all the surface in the vicinity of the Missouri and Big Sioux rivers to a depth varying in thickness ----5 to	100
7.	Sandstone, soft and friable at base, but more coherent above----- (In White's section of the Cretaceous, at Woodbury or Sargeant Bluffs, this sandstone is represented as divided by a bed of mottled, indurated clay four feet thick.)	25
6.	Lignitic shale----------	1½
5.	Potter's clay----------	6
4.	Fire clay----------	6
3.	Variegated clays, very irregularly bedded, with bands of yellow, blue and brown, and streaks of micaceous sand, quite free from nodules of iron oxide or iron pyrites, very easily vitrified, but when mixed with 4 makes a superior paving brick----------	6
1 and 2.	Reddish clay, stained with ferric oxide, burns a light red, suitable for making pressed brick and terra cotta work--------	25

A short distance east of the Holman brick works are the works of the Sargeant Bluffs and Sioux City Brick Company. All the clay used here, as well as at the Holman brick yard, lies below the level of the sandstone number 7.

The most valuable articles produced at present from the clays of Sargeant Bluffs are common pottery and paving brick. By proper selection clays admirably adapted to the manufacture of these articles may be obtained here in quantities sufficient to support flourishing industries for an indefinite period. The Sargeant Bluffs and Sioux City Brick Company are devoting their splendid plant largely to the manufacture of paving brick, and paving brick of very superior quality are made at the Holman yards. Common building bricks are also made in large quantities; but the time is surely coming when the twenty-five feet of superior clay, represented by numbers 1 and 2 of the section (figure 16), will be utilized in the manufacture of common, moulded, and ornamental pressed brick and terra-cotta work. Costly machinery may be needed, and it will doubtless be nec-

essary in order to reach artistic results, to use a mixture of raw and burned clays ground together, but as our cities increase in size and wealth the demand for such building material will justify the necessary expense as regards plant and methods of manufacture. Even now Iowa imports and uses pressed brick enough to support a number of such plants as that here contemplated.

No exposures of Cretaceous were observed between Sargeant Bluffs and Sioux City. The next outcrops were seen at Prospect Hill, above the mouth of Perry creek, but the face of the bluff is so covered with talus as to make it difficult to get a satisfactory section. It is easy enough to make out the presence of sandstones and shales possessing the general characteristics that distinguish the Cretaceous deposits of this region at numerous exposures, but the thickness and sequence of the several beds, owing to lack of time, had to be left undetermined.

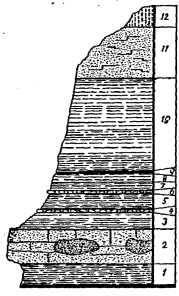

Figure 17. Section at North Riverside.

At Riverside park, above the mouth of the Big Sioux river, a section exposed in the bluffs gives the following succession of beds. The section begins near the North Riverside station, above the level of the electric railway track.

		FEET.
12.	Loess, with beds of sand and gravel in lower portion, of Pleistocene age, thickness very variable.	
11.	Calciferous, somewhat shaly sandstone, with crystals of selenite in thin partings. Better seen at the works of Sioux Paving Brick Company, about one-half mile farther north, where it has a thickness of	15

		FEET.
10.	Variegated shale, with streaks of red and brown, and thin, interrupted beds of sand; red streaks ocherous, resembling mineral paint; selenite crystals somewhat common	28
9.	Thin band of lignite	½
8.	Light gray shale, somewhat gritty	2¾
7.	Clay-shale	2½
6.	Ferruginous nodules like number 4	½
5.	Shale	5
4.	Hard iron nodules or concretions	½
3.	Clay-shale	5
2.	Sandstone, with concretionary masses, some of which are many feet in extent and resemble quartzite in hardness	10
1.	Dark gray shale, tested by Mr. W. M. Byam, Superintendent of the Sewer Tile Works, and found to be a superior quality of fire clay; thickness exposed above railway embankment varies owing to somewhat steep descent of grade of railway	4 to 6

A short distance above the North Riverside station of the electric railway, a company, with Mr. W. M. Byam as manager and superintendent, has established works for the manufacture of vitrified sewer tile. The clays from the different beds, 1, 3, 5, 7, 8, 9 and 10, are mixed in such proportions as experience has shown will give the best results. Nothing but sewer tile is made here at present, but by selecting the clays from the different beds a variety of highly useful products might be turned out. For example, according to tests made by Mr. Byam, the clay of bed number 1 produces a very superior quality of fire brick, and with proper handling may be made into all the great variety of articles for which fire clay is needed. Beds 3, 5, and 7 furnish potter's clay, and by careful selection it is quite probable that material for the manufacture of yellow table-ware may be obtained. Bed number 10 contains a high percentage of oxide of iron and so, in burning, it assumes a beautiful red color. It is suitable for the manufacture of red terra-cotta ware and fancy brick, while by glazing it may be made into a pleasing variety of ornamental tiles. The selenite, so common in

certain parts of this bed, may cause some disappointment in the first experiments, since, if it is not thoroughly ground and mixed with the clay, it causes white spots in the burned products. The difficulty is one that can be overcome by means purely mechanical.

A short distance north of the Sewer Tile Works is the plant of the Sioux Paving Brick Company. The clay used at the time of my visit belongs to the beds lying between the heavy sandstone number 2 and the calciferous, shaly sandstone of number 11 in the section near North Riverside. The thickness of the several beds is the same and they succeed each other in the same order as at the preceding station, but selenite seems to be more common in the upper beds, and nodules of iron pyrites are very abundant. No paving bricks are made here at present, although the materials for their manufacture are, in some respects, all that could be desired. The building bricks turned out by the company are sometimes much disfigured by the presence in the clay of pyrites which burns into dark brown crumbling masses of ferric oxide. The bricks are, therefore, rendered unsightly by being spotted and blistered. To obtain satisfactory results this clay should be treated in some way to exclude the small nodules of pyrites. Dry grinding and sifting or some other method can easily be employed to obviate the difficulty.

About three miles farther up the Big Sioux, at Cedar Bluff, is one of the best natural exposures of Cretaceous clays seen in this region. The height of the section exposed is about one hundred and thirty feet. The succession of beds is the same as already seen farther down the river, except that the Cedar Bluff section exposes strata lying both above and below the level of any seen at Riverside. The beds at the point last mentioned are the equiv-

alent of beds that occupy a middle position in the face of Cedar Bluff.

The same clays are exposed at a number of points in the neighborhood of Cedar Bluff, notably along the small creek that comes down past the residence of Mr. D. H. Talbot. They also crop out on the west branch of Perry creek, on the farm of Mr. Sloan, in Sec. 4, Twp. 89 N., R. 47 W. They are seen in an excavation made in quarrying sandstone for building purposes on Sec. 27, Twp. 90 N., R. 48 W., and again they constitute an important factor in the section exposed by the undermining action of the river at the site of Crill's mill, on Sec. 32, Twp. 91 N., R. 48 W. They were not seen at any point farther north.

Lying above the clays described is another series of clays the economic uses of which have not yet been tested. These constitute the beds referred by Meek and Hayden to the Fort Benton group. They have a thickness of about forty feet, are rather dark colored, free from interstratified beds of sand, seem to have little or no pyrites of iron, but are charged with crystals of selenite; nevertheless, this last mineral is not present in such quantities as to interfere with their profitable manufacture, when tests have determined the uses to which they are best adapted. Bones of marine reptiles related to Plesiosaurus are not uncommon in the Fort Benton group, and associated with the remains of Saurians are the vertebræ and other skeletal parts of true bony fishes, Teliosts. The shales of the Fort Benton group were first seen and recognized on Sec. 35, Twp. 90 N., R. 48 W. At this point they had been excavated by Mr. Talbot in making a cistern. In the process of digging the workmen came upon a very perfect reptilian skeleton, which, under the direction of Mr. J. C. C. Hoskins, was obtained almost entire. The skeleton is now the

property of the Sioux City Academy of Science. Not having seen this interesting specimen, I am unable to say anything respecting its zoological affinities, farther than that it is probably the remains of a marine Saurian belonging near the Plesiosauridæ. The same shale is seen in great abundance at a land-slide that recently took place a short distance north of what is known as the Williams place, below the mouth of Broken Kettle creek, on Sec. 9, Twp. 90 N., R. 48 W. An acre or more of surface was uncovered by the slide, and hundreds of thousands of tons of the Fort Benton clays are now exposed in great heaped and tumbled masses. A few bones of fishes were the only fossils observed. This same shale was seen in the bank of the Big Sioux, on the Dakota side, at Otis' mill, about eight miles north of Akron, at which point it contains an unusual number of impressions of *Inoceramus problematicus*.

Lying above the shales of the Fort Benton group we find the Inoceramus beds of White, the Niobrara group of Meek and Hayden. This is the formation that embraces all the beds of chalk and soft limestone exposed at so many points up and down the Big Sioux river. Excellent outcrops are seen on sections 1 and 2, Twp. 89 N., R. 48 W., in Woodbury county. In the next township north, in Plymouth county, it occurs in considerable force on lands belonging to Mr. Talbot, in sections 35 and 36. In the same township there are good exposures on lands of Mr. La Barge, in section 26, at the land-slide already mentioned, on section 9, and again on a small branch of Broken Kettle creek, in section 11. In the next township north, Twp. 91 N., R. 48 W., it is seen a short distance above Crill's mill, while on the lands of Mr. Moran and the lands adjacent, in section 19, there are numerous exposures. There are scores of indications of the existence of

these calcareous beds at points not mentioned. Indeed they are very generally distributed throughout the region. While they have been cut away by erosion in the ravines and valleys, they may be looked for with confidence in all the hills at the level of the outcrops mentioned. The most northerly outcrop observed was at the point in Dakota already cited near Otis' mill, where they occupy their usual position immediately above the shales of the Fort Benton group.

The Niobrara beds in the region studied have a maximum thickness of twenty-five to thirty feet. The section as indicated by observations at different exposures, would consist of:

		FEET.
4.	Loess	8
3.	Chalk	4 to 6
2.	Soft limestone, splitting into thin slabs and crowded with shells of Inoceramus	12
1.	Chalk	12

Everywhere the chalk rests on the shales of the Fort Benton division. Its uses are in the manufacture of lime for building and fertilizing purposes and in the manufacture of Portland cement.

The Cretaceous beds of Plymouth and Woodbury counties furnish very little building stone. The hard, quartzite-like masses of bed number 2, figure 17, illustrating the section at North Riverside, are unsurpassed in quality, but their distribution is so irregular and uncertain that the bed can never be worked with any assurance of profitable return. At the exposure, known locally as Reese's Granite quarry, on Sec. 11, Twp. 89 N., R. 48 W., the concretionary quartzitic masses are large, and numbers seem to occur in close proximity to each other, and here some quarrying has been done. On Sec. 27, Twp. 90 N., R. 48 W., near the wagon road and partly below the flood plain

of the river, is an artificial excavation which exposes strata below the level of any seen at Cedar Bluff or farther south. At the base of the section lies a band of micaceous sandstone, two feet in thickness, which is of excellent quality and has been quarried for building stone. The limited thickness of the bed and the great amount of material above it precludes the probability of its being worked at a profit unless the overlying clays can be converted into useful products. This same bed, now concealed by a thin mantle of talus, was formerly seen at Cedar Bluff, Prospect Hill, and other points along the bluffs near Sioux City. Some portions of the Inoceramus beds on the farm of Mr. Moran, at the locality already cited, are usually compact, and have been quarried to a considerable extent to furnish material for foundations.

The chief industries of the region about Sioux City, so far as they are dependent on its geological resources, will be those devoted to the transformation of its unlimited beds of clay into articles of economic value. These beds exist not only at the points where they have been naturally or artificially exposed, but they extend practically throughout all the hills up to a level of one hundred and ten or one hundred and fifteen feet above the average stage of water in the Big Sioux river. They extend up the stream until the bluffs fade into the rolling prairie of northern Plymouth county. Borings show their presence in Sioux county to a depth of one hundred feet or more below the surface. The width of the area they occupy has not been determined, but it may be set down as several miles. The clays are by no means of the highest grades, but there are clays enough to supply the world with all the products that can be made from clays of such grades as do occur. Among the numerous articles that

may be produced, it will be sufficient to specify building brick, paving brick, fire brick, pressed brick, pottery, yellow ware, terra-cotta, drain tile, sewer tile, and fancy or ornamental tiling. It requires no severe stretch of the imagination to look forward to the possibility of macadamizing some of the frequently impassable stretches of road leading to Sioux City with burned clay. Burned clay is already in use in some localities as railway ballast.

The forty feet of Fort Benton shales lying beneath the chalk have not yet been tested by any of the manufactures. It is not probable that they will be found to possess any marked superiority over clays already in use, but the particular product to the manufacture of which they are best suited must be determined by experiment.

Less extensive and less important than the clays are the beds of chalk and limestone that cut through the hills at a level of about one hundred and fifty feet above the river. The most important use of these beds, as already intimated, will be the manufacture of Portland cement. If such manufacture is ever undertaken it should be with such a combination of capital as would unite the production of cement on a moderate scale with the manufacture of clay on a comparatively large scale. The removal of the chalk, if the works are properly located, would simply serve to strip and expose the clay.

The heights at which I have said the clays and chalk beds occur in the bluffs are only approximate, and even then are true only for the vicinity of Sioux City. As we go northward the height of the several beds above the level of the river becomes less than the figures mentioned, for two reasons. The valley and the channel of the stream gradually ascend in that direction, and so, if the Cretaceous strata were absolutely level, their elevation

above the water would become progressively less and less. But the strata are not level. They are inclined very gently toward the north, or rather, toward the northwest; and so the slope of the valley in one direction combined with the inclination of the strata in the opposite direction gradually reduces the height to which any given bed rises above the level of the river. At Crill's mill, for example, the reduction in apparent height is very noticeable, the amount being fifteen feet. Without giving a detailed account of the observed height of the several exposures it will be sufficient to say that at Otis' mill, the most northerly exposure visited, the summit of the Fort Benton shales, which at Sioux City is at least 140 feet above the river, rises to a height of scarcely twelve feet. At Yankton, which is about ninety feet higher than Sioux City, the Fort Benton shales have disappeared below the level of the Missouri, owing to the slight westward dip of the strata. The Cretaceous beds of this region illustrate the general geological law, that in regions that have not suffered violent disturbance the dip is at right angles to the general trend of the shore-line of the sea in which the beds were laid down.

On Sec. 1, Twp. 89 N., R. 48 W., a spring occurs, the waters of which contain Lithium carbonate in solution. It is locally known as the Lithia Spring, and is acquiring a reputation for medicinal properties. This seems to be one of the series of springs that mark the line of junction between the Fort Benton and Niobrara groups. Whether or not these springs are all equally medicinal will be a proper subject of inquiry for the chemist and the geologist appointed to investigate the mineral and artesian waters.