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Record of the Grinnell Deep Boring

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these exhumed boulders, as they occur at Graniteville, in Iron county, where they are known as "elephant rocks," are shown in plate iv.

The final stage of disintegration is the bed of sand with occasional decomposed pebbles of the original rock scattered through it. In the decomposition of granite the texture may remain in appearance as in the original rock, but upon excavation is found to be soft, incoherent sand.

RECORD OF THE GRINNELL DEEP BORING.

BY ARTHUR J. JONES.

Work was begun on the deep well in October, 1892, but it was not completed until the following year. The ordinary churn drill was used and the hole was first drilled eight inches in diameter, but later the upper portion was enlarged to ten inches. The record has been more carefully kept than is usual in drilling such wells, but cannot be relied upon as absolutely exact. In many cases the fragments of the overlying stratum are mixed with that underneath, and the thickness of each formation cannot be exactly determined. This renders the results only approximately correct, but it is believed that a fair degree of accuracy has been attained.

The top of the well is at an elevation above the sea of 1,023 feet. For 212 feet the drill passed through soil, loess and drift, but no record was kept. At this depth a hard limestone was encountered. The sample consists of small pieces of fine-grained limestone mixed with sand and gravel. A few pieces of coal and bituminous slate, which could hardly have been introduced from the surface, were also present. It had been thought that the coal measures probably extended as far as Grinnell, but no positive evidence of this had been obtained prior to the sinking of this well. The gravel is the base of the lower till and the limestone evidently Saint Louis. At this point a strong flow of water was encountered. It rose to within 90 feet of the surface; higher than at any subsequent flow. The water was unfit for use, being almost yellow and strongly mineral; it had

no bad smell and was not of the same quality as the water found in the forest bed.

The next sample was taken at a depth of 220 feet. This is pure limestone with calcareous shale. The formation extends to 240 feet where it passes into dark shale and impure limestone. The sample contains a considerable quantity of iron and is very arenaceous. In it were found numerous small crystals of gypsum, which had evidently crystalized out of the material after it had been placed in the bottle. It probably resulted from the decomposition of iron sulphide, and the consequent action of sulphuric acid on the limestone.

At 270 feet there was found a coarse, impure, hard limestone, dark in color. This resembles the brecciated base of the Saint Louis, and is probably referable to that horizon.

The next sample, considered to be the upper portion of the Augusta, shows argillaceous shale with numerous pieces of fine-grained limestone. This formation still continued at 365 feet, becoming somewhat lighter in color. At 400 feet, however, dark, calcareous shale was found which contained a large amount of iron and silica. This was succeeded by blue, calcareous shale, intermixed with small pieces of soft limestone. Twenty feet below, this merged into fine-grained, calcareous shale which, at 440 feet, passed into darker shale. Following this was light, soft, fine-grained shale. This is probably very near the base of the Augusta, making this formation a little over 200 feet in thickness. No distinguishing characteristics can be discovered in the two adjoining samples, one of which is referred to the Augusta, the other to the Kinderhook. In the well at Sigourney the base of the Augusta was found at 365 feet. Since in this well the level of the top of the Saint Louis is 200 feet lower than it is in the one at Grinnell, it would seem that the base of the Augusta would here be at nearly 420 feet, the exact thickness being dependent upon variations in the thickness of the strata.

If this conjecture is correct the uppermost member of the Kinderhook is represented by twenty feet of light, hard, brittle shale at 530 feet, which in turn passes into dark calcareous shale at 550 feet. The latter continued for twenty feet when limestone was found to occur again. It is fine-grained and associated with light, calcareous shale. There is little probability that this and the succeeding strata are entirely limestone, but are limestone and shale alternating, with, perhaps, considerable

more shale than limestone. From 600 to 765 feet occur alternating dark and light shales with carbonaceous matter scattered through them.

The nature of the next sample is such as to place it with Devonian limestones as nearly as can be determined, thus making the base of the Kinderhook at the shales already mentioned. The Kinderhook then, is here nearly 270 feet in thickness. The upper stratum of the Devonian in accordance with this conjecture is fine-grained, compact limestone with drab shale. This was found at a depth of 800 feet. Below this there occurs a series of shales which extend to a depth of 940 feet. At 810 feet there was a fine-grained, calcareous shale followed by darker shale at 850 feet, which showed some indications of the presence of limestone. Below this, light-colored, porous shale made its appearance. At 940 feet limestone is encountered again. It is coarse, dark and impure; with it are pieces of dark shale. The limestone becomes more compact at 949 feet, and is of two kinds, blue and gray. Numerous crystals of iron pyrite are scattered through the it. Twenty feet lower the formation changes to light shale.

The limestones which follow seem to be very closely associated, being strikingly similar in lithological character. It seems better, therefore, to make the base of the Devonian at 990 feet, with the shale last mentioned. The total thickness of the Devonian would thus be nearly 200 feet. No attempt can well be made to separate these strata, for there seems to be no adequate grounds for such a division. It seems best, therefore, to simply refer all to the Devonian and ignore the divisions.

There next occurs a series of cherty limestones extending from 990 feet to 1,200 feet, probably marking the Niagara at 990 feet. The sample shows coarse-grained, hard, blue limestone, with a little chert and shale. This passes into a fine-grained, compact, white limestone with chert, which continues to 1,065 feet where it becomes exceedingly cherty. Intermixed with it are also grains of pure, transparent quartz and rounded pebbles of a purer and harder limestone, somewhat darker in color.

At 1,087 feet the limestone is darker, bluish and impure, with pieces of chert and flint. A finer-grained, light limestone with less chert is disclosed by the next sample at 1,130 feet. Forty-five feet below, this gives place to a dolomitic limestone

with some chert and dark shale. This extends to a depth of 1,200 feet.

At this point the nature of the strata seems to change entirely, the limestone giving place to a series of shales, which from their position may properly be referred to the Maquoketa shales, thus marking the base of the Niagara at 1,200 feet. These shales are light-colored and interbedded with thin layers of limestone. Carbonaceous matter was also intermixed with the shale and limestone. This formation can not be far from 150 feet in thickness.

The sample taken at 1,320 feet shows the nature of the strata to have changed again. It is a fine-grained, brown, arenaceous limestone, containing a large amount of iron and magnesium. Lower down it becomes coarser, and at 1,380 feet it gives place to dark shale which continues for twenty feet. From 1,400 feet to 1,475 feet there occurs a fine-grained limestone decidedly dolomitic and very ferruginous. Unfortunately there is no record of the strata between 1,475 feet and 1,610 feet. A drill was lost and in attempting to pass it the samples were forgotten. The dolomitic character of the limestone between 1,320 feet and 1,475 feet would seem to indicate that they belong to the Galena group. If so, then the contact between this and the Trenton is in the gap between 1,475 feet and 1,610 feet.

The first sample of what is called the Trenton resembles ferruginous sandstone, but is in reality fine-grained, highly ferruginous dolomite with small pieces of white chalky matter, nearly pure carbonate of lime. This continued through 1,625 feet, becoming less ferruginous, and gave place at 1,630 feet to coarse, impure white limestone. At 1,640 feet a piece of blue shale about two inches long was brought up with the drillings. This was filled with fragments of the shells of brachiopods and pieces of bryzyoans. There were also numerous crystals of pyrite scattered through it. Fifteen feet lower, at 1,655 feet, the drillings disclosed a layer of dark, impure ferruginous limestone, also dolomitic.

This is considered to be the base of the Trenton group, for the next sample taken at 1,700 feet is gray, slightly calcareous sandstone, becoming lighter-colored, and more nearly pure at 1,740 feet. This evidently represents the Saint Peters sandstone. Here, between 1,740 feet and 2,002 feet there is another gap in the record. As the drill was penetrating the sandstone a roaring sound was heard, and the drillings were washed away by a

strong current of water. The water which had remained at a level of nearly 100 feet below the surface immediately sunk, but after some time returned to nearly the same level as before.

The drillings continued to a depth of 2,002 feet, where the sample discloses a white limestone, slightly dolomitic. It is also very arenaceous, containing nearly half its bulk of irregular grains of pure white translucent quartz. It is probable that this is among the lower members of the Oneota limestone.

Up to this time the flow of impure water found at the top of the Saint Louis had resisted all efforts to check it, and hence, all the water found below was tainted by it. A means was at last devised by which it was entirely checked. The water at the lower level was found to be of good quality, and to have a moderate flow, coming to within 230 feet of the surface.

During the month an average of 12,800 gallons were pumped every twenty-four hours; while during the summer months very much more was used without diminishing the flow.

A careful analysis of the water was made by Mr. Verbeck of the department of chemistry, at Iowa College, the results of which are here given:

	GRAINS
Calcium carbonate	7
Calcium sulphate	41.1
Magnesium sulphate	30
Sodium sulphate	27.34
Sodium chloride	.87
Silica iron and alumina	.7
Total solids at 120°C	120.75
Hardness in degree	44

The water is universally liked and very generally used. No bad effects from its use have been noticed.