"Quicksand Pockets" in the "Blue Clay" of South Bend. By W. M. Whitten.

The public water supply of South Bend comes from artesian wells driven to a water-bearing gravel 60 to 80 feet below the surface of the St. Joseph River. In this gravel the water is under a pressure sufficient to raise it about 25 feet above the river.

The impervious stratum which confines this water is locally known as blue clay. This deposit is from 13 to 50 feet in thickness, and the territory in which wells can be obtained which flow at approximately the same level, indicates that it is several miles in extent.

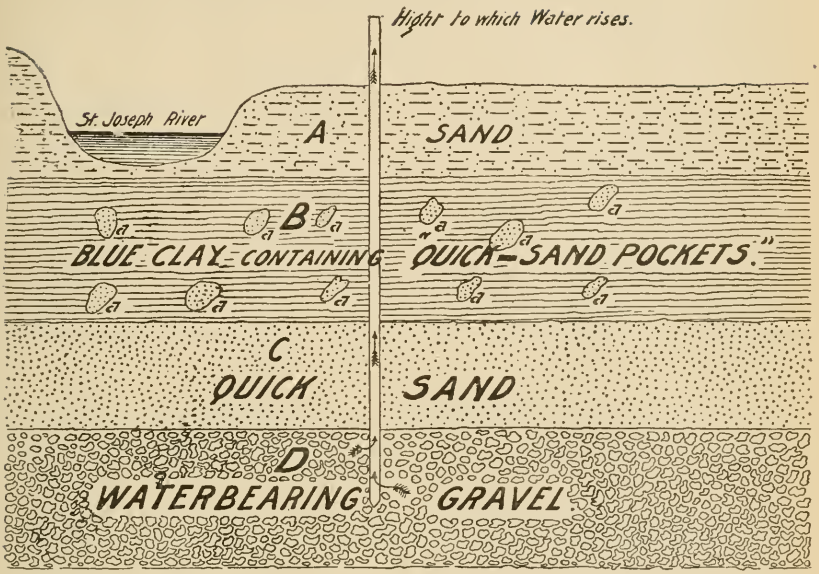
Between the blue clay stratum and the water-bearing gravel is a deposit of what is locally known as quicksand, which varies in depth from 10 to 40 feet.

Throughout the deposit of blue clay, distributed somewhat like boulders in the drift, are numerous masses of the quicksand, which are locally known as "quicksand pockets." These are of all shapes and vary in size from a few cubic inches to many cubic yards.

The record of borings of well No. 21 shows the following strata:

Sand	20 feet.
Blue clay	31 feet.
Quicksand	24 feet.
Gravel	16 feet.

And may be represented by the following:



A—Surface soil sand.
B—Blue clay containing "quicksand pockets."
C—Quicksand.
D—Water-bearing gravel.
a, a, a, a—Quicksand pockets.

Both the clay and quicksand are entirely free from pebbles, so much so that notwithstanding they contain a large percentage of lime (10 to 14 per cent.), the ingredients are so finely pulverized that no damage has ever been known to occur from the formation of quicklime in burning wares made from them. The clay is almost entirely free from grit and the quicksand contains only extremely fine sand. These facts indicate that both have originally been deposited in quiet water. There is, however, no indication of stratification to be found in the clay, but on the contrary the entire deposit (so far as it has been observed) has the appearance of having been greatly disturbed and subjected to a kneading process. Moreover, the presence of these detached masses of quicksand in the body of clay precludes the supposition that the mass as a whole remains as originally deposited.

Chemically the clay and quicksand differ much less than any one acquainted with their characteristics would imagine, as the following analysis shows:*

	Quicksand.	*Blue Clay.*
	Per Cent.	*Per Cent.*
Water and carbonic acid	18.03	17.38
Silica (SiO_2)	49.48	45.89
Lime (CaO)	10.66	13.44
Magnesia (MgO)	7.69	7.67
Alumina (Al_2O_3)	7.80	9.05
Iron oxid (Fe_2O_3)	5.30	5.68
Titanic oxid (TiO_2)	.27	.21
	99.23	99.32

In general appearance, also, the two are quite similar, yet, on close examination, the limits of the "pockets" are easily determined. Within these limits the material is distinctly "quick sand," while without the limits it is as distinctively clay. The clay deposit has been used quite extensively. It makes a fine white or cream-colored building brick, and when vitrified makes a good street paver. It is also used in the manufacture of Portland cement. But manufacturers find that an admixture of the quicksand makes the clay difficult to mold by machinery, prevents the uniform vitrification necessary for good street pavers, and totally destroys its value as an ingredient in the manufacture of Portland cement. These quicksand pockets, therefore, injure the commercial value of the deposit.

The presence of these pockets, filled as they are with material differing from that which immediately surrounds them, but identical with that which underlies the deposit, together with the fact that the clay appears to have undergone much disturbance, suggests the possibility that their contents may have come from the quicksand stratum beneath the clay.

The base of the clay has not been reached by any excavation and, therefore, no opportunity has been afforded to examine the lower portion of the deposit, but at the town of Mishawaka, four miles east of South Bend, I had an opportunity during the past season of observing somewhat similar phenomena. In a sewer trench on Second street, in that town, there appears a deposit of clay from one to four feet thick, overlying

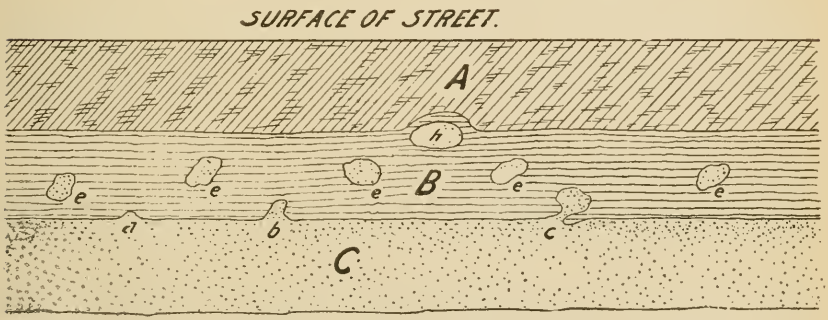
*Analysis by Wm. M. Whitten, Jr., B. S., M. S.

clean sand. Six hundred feet of the trench passed through this formation and in this distance I saw quite a number of masses of sand embodied in the clay, forming "pockets" of sand in this clay deposit very similar to the "quicksand pockets" in the "blue clay" of South Bend.

These masses of sand were compact, and as distinct from the clay as a boulder of granite or limestone would be, and their boundaries were almost as sharply defined.

At the base of the clay there appeared what might be taken for sand pockets in different stages of formation. At one point there was a slight, but distinct upward curve in the clay, which was filled with sand, as at "a" of the following "section." This might be taken as the beginning of a sand "pocket." At another point this was more pronounced, as at "b," and may have been a sand pocket further developed; and at one point there was a mass of sand about one foot in diameter almost completely surrounded with clay, leaving a neck of only two or three inches of sand to connect it with the sand deposit below, as at "c."

SECTION OF SEWER TRENCH ON SECOND STREET, MISHAWAKA.



A—Surface soil, unstratified.
B—Clay deposit containing sand "pockets."
C—Sand, water laid.
a—Sand pocket beginning.
b—Sand pocket further developed.
c—Sand pocket nearly complete.
e, *e*, *e* and *h*—Sand pockets complete.

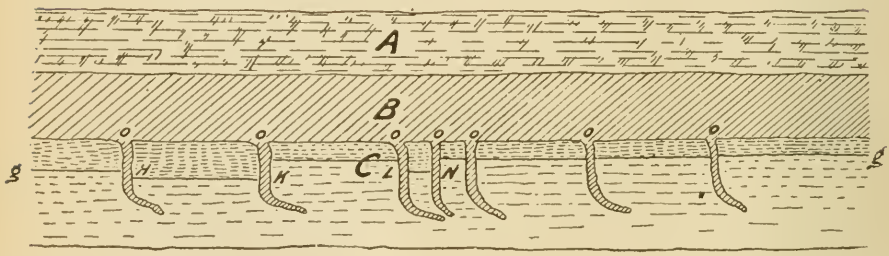
At points where pockets were near the top of the clay there seemed a tendency to raise the clay above the level of the body of that deposit, as at "h."

Soon after the meeting of the Academy the excavation of the trench further east on the same street disclosed another clay deposit in which all the different phases of sand pockets were present and constituted a much larger percentage of the mass.

These facts seem to indicate that these masses of sand have been gathered up from the underlying strata and raised partly or wholly through the clay to the positions in which they were found. If so, the same force might be invoked to fill the "pockets" in the "blue clay" at South Bend with the quicksand underlying that deposit.

It is difficult, however, to conceive of these detached bodies of sand retaining their distinctive character and a compact form while being transferred from the underlying strata to the positions in which they were found, unless they were solidly frozen during the process, for otherwise they would have lost their identity and simply become mixed with the clay. The best explanation of these facts that I can think of is to assume that during a retreat of the ice the sand deposit has been uncovered and solidly frozen, and in that state has been overridden by the re-advancing ice, at the base of which the clay was transported, and that frozen fragments of sand have been detached from the main body of that deposit and raised to the position in which they were found, in the same manner that fragments of rock, over which glaciers move, are said to become detached and raised by the movement of the ice.

Some plausibility is given to the above assumption by a study of the following section of a sewer trench excavated on Leland avenue, South Bend, in 1894. The trench runs north and south:



A—Shows surface soil, sand and gravel.

B—Clay deposit from 1 to 4 feet thick, unstratified.

C—Fine sand, containing distinct horizontal stratifications or markings, *g*, *g*, *g*, *g*, which are faulted at H, K, L and N.

o, *o*, *o*—Are dyke-like masses of clay extending down from the main body of clay into the stratified sand a distance of from 4 to 8 feet.

The dikes crossed the trench about N. 60 degrees E. and S. 60 degrees W. They were from 4 to 12 inches in width and were nearly vertical from the clay down to a depth of 2 or 3 feet, and then curved to the northward more and more as the depth increased. At their junction with the main body the clay was compact and solid, but further down it became lumpy, the lumps having the appearance of having been rolled and rubbed over sand, and intermingled with the lumps was an amount of sand increasing with the depth. The lower portion of the dikes had the appearance of having been filled by dry sand, and the clay lumps dropped in loosely from above.

At the junction of the dikes with the main body of clay the angle on the south side was rounded off while on the north side the angle was sharp, and was less than a right angle and in some cases became quite acute. The line of contact at base of the clay indicated that a rubbing movement had taken place from the north or northwesterly to the south or southeasterly. The lower half of the dikes were so nearly horizontal that they could not have been filled by clay and sand dropping from the top. From the nature of the fine sand it would be impossible to open crevices, or cracks, therein, to be filled with the clay from above, unless the sand were frozen solid. From these facts I conclude that the stratified sand must have been deposited with the horizontal markings continuous across the dikes, where they are now faulted. That in this condition the sand was frozen during an interglacial period, or a temporary retreat of the ice. While so frozen some convulsion opened cracks or fissures in the frozen sand to the depth of the dikes, and probably produced the faults in the horizontal stratification at the same time; that when so opened the fissures were so nearly vertical that clay lumps and sand from the top could drop to the bottom; that while in this condition the sand with its open fissures was overridden by ice, the base of which transported or shoved the clay over the sand, rubbing off particles of clay and sand to fall to the bottom of the crevices until the dikes were formed (and in this connection it may be of interest to state that in the bottom, or toe, of one of these dikes I found well preserved bits of wood).

That after the crevices were filled the sand, protected by ice and clay from the low temperature to which it had been exposed, gradually thawed out from below by the heat of the earth. That the movement of the clay was communicated, to some extent, to the sand beneath it, the

surface moving faster than the lower strata, thus producing the curved position of the dikes and rounded edges on one side and the acute angles on the other side of the dikes, where they join the main body of clay.

I do not recall any "pockets" of sand in the clay in this trench, but at that time I probably should have given little attention to them had they been there, and this may be an instance of "seeing without perceiving," but the facts above stated clearly indicate that frozen sand may be expected to act as other rocks act under like conditions.

No surprise would be occasioned by finding a sandstone boulder raised from its bed and incorporated in the drift clay. The grains of sand may be united as firmly by congealed moisture as by some of the cements that unite the grains of sandstone, and therefore, if it be conceded that frozen sand may be overridden by advancing ice, it is not unreasonable to conclude that masses of the frozen sand might be detached from the main body and raised and incorporated in the drift in the same manner.

The Cady Marsh. By T. H. Ball.

Among the physical features of Lake County, Indiana, of interest to the scientific observer is one known as the Cady Marsh. It covers mainly what are now sections 28, 29 and 30, in township 36, range 8, west, and sections 25, 26, 27, 28, 29 and 30, in range 9, west, also in township 36.

It is now crossed by the Chicago & Erie Railway, and, in part, by the Grand Trunk. Three wagon roads now cross it, and one large ditch, the Hart Ditch, cuts its western expansion.

It was originally, that is, sixty-three years ago, when it was first seen by the white settlers, covered with water. It was considered dangerous for a man to undertake to cross it on horseback.

It lies between two of the great sand ridges of Lake County. These two ridges coming together some five miles from the east line of the county, define its eastern limit, and as the northern ridge runs nearly west into Illinois and the southern passes south of west also into the State of Illinois, the western expansion of this marsh joins with other lowland which on an early map of Indiana was called Lake George. The water in that so-called lake is said to have been from about two to seven feet in depth. This early Lake George has been drained by the great Hart Ditch, which passes from Dyer on the State line, and running a little east of