ON THE FLINTS OF THE CHALK OF YORKSHIRE.

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PART I.

(Read May 4th, 1877.)

In this paper I purpose to show the true distribution of flint in the Chalk of Yorkshire, and to make a few observations of geological interest. A glance at the map will show that the Chalk hills or Wolds of Yorkshire present a crescent-shaped appearance. Their outer margin stands boldly 300 and 600 feet above the Vale of Pickering on the north, and somewhat higher, and equally abrupt, over the plain of York, on the west. The highest point of elevation is found close to Garrowby Hill top, at a height of 808 feet above the sea level.

The beds exhibit numerous local displacements, some of a very violent nature, but the general dip of the whole mass (except a narrow strip on its northern edge, which inclines slightly to the north) appears to be towards a central point in Holderness, in the vicinity of Dunnington and Hornsea. The dip is greatest towards the south and south-east. At the north landing, Flamborough, the dip is from 12 to 14 degrees to south south-east. Southwards from that point it is much less. The northern edge of the Wolds appears to have been partially eaten away and straightened by marine denudation, as shown by reference to the map. With this trifling exception, there is no evidence whatever now existing of Chalk having extended further north in England. The present form of the Wolds seems to suggest that they are an accumulation by animal secretion, after the manner of an Atol or circular reef, probably one of a chain, rather than the fragment of a vast sheet of Cretaceous mud deposited in deep water.

The Chalk area may be divided into two distinct portions—

A. Flint-bearing.

B. Non-Flint-bearing.

On the accompanying map, with which I shall illustrate my remarks, the portion covered by lines and small circles denotes the surface area of the Chalk with flints; the portion free from lines denotes the surface area of the Chalk without flints; whilst the narrow zone, shown by broken lines, denotes the area of the gradual blending and dove-tailing of the two kinds of chalk.

FLINT-BEARING.—The flint-bearing portion has an average breadth

of about six miles, except between Flamborough and Filey, where it has been eaten away by the action of the tides, and is only about one mile in width. Its greatest ascertained thickness is about 400 feet, and in the main it lies conformably on beds of grey and marly chalk. These basement beds vary in colour from a dirty grey to a dirty yellow, with lines of nodular secretions in places, and at the base runs into the Red Chalk. They contain no flint, and are found to range from 20 to 80 feet in thickness.

For a full knowledge of the existence of flint throughout the area marked by circles on the map, I am indebted to many kind correspondents and to many personal visits. The most southern point of the flint-bearing beds on the coast is at Silex Bay, opposite the Light-house at Flamborough. Here, at first, flint is very sparingly distributed in small detached nodules, but after passing northwards for about three-quarters of a mile, these increase in size and number, and gradually become associated with nearly horizontal lines and tabular beds, which extend unbroken for considerable distances. These tabular beds increase in importance northwards, and before reaching the north landing at Flamborough are abundant, and in places attain a thickness of six to eight inches. Protruding from one to two feet above the clean-washed Chalk beds, which at most times form the beach at the north landing, are several stump-like portions of large columns of flint, with an admixture of chalk, measuring from 2 to $5\frac{1}{2}$ feet in diameter. These for the most part have a dish-shaped cavity in the centre from 1 to 2 feet in diameter, filled with hard chalk.

On the south side of the landing, low down in the face of the cliff, and in a line with those protruding from the beach, is a specimen almost entire and standing erect. It measures $6\frac{1}{2}$ feet in height and $3\frac{1}{2}$ in diameter. At the top there is exposed for a distance of ten inches on one side a centre core of chalk or chalky flints, 12 inches in diameter, and slightly fluted horizontally. On each side of this specimen, as of all the others, which I have closely observed, there is a bending downwards of the adjacent beds of Chalk, the compression disappearing immediately above and below the specimens. This local dip or bending extends from 4 to 8 feet all round, according to the size of the specimen, and is a very puzzling feature. A little way further round to the south, high up in the cliff, a similar specimen lies apparently on its side, with one end slightly protruding. This specimen seems to have been uprooted previous to its entombment, as quite near are others in a standing position. North-

wards from this point to Speeton, I observed, during a visit last autumn, in the cliff and on the beach, not fewer than thirty specimens, whole or in fragments. A portion of one of these, 8 stones in weight, my man and I (after exploring till a late hour among the huge blocks of chalk thickly scattered on the shore) jointly carried up the steep and rugged ascent of the cliff to the Speeton Station. This specimen gives a fine horizontal section, and shows numerous zones of flint, alternating with zones of chalk. From Flamborough to Speeton, flint is present in the cliff everywhere, and in all forms.

A similar specimen to these huge Flamborough aggregations I remember observing ten years ago, in a pit at the Painsthorpe Wold, near the N.W. margin of the Chalk. And in a short memorandum made at the time, I curiously described it as a "carrot-shaped mass of flint, spar and chalk, intermingled 8 to 9 feet high, 2 feet in diameter, and standing erect." I do not know of these remarkable formations elsewhere in Yorkshire,* but similar large masses of flint are found in the Chalk of Norfolk and by Sir C. Lyell are called "pot-stones." They also exist in the Chalk near Belfast, and were termed by Dr. Buckland "Paramoudra."

Proceeding westwards along the north boundary of the Chalk range, flint is distributed everywhere, either in tabular layers or in beds formed of nodular masses, much resembling a pavement of irregularly sized boulders, or in horizontal lines of detached nodules, and always accompanied with a few lumps of various sizes scattered broadcast in the mass. The same section often presents the whole of these forms. From base to summit, these different forms and arrangements of the silica in the Chalk are observed; yet no two sections, even of the same horizon, present exactly the same appearance, and the variation is sometimes considerable, even in a limited area, as a few extracts from my note book will suffice to show.

1st. At the foot of the Chalk range opposite Speeton and Reighton are large masses of flint of various forms.

2nd. A pit on the high ground just to the south of Reighton exposes several thick tabular beds, each consisting of several thin layers of flint, much mixed with chalk, lying one upon another, but not united, *i.e.*, parted by films of fuller's-earth or a little chalk.

* Since writing the above, I discovered, August 15th, 1876, a similar specimen protruding from the face of a large chalk pit at the south end of Thixendale. It consisted of flint mixed with flinty chalk, and measured 6 feet high, 3 feet in diameter near the bottom and 4 feet near the top. Its bottom was rounded in the form of the underside of an hemispherical dish or bowl.

One of these compound beds measured in several places from 9 to 10 inches in thickness.

3rd. At the lime-kilns, about a mile away from the last mentioned pit, on the road to Hurmanby, the silica assumes the form of nodules only, either arranged in horizontal lines or distributed at random through the Chalk. They are of all sizes and shapes, the larger having commonly several pointed branches shooting out in various directions.

4th. Passing onwards to the foot of the Wolds, within half-a-mile of Muston, a large pit shows two beds, each about 9 inches in thickness, and seven others from 1 to 3 inches in thickness. In addition to these are several somewhat round and flat nodules and many-pointed oddly-shaped lumps, some distributed in horizontal lines and others scattered at random in the Chalk. Under the lower thick bed above-mentioned, in places extending a distance of several yards, is a thin bed of banded flint separated from the thick bed above by a little fuller's-earth, and in some places by a little chalk, varying from one-eighth to three inches in thickness. From here, along the foot of the Wolds, close to the south of Folkton and Flixton, flint exists in abundance.

5th.—Further westwards, in a large pit, about one mile S.E. of Wharram-le-Street, and in another pit on the west brow of Acklam Wold, the flint is rather sparingly distributed in detached nodules of every form, and varying in size from a pea to a large pumpkin. Here, as in some other places, the flints are coated with a leathery-looking skin or substance, whilst the interior is mostly of a light colour, and more or less variegated.

6th.—A pit close to the village of Bainton exposes the Chalk to a depth of 30 feet, midway through which runs one horizontal bed of small detached nodules of flint. There is here an almost vertical fissure, varying from two to five inches in width, extending from top to bottom of the pit. The portion below the horizontal flint-bed above-mentioned, is charged with detached nodules, resembling those in the horizontal bed itself; but above this bed the fissure is filled with crumbled and disintegrated chalk, without the slightest trace of flint. These oblique veins of flint are of rare occurrence in the Chalk of Yorkshire. I only know of three other examples—one at Fimber, one at Fridaythorpe, and one at Silex Bay, all of which are of small extent.

I need only mention further that at Bishop Burton, Cherry Burton, Etton, Blue Pits, Little Weighton and Hessle (which last is the southern limit of the Yorkshire Chalk), flint exists in all the forms

which I have named, and in great abundance. Along the west boundary a similar development of flint may be noted. Seams of flint, made up of knotty projections, are in some places very irregular in form, and at short distances vary from 2 to 20 inches in thickness.

For a knowledge of the existence or non-existence of flint in a portion of the Chalk area which lies beneath the Glacial Drift of Holderness, I am indebted to Mr. Villiers, of Beverley, who has kindly given me a list of borings made under his supervision. The cross shading on the map in the neighbourhood of Hull mark the site where flint is found. "At Beverley Parks," he says, "at Cottingham, Hull town, and Hull Gaol, Hessle Road, and St. John's Wood (Hull), beds of flint are found 3 to 4 feet apart. At Molescroft the beds are very thin." He adds, "In the neighbourhood of Hull the flint is met with as soon as the Chalk is reached, in beds about two inches in thickness, and some distance apart; but in passing downwards, these beds increase in number; and at a depth of 150 feet in the Chalk, they are 6 inches or more in thickness. Below this level the flint-beds diminish in importance, and at a depth of 300 to 400 feet they are very thin and far between." At Marfleet, about one mile to the east of Hull, the flint runs out." He has not observed flint in any other part of Holderness.

THE FLINTLESS CHALK rises from beneath the Tertiary and Post-Tertiary beds of Holderness, and acquires a considerable width at its northern limits, as is shown on the map, but in coming southwards its surface area narrows considerably. It underlies the whole of Holderness. At Dunnington it is met with at a depth of 120 feet beneath the surface. At Hornsea-Burton near the sea, at 139 feet; at Hornsea town at 108 feet. At the last-mentioned place it has been bored completely through, and its ascertained thickness at this spot is 800 feet, resting on blue clay or shale. Here, as in all other borings in Holderness (except the few in the immediate neighbourhood of Hull), *no flint* has been observed.

The structural characteristics of the Flintless Chalk may be best observed in the fine coast section, commencing about one mile to the north of Bridlington Quay, and extending to Silex Bay, opposite to the lighthouse of Flamborough. On Sept. 30th, 1874, Dr. Wood, Mr. Sterricker, and myself, walked along the beach, and closely examined the face of the cliff between these points, without finding any trace of flint, with the single exception of one solitary lump of cherty flint, found in the midst of a closely-packed accumulation of broken-up *Inoceramus*, *Ostrea* and other shells,

situated about a quarter of a mile S.W. of the south end of Danes Dyke. Near the south landing, Flamborough, I noticed, in a limited area, several similar accumulations of broken shells, cemented together with chalky matter, but without the cherty substance. These heaps appear to be from 2 to 4 feet in diameter, and from 2 to 6 inches in thickness. They are at a height of 6 or 8 feet from the base of the cliff. A close inspection would probably result in the discovery of others at various elevations. I am of opinion that these nests of crushed shells may possibly be the ejectamenta of shell-crushing Cestracions of the Cretaceous Sea, and if so, mark their frequent lairs as clearly as the old "Kjokken-möddings," or shell-mounds, mark the site of primitive Danish and other settlements. We also observed an unusually large amount of Iron Pyrites, especially in the north-eastern half of the above-named section, which has in part gathered round sponges and other organic remains, and in part occupied the spaces left by their decay.

It is now quite obvious that this very thick mass of Flintless Chalk, which forms the substratum of the whole of the Holderness basin, and which rises to the surface at its northern and western margins, must be either, 1st, posterior to, or, 2nd, contemporaneous with the thick flint-bearing beds by which it is fringed, and with which it gradually intermingles through the area shown on the map by the narrow irregular strip of blended colours. If posterior, it is quite the reverse of the order of deposit observed in the Chalk of the South of England, though I believe almost identical with that assigned to the Chalk formation in Ireland. If contemporaneous, there is to my knowledge no mention of a parallel case in England.

Separating, as I have before intimated, the Chalk with much flint, from the Chalk without any flint, is an area varying from 1 to 3 miles in width where the two kinds dovetail, and are gradually incorporated with each other.

Proceeding northwards from the most southern point of this area, and exploring the pits along its course, we find, at first, that in an extensive pit at the Victoria Works on Beverley Westwood, 150 feet above the sea level, or Ordnance datum line, and in a bore at Beverley town, reaching 72 feet below the sea level, no trace of flint exists; but at the Grand Stand, on the N.W. margin of Westwood, and at Park House moat, $1\frac{1}{2}$ miles further north, 130 feet and 75 feet respectively above the sea level, flint is sparingly distributed in scattered lumps. Whilst at Bishop Burton and

Cherry Burton, $1\frac{1}{2}$ miles to the west, and 150 feet above the sea level, flint abounds.

In a pit just to the south of Bainton, at an elevation of 127 feet, flint is observed, though in comparatively small quantity; whilst in a pit one mile to the east, in a line with Burn Butts, only 7 feet lower than the last-mentioned pit, it has entirely disappeared. About one mile north of Bainton is a pit (174 feet) containing a small proportion of flint, whilst, again, about one mile to the east, a pit (150 feet) is quite free from flint.

Further north, and on the east side of Tibthorpe Wold Farm, adjoining the Beverley Road, is a pit (225 feet) containing a medium quantity of flint; whilst this time, considerably to the west and N.W., in a pit (225 feet), just to the east of Gameslack Farm-house, and in another (487 feet) a little south of Life Hill, no flint is found. But only half a mile to N.W. of these points, at elevations ranging from 225 feet to 500 feet above the "datum line," flint is tolerably abundant everywhere.

At Cowlam and Weaverthorpe Pasture, 500 feet to 525 feet above the sea, flint is sparingly and irregularly distributed. To the south and S.E. of these points no flint has been observed, except when deepening a well at Langtoft during the autumn of 1874, when it was met with at a point only 100 feet above the sea level. At Kilham, a little further S.E., several borings were made, during the dry summer and autumn of the above year, to within 25 feet of the sea level, without touching any flint.

In a large pit close to Weaverthorpe, on the road to Butterwick, the beds of Chalk and flint stand on edge, and trend nearly east and west; but in another extensive pit by the roadside, half a mile further east, the strata are nearly horizontal. Both pits contain a medium proportion of flint. South of this place the flint soon disappears. At the north end of the village of Foxholes the strata are much folded, showing short steep inclinations (much resembling those sharply curved strata in the cliff at Bempton, and of which it is probably a continuance), alternating north and south. Here flint is found in broken beds and in detached nodules. South, again, the flint soon disappears.

At Fordon, in the valley near the church (226 feet), and also a quarter of a mile south, on the brow of the hill (350 feet), flint is found in tabular beds and in detached nodules. From here it rapidly diminishes, and about one mile south of Fordon, and a quarter of a mile north of Wold Newton, a large pit, giving a section over 40 feet in elevation, shows no trace of flint.

In the railway cutting one mile south of Hurmanby Station, at an elevation of 250 feet, flint abounds, whilst at Caddy Barf Barn, in a pit by the railway (225 feet), one mile further south, there is no flint; but half a mile east it is again found in abundance, at elevations ranging from 300 feet to 400 feet. Proceeding along the railway towards Bridlington, 275 feet to 300 feet above the sea level, no flint is found, either in the cutting or in the pits in the adjoining fields; but half a mile to the east at Speeton Bampton, and on to Flamborough, in pits ranging from 300 feet to 400 feet above the sea level, flint is found in great quantity. From the north landing, Flamborough to Silex Bay, flint rapidly diminishes, and in the same beds of Chalk—which are here nearly horizontal—a little further south ceases altogether.

After a careful inspection of numerous pits along the connecting margins of the two Chalk areas, I am persuaded, much against previous impressions, that the flint-bearing and non-flint-bearing Chalk areas are in the main contemporaneous in Yorkshire, and that the diminution and final running out of the flint takes place, all along the inner margin of the area shown on the map by small circles, in a horizontal direction, there being no trace of an overlying; but in some places only the flint extends further inwards in the lower beds of Chalk than in the upper. This oblique termination is not clearly visible in the coast section.

Now, that a rim of flint-bearing Chalk should encircle an area of non-flint-bearing Chalk is a geological puzzle, which becomes infinitely more perplexing when we find, from a series of careful analyses, that this Chalk without flint contains as much as 4·28 per cent. of silica, whilst the Chalk with flint contains only 2·12 per cent. Why this silica should so form into flint in one portion of the Chalk and not in another, and what are the conditions which induce this disseminated silica to thus aggregate, are questions of deep scientific interest, to be solved, apparently, by the chemist only.

PART II.

(*Abstract*).

In the second portion of the paper the author recapitulates the conclusions of the first portion, and expresses his intention of speculating upon the facts therein recorded.

1st. As to the relative age of the flint.

2nd. As to its mode of formation, and the cause of its numerous shapes.

A. In disposing of the first proposition it is necessary to show whether the formation of flint is, or is not, contemporaneous with the chalk beds in which it is found, and with which, when bedded, it is (with rare exceptions) conformable. He concludes that both the tabular layers and the more isolated forms are not, like the thin seams of fuller's earth, of the same age as the chalk—*i.e.*, the silicification is subsequent.

B. In dealing with the second proposition he adduces certain forms most distinguishable, *viz.* :—

1. Casts of interiors.
2. Forms due to the growth and decay of submarine plants.
3. Casts from cavities left by various fungiform and other fucoidal masses.

He also notices a bark-like covering, which may be the remains of the skin of the fucoid, and concludes that the horizontal beds and tabular masses of flint are the filled-in hollows left by the decomposition and dissolution of large sheets of fucoids. These mark periods of excessive growth, after which they were covered up with chalk mud, then decayed away, and were after a time replaced in form and outline by silica.

C. This is effected by infiltration, the result of the collection of silica from the general mass of chalk. The segregation of the molecules of silica proceeds till "arrested by cavities left by the wasting away of animal or vegetable tissues, and there held in chemical union with kindred molecules left by these decaying organisms." This, however, only takes place under certain conditions; for, if the process were constantly going on, we should have the greatest accumulations of flint in the very lowest beds of the Chalk, which is by no means the case always. Before this process or action is set up, the molecules of silica and lime carbonate throughout the Chalk, are only in mechanical union, as is the case with these same substances in the interbedded fuller's earth. But under certain conditions, which the author does not venture to suggest, a more intimate union between the molecules of silica is effected, and flint thus formed.

D. *Peculiarities of flint.*—Veins of flint, though very rare, bear out the infiltration theory—Bainton vein.

Banded flint due in a great measure to the replacing of decaying tissues of animal or vegetable bodies—the tissue arrangement only visible where the silica is variably charged with colouring matter.

Flint a pseudomorph after organic forms, and not after amor-

phous carbonate of lime, or other inorganic substances. Alluding to the interception of shells, ventriculites, and all kinds of minute organisms in flint, he explains it by such bodies having settled and become enveloped in the growing fucoid.

E. Where the flint-bearing area merges into the non-flint-bearing the calcareo-siliceous masses are more numerous than those of pure flint, ranging from 20-80 per cent. silica. In addition we find nearly pure lime carbonate taking every form of flint throughout the flint-bearing as well as the non-flint-bearing Chalk. The subtraction of a portion of the silica for the formation of flint explains the difference between the 2 and the 4 per cent. silica in the respective chalks; that in the flintless portion remaining in the same condition as when originally supplied to the accumulating sediment.

But this non-aggregation of silica in the flintless Chalk is not due to the want of forms, the results of the decay of animal and vegetable substances, as sections will disclose shapes resembling every form of flint, including even banded specimens. These forms, like the flints, are due to casts from cavities left by the destruction of organic substances.

Some of these, like the flints previously mentioned, are coated with a brown leathery substance, which the author considers to be the remains of the cuticle; this leathery coating defines the true shape and size of the body.

Since writing the above, the author has read Professor Rupert Jones' paper on "Quartz, Chalcedony, Agate, Flint, Chert, Jasper, and other forms of Silica Geologically Considered." The leading theory propounded he has a difficulty in believing; and considers it should be shown how amorphous lime carbonate can be replaced by silica, whilst calcite and arragorite are not. Also that the whereabouts of the displaced chalk should be accounted for. In the Speeton section of 350ft. the flint is equal to 24ft. vertical.

The direct infiltration into susceptible cavities, formed by organic decay, is the more simple explanation.

In fact, this simple and everyday process of nature is not only designed to explain the formation of flint and other aggregations of silica, but of nearly every size, form, and peculiarity of nodular or amorphous mass, in every aqueous deposit, from the dawn of plant and animal life to the present epoch.