On the manner of occurrence of Beekite and its bearing upon the origin of Siliceous Beds of Palæozoic Age.

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IN the New Red brecciated conglomerate of the coast of South Devon there are numerous fragments of Devonian limestone, on the weathered exterior of some of which botryoidal and concentric chalcedony is commonly found. There does not seem to be anything in the nature of the material to call for a new name from a mineralogical point of view; but, as the chalcedonic shells to be described are peculiar in their mode of occurrence and form and are locally called Beekites, and the mineral is commonly spoken of as Beekite, after Dr. Beek, Dean of Bristol, who first called attention to it, I will use the word where convenient.

The subject is not new; but I approach it from a different point of view from that of previous writers, and offer what seem to me to be some important corrections as to matters of fact.

Kenngott, in the *Sitzungsberichte Wien. Akad.* Vol. X. 1853, p. 292, under Beekit, refers to Dufrénoy, Vol. III. p. 750.

Dufrénoy, Vol. IV. p. 694, under Beckite, refers to Kenngott, who speaks of the "so-called Beckit" in the *Mineralogische Forschungen*, 1853, p. 102.

Pengelly described it, *Trans. Geol. Soc. Cornwall*, Vol. III. 1847-60, p. 309, and before the Brit. Assoc. at Cheltenham, 1856, *Rept. Proc.* Sects., p. 74.

Kesteven again called attention to the Beekites in a letter to the *Athenæum*, Aug. 27th, 1859.

They are described (*sub voc.*) in Bristow's *Glossary of Mineralogy*, 1861.

Daubrée, in *Les Regions invisibles du Globe et des Espaces célestes, &c.*, Paris, 1888, p. 63, gives a figure of a Gryphæa with Beekite.

Prof. Church investigated their chemical and physical relations and explained the results of his experiments and observations in an article in the *Phil. Mag.* Ser. IV. Vol. 23, p. 95.

This paper is referred to in the short notice of Beekite in the *System of Mineralogy*, 1872, by Dana, who follows the spelling of Dufrénoy and Kenngott.

Prof. Church comments upon the views of Pengelly and of an Exeter correspondent, Mr. Vicary, who all suppose that in one way or another, and at one time or another, the chalcedony was deposited upon the corroded exterior of the calcareous organisms, or more rarely on fragments of limestone. He gives a letter from Dr. Gladstone, in which he remarks upon the difficulty of explaining how, if the silicification of say a coral begins all round the outside, it can advance into the interior, and how the carbonate of lime within can be removed.

Prof. Church quotes an analysis given by Kesteven, which shows a most unlikely percentage of 45 per cent. of carbonate of lime; and then gives a more careful analysis of his own, describing the precautions taken, in which the percentage is reduced to 3 per cent., and explains the chemical process by which he infers the Beekites were formed.

These Beekites occur commonly in the New Red, along the coast south of Torquay, so that there is abundant opportunity of observing their mode of occurrence and varieties of structure.

In the decomposed parts of the conglomerate where water has freely percolated, the limestone has often disappeared altogether, and it is there that the Beekites which are most prized are found. These are chalcedonic shells, from which the calcareous portion has been dissolved, so that the earthy residuum inside rattles when shaken, and which are so thin that they will float in water. When, however, I followed the bed in which they occurred to where the limestone fragments were not decomposed, no Beekite whatever appeared in the solid rock, or on a newly broken face. If it was seen on any included fragment here, it was on the upper side only, which was exposed to the action of the surface water, or down by the sea on the side washed by the spray. It was not probable that chalcedony could have been thrown down in such circumstances since these pebbles were exposed to the action of surface water, and so I sought some other explanation, and made a collection of specimens in all stages of development, in the course of which investigation I noticed that the tubercles of Beekite stood out from the surface only so far as the limestone pebble had originally extended.

Thus it was suggested that the Beekite was formed *just within* the limestone fragments, and that it was only developed and brought to light by the removal of a thin, irregular outside film or shell of rock which had not been silicified.

In order to put this to the test of experiment, I broke some of the solid fragments, and found that a band near to, but not quite touching the exterior of the pebble was replaced by silica, and slices of this portion showed under the microscope the concentric arrangement of the chalcedony. Also when pebbles which had previously shown no trace of Beekite were left for a short time in dilute hydrochloric acid, the botryoidal Beekite was developed on the surface. This explains why analyses of the exterior of such a fragment would show a high percentage of carbonate of lime unless precautions were taken for the removal of the covering layer of limestone.

The Beekite is, therefore, clearly only a chalcedonic chert formed by replacement at some unknown time, and under conditions not yet ascertained, a little way below the surface of pebbles and angular fragments of limestone in the New Red conglomerate, but generally extending to no great depth into the limestone fragment, so that when the calcareous portion has been weathered away, the siliceous part remains as a hollow shell.

The solution is probably carried on and the replacement continued by water entering through holes, such as are seen in many agates and some Beekites.

A similar formation has been observed in other deposits, and specimens are exhibited from the Carboniferous and Cretaceous rocks.

Many of the fossils are replaced by silica, and seem often to have furnished a way for the solution to penetrate more easily into the interior of the fragment; but the usual description that the Beekite was deposited on, or is pseudomorphous after corals and other fossils, is not correct, nor does it appear even to have always preferred the calcareous organic remains; but the silica seems to have replaced parts of the limestone fragments included in the conglomerate, whether they contained fossils or not.

This may be well seen in some of the specimens exhibited, especially that containing the crumpled Stromatopora.

Perhaps further observations may show that the character of the original calcareous organism may have affected it, as, for instance, in the case of shells; seeing that it makes much difference in their mode of fossilisation whether they consisted of calcite or aragonite.

It sometimes appears as if the Beekite had more readily replaced the matrix than the fossil, and, as it thus surrounded the organism, when the calcareous part was weathered away, the Beekite would in such cases seem to have been deposited upon the organism.

The only influencing condition seemed to be the presence of a greater or smaller quantity of organic matter disseminated through the limestone; for I observed that it was more apt to occur in the fragments of bituminous limestone than in those of the more altered and crystalline rock. This difference in the amount of organic matter in the limestone fragments included in the conglomerate was suggested also by the very different effect produced by different fragments on the matrix of the conglomerate, the red colour of which was in some cases discharged for one or two inches round the pebble, while in others, on the contrary, the colouring matter of the surrounding red rock remained, and the limestone pebble itself was stained by it. But this organic matter was not the animal matter of the coral or other fossil which might be seen there now, as I have shown that the Beekite did not generally follow the organism. The bituminous limestones form great masses in the Devonian of the surrounding district, and so do the whiter more crystalline rocks. The fragments are evidently derived, some from one, some from the other beds of limestone. So we must seek the source of the bituminous matter in some circumstances of wider extent than any small organism of which a portion may happen to be preserved in the limestone fragments we are examining.

The original joints of the limestone are often picked out by the interruption of the replacing mineral in such a manner as to have suggested that the fragments had been broken and the parts relatively shifted since the formation of the Beekite; but this appearance is often delusive, and really due to the previous displacement of the parts most susceptible of the subsequent metasomatosis.

The conglomerates contain also *débris* of granite, with soda and potash felspars decomposing—an important point to bear in mind when we are inquiring into the mode of transport of silica in solution in deep-seated rocks.

The point that appears to have struck all the earlier observers most is the occurrence of the Beekite in concentric rings—Pengelly and Kesteven relying upon the uneven surface of the Beekite in support of their view that they were silicified *in situ*, that is to say, that fragments had not been rolled since silicification took place, while Prof. Church's Exeter correspondent compares them to tubercular or botryoidal chalcedony with the tops of the mammillations rubbed off. But the angular character of many of the limestone fragments in this conglomerate shows that they have not been much rolled, as the calcareous portions would have been worn sooner than the siliceous had they been exposed to shore action; which is not the case.

In considering the above suggestions, I would point out further that there is no banding of the Beekites from exterior to centre, as in the case of many rocks stained from joints *in situ*, or of included pebbles.

Nor is there any grouping of spherules, as in the concretions of the Magnesian Limestone.

The Beekite occurs in annular masses concentric to a small initial tubercle, the concentric rings lying in planes parallel to and just below the surface of the fragment.

The rings are not sections of globular masses; but on exposure to the weather or treatment with acid, annular portions, complete as originally formed, are found arranged in the same plane round the central tubercle.

As these interrupted annular portions occur near to the surface of the fragment and at a uniform depth from it, it is clear that the interruption of continuity is not due to the arresting of infiltration by the previously thrown down silica, as might be suggested if there had been a succession of shells of chalcedony with intermediate limestone from the surface towards the centre of the fragment.

It must, therefore, have something to do with the using up of the material found in the limestone. When the tubercle was formed, that which had an affinity for it or its solvent was used up within available distance, and no more silica was thrown down till a considerable distance had been reached, beyond which the process was repeated.

I will not venture to offer any more exact explanation.

Where did the silica come from? Its course will surely some day be traced.

There is no similar cementing of the conglomerate; and this formation of Beekite has taken place in the body of the included limestone fragments only.

What, then, were the possible conditions under which in a conglomerate with a siliceous sandy matrix cemented by carbonate of lime, the marginal portion of some of the included fragments could be replaced by silica, so that the actual outside film should be limestone, but the next layer to a thickness of ⅛ in. to ¼ in. should consist of concentric rings of chalcedonic chert?

Had beds of limestone existed there, in the New-Red, would they not have been wholly or partly replaced by silica in the same manner, and bands of chert or jasper have been formed?

There are many rocks of considerable extent and thickness, the whole of which are known to be, as far as their mineralogical and chemical composition are concerned, almost entirely of secondary origin, *i.e.* due to metasomatosis. The number of these is being continually increased, and suspicions hang round many more, with regard to which proof is yet deficient. Among these rocks the more or less purely siliceous formations are at any rate not the least conspicuous: beginning with the obvious flints and flint-bands of the chalk, with regard to which, that which was a controverted point between Bowerbank, Toulmin Smith and others long ago, is now pretty well settled, and the flint is allowed to be due to replacement of part of the chalk, which might or might not be limited by, or which might not even contain a complete organism. A difference of temperature in the water which held the silica in solution as the chalk was depressed within higher or lower subterranean isotherms, or sunk to depths when the increased pressure allowed the water to hold more carbonic acid to act upon silicates; or the oscillation between levels of recurring saturation of the mass by water; or the arresting of change at the level of constant saturation,—all these would be potent if not sufficient causes by reference to which we can get over some difficulties in the distribution and mode of occurrence of both tuberous and tabular flint. But in the case of the platy flint, which has replaced the chalk along either side of nearly vertical joints, we have to bear in mind that jointing due to shrinkage is a structure which must have been produced after the elevation of the chalk from the levels of saturation; and, except on the hypothesis of a second period of depression, we must accept a limit of depth for the age of the formation of platy joint flint, or attach no great importance to the causes connected with increment of temperature and increased pressure mentioned above.

So, in the still older carboniferous rocks, the origin of the chert of the Millstone Grit has given rise to some difference of opinion; but, for the purpose of our present inquiry, it matters not whether it has been derived wholly from the siliceous spicules of sponges which grew on the spot, or has been carried by infiltering water from quite different parts of the mass; there seems little doubt that where we find it, and as we find it, it mostly has been in solution, and has gathered round whatever siliceous grain or spicule might be there to form a nucleus, or has been precipitated in whatever interstitial portion of the gritty rock it could in favourable circumstances find a resting-place.

I have long thought that the bands of jasper and jaspery rock (not the Lydian stone) which occur in the carboniferous and Greywacke rocks have had a similar origin, being limestones changed by replacement into siliceous rocks.

The rarity of limestones throughout great masses of deposit formed during a period when life was abundant calls for some explanation; and it may be that the metasomatosis which we observe in newer formations, partially replacing the carbonate of lime by silica, may have been carried still further in the older rocks. In the case of very earthy and impure limestones, there would not be so much to suggest that such a change had taken place. There would be only a more siliceous band here and there in the midst of more aluminous slates and shales.