

Kilkenny, Ireland (Irish Acad. Trans. 1871). On *Stagonolepis Robertsoni*, etc. (Q.J.G.S. 1875). On the evidence as to the Origin of existing Vertebrate Animals (lectures, *Nature*, 1876). The Rise and Progress of Palæontology (*Nature*, No. 24, 1881). The Coming-of-age of the "Origin of Species" (1880, Roy. Inst. Proc. 9, 1882).—It will be seen that Professor Huxley was a frequent contributor to the pages of the GEOLOGICAL MAGAZINE, and was one of its constant supporters since its commencement in 1864.

His last paper to the Geological Society was "Further Observations upon *Hyperodapedon Gordoni*," read May 11, 1887: see Q.J.G.S., vol. xliii, p. 675, pls. xxvi and xxvii. His latest work (published in conjunction with Dr. Pelsener) is on *Spirula* ("Challenger" Reports), 1895.

"Four kings laboured to build a mighty hall, the Hall of a Hundred Columns, at Karnak. In a century they built it, and they died; but the hall remains. Four men [Darwin, Tyndall, Huxley, Spencer], more than all others, have raised up within this century an edifice which is the crowning glory of British science; and before the century closes three of them are dead. But the edifice stands, and will stand, as a lasting monument to the power of truth and fearless investigation."—*Pall Mall Gazette*.

For further details see also "Men and Women of the Time," *The Times*, *Athenæum*, *The Standard*, *Daily Chronicle*, *Daily News*, etc., July 1st. H. W.

ORIGINAL ARTICLES.

I.—PITTED PEBBLES IN THE BUNTER CONGLOMERATE OF CANNOCK CHASE.

By T. MELLARD READE, C.E., F.G.S., F.R.I.B.A.

(PLATE XI.)

IN a letter to this MAGAZINE of May, 1895, headed "The Indentation of the Bunter Pebbles," Mr. W. S. Gresley criticizes the summing-up of my views, given in the 'Annals of British Geology' (1892, p. 52), that "The indentation of the pebbles he considers to be the result of contact-solution, the water being retained at these spots by capillary attraction." It would have been more satisfactory if Mr. Gresley could have read my original paper¹ before penning his letter, as he would then not have assumed that I "adduce no evidence in support of the chemical theory."

Perhaps I may be permitted in the pages of this Journal to re-state, and if necessary expand, my reasons for thinking that the "indentations" were not mechanically impressed, as the term rather assumes, but were simply due to solution at the points of contact. In the absence of specimens of the pebbles themselves, to thoroughly understand the question a good photograph is required, and this I have endeavoured to supply, so that my statements can be literally followed.

These are my points—

First.—If the pittings or depressions were due to mechanical pressure, the material of the pebble which was "indented" would

¹ The Trias of Cannock Chase, Proc. Liverpool Geol. Soc., Session 1891-2.

show signs of distortion. This it never does in any of the examples I have examined. A reference to the photograph will show this clearly; the depressions are perfectly sharp at the edges, and the pebble retains its external shape. The material formerly occupying the depression has been *removed*, not displaced.

Second.—The pebble that is “indented” is often harder than the pebble which indents. The “indenting” pebble is never distorted, but is frequently fractured.

Third.—Out of six indented pebbles now before me, separately collected by myself, Mr. Henry Beasley, and Mr. Edmund Dickson, when our observations were made at Cannock Chase in 1891, only one shows signs of fracture—this is *b* shown in the photograph. It is quite evident that the “fractures” are simply joints, such as may be found in many pebbles, having no indentations upon them. This pebble is a purple ferruginous sandstone or grit, almost as hard as quartzite, but not having a lustrous fracture. The interior of the “indents” is in most cases light grey, the purple colour having been discharged—another evidence of solution. There are also four quartzite pebbles from the Bunter of other localities sent me by Mr. Beasley, one of which, measuring $2\frac{1}{4}'' \times 1\frac{3}{8}''$, has been fractured and recemented by a deposit of silica which closes up about one inch in length of the crack, and is consequently subsequent to it.

Fourth.—Fractures are a sign that the material of the pebble is rigid, and that it cannot be squeezed out of shape. Their existence is to a certain extent evidence against the mechanical theory. I think no geologist will contend that the pebbles have been hardened and indurated since they became pebbles; their smooth worn surfaces show that the rock they were formed from was in the same condition as the pebbles are now.

Fifth.—The indenting pebbles *perfectly fit* the indents of the pebbles. If the indents were the result of mechanical movement this would not be likely to happen in all cases. The “indents” in the ten pebbles before me vary from $1\frac{1}{4}$ inches long by $\frac{3}{4}$ inch in width, shallow and pear-shaped, to circular pits only $\frac{1}{16}$ inch in diameter. They are of all shapes, a saucer-like shape predominating. Some of the pebbles are cemented into their places by a deposit of silica. When the indenting pebbles are removed the cup or depression is seen to be smooth, frequently having a deposit of silica over the surface, sometimes one of carbonate of iron. This deposit of silica in the case of the real quartzites is so hard that a knife will not pierce it.

Sixth.—The pittings are, in the more marked cases before me, principally confined to one side and the edges of the pebbles. The opposite side often has adherent somewhat loosely cemented sand and small pebbles. I take this, which is on the flattest side, to be the bed of the pebbles, and the pitted surface to be the top surface. Why should this be the case on the mechanical assumption? There is not much evidence of lateral pressure in the stratum in which the pebbles occur, and statical pressure one would expect to be equally effective top and bottom.

Seventh.—Let us try what the maximum statical pressure at any time on these Bunter rocks may have been. If we assume that a mile in thickness of rock at one time existed over the Bunter Conglomerate of Cannock Chase, I think it will not be above the mark. At 15 cubic feet to the ton, a column of rock a mile high would give 352 tons to the square foot. The crushing weight of granite cubes is about 720 tons per square foot on the average. Quartzite is harder.¹ If the whole pressure of the column of rock were equally distributed, it would necessarily neither crush nor disturb the quartzite. If, on the other hand, the pressure was increased by being concentrated on certain points, fracture, not distortion, would be the result, from the other parts of the pebble being unsupported. The smaller the indenting pebble the more cogent is this argument.

It is quite remarkable how numerous minute pebbles leave their marks on the very hard sandstones. Pressure applied to them in such a way as to tend to stamp them into the boulder would inevitably crush them, for it is a condition of indentation by pressure that the pressure cannot be applied in a manner to prevent crushing. There seems to be little relation between the hardness of the pebbles and the existence of the indentation. One small pebble, a specially light sandstone showing casts of fossils, has two well-formed pittings in it, and evinces no sign either of fracture or crushing.

Eighth.—But we have positive evidence that at the points of contact of the pebbles solution and deposit have been going on. In most of the depressions there is a deposit of silica which smooths the surface of the depression and unites the grains of rock. In some cases, when a joint or crack traverses the depression, this silica fills it up. The grains of silica, where they are seen in the depression of true quartzite pebbles, show like a mosaic, and appear to be flattened or cut off on their upper surface. I think it extremely probable that solution and deposit have gone on alternately. That solution of the silica has taken place, there is evidence on all hands, including the adherent sand and gravel, for solution must precede deposit. Solvent action would concentrate itself on the continually damp spots, and these are the points of contact of the pebbles, especially on the upper surface of the larger pebbles. The Bunter is a water-bearing rock, and water has a free circulation through it. Referring to the figure given by Mr. Gresley, I would respectfully submit that the branch fractures from the depression are not a proof that the depression was due to the same cause as the fracture. One pebble could not be driven into another without distortion of one or both, as already explained; and the fractures are a proof of the pebble giving way and breaking up without distortion. Also the fractures are not shown to cross the depression or indent. In none of my examples are there any radiating fractures.

¹ Quartz-rock, Holyhead, is given by Mallet as 1641·6 tons per square foot across laminations, and 900 tons parallel to laminations.—Manual of Rocks, Tables, etc., D. K. Clark, p. 631.

The following is an analysis of one of the Cannock Chase pebbles given in my original paper, and made by Mr. P. Holland, F.C.S., a member of the Liverpool Geological Society:—

Analysis of an indented pebble from Stile Cop Gravel Pit, near Rugeley.

Si O ₂	...	...	...	...	...	...	...	...	79.26
Al ₂ O ₃ +Ti O ₂	...	...	...	...	...	...	...	...	9.60
Fe ₂ O ₃	...	...	...	...	...	...	...	...	4.80
Mn O	...	...	...	...	...	...	...	...	0.08
Ca O	...	...	...	...	...	...	...	...	0.22
Mg O	...	...	...	...	...	...	...	...	0.97
K ₂ O	...	...	...	...	...	...	...	...	2.23
Na ₂ O	...	...	...	...	...	...	...	...	0.19
Combined water	...	...	...	...	...	...	...	...	2.79

100.14

As further illustrating solvent action at the points of contact, I may refer to a pebble of hard compact grey limestone (probably Carboniferous), 3 inches in diameter, $1\frac{1}{4}$ inches thick, rounded and disc-like in form, from the Bunter Conglomerate near Wolsley Bridge. There are two well-marked dish-like depressions in the stone respectively 1 inch and $\frac{3}{4}$ inch in diameter, which are coated with a thin deposit of carbonate of lime. There is also a good deal of adherent quartzose sand cemented together with carbonate of lime. Here the pebble is of *limestone*, not quartzite or sandstone; yet the same kind of action has gone on, namely, solution of the limestone at points of contact and re-deposit of the carbonate of lime. There is not the slightest sign of fracture to be seen.

EXPLANATION OF PLATE XI.

FIG. 1.—Photograph of three boulders or pebbles from the Bunter Conglomerate of Cannock Chase.

- a. Very hard, fine close-grained grit, boulder, or pebble, $7\frac{3}{4}$ in. \times 6 in. \times 4 in., well rounded and worn. It is covered with "pittings"; the prominent circular saucer-like depression which shows in this, and more plainly in Fig. 2, is $\frac{5}{8}$ inch across. There is a shallow depression $1\frac{1}{4}$ inches long on the upper part of the pebble which is not seen. These pittings are found as small as $\frac{1}{16}$ inch in diameter, but embedded grains of quartz have been found only $\frac{1}{30}$ inch in diameter. The pebbles, where entirely clear of adherent sand, are quite sharp at the edges, as may be seen on examining the plate with a lens. The surface of the pittings is mostly granular, but in some cases has a deposit of silica upon it. The projections above the general surface of the boulders are either whole pebbles, broken or decayed pebbles, or groups of pebbles with sand between cemented thereto. The cemented sand sometimes makes a rim round the depression. Most of these small pebbles, with which the large one is roughened, are counter-sunk or embedded in the boulder, and if removed would disclose pittings. They are generally very firmly cemented into the depressions with silica, and fit them exactly. The opposite side of the boulder has a good deal of adherent sand and gravel, but not many "pittings," which are principally confined to the surface shown in the photograph and to the edges. (Stile Cop.)
- b. Hard, fine-grained, purple-brown coloured grit boulder, or pebble, full of joint planes, along three of which it has split; these broken joint surfaces are covered with ferric oxide. The "pittings" are very numerous, and are of a lighter colour than the surface of the pebble, which is well water-worn. One of the pittings is canoe-shaped, $1\frac{1}{4}$ inches long by $\frac{1}{4}$ inch wide. There are small pebbles adherent and imbedded; in this and most other respects the description of boulder a applies to boulder b. (Stile Cop.)

- e. Purple-coloured quartzite boulder or pebble, $5\frac{1}{2}$ in. \times $4\frac{1}{2}$ in. \times 3 in., a flattened oval in form, covered with depressions of a less decided type than *a* or *b*. The surface of the depressions are white from a deposit of silica therein. There is only one small adherent bit of gravel. The opposite side to that shown in the photograph has no "pittings," but a good many small adherent patches of sand about $\frac{1}{4}$ inch in diameter, apparently indicating the points of contact of small pebbles or gravel, now removed. There are depressions on the edges. (Stile Cop.)

FIG. 2.—The boulders shown are the same as in Fig. 1, but arranged in a way to get the light from another direction to show up some of the features not properly developed in Fig. 1.

II.—TWO OCCURRENCES OF RADIOLARIANS IN ENGLISH CRETACEOUS ROCKS.

By GEORGE E. GRIMES, B.Sc., A.R.S.M., A.R.C.S., F.G.S.

THE opinion that fossil Radiolarians were entirely limited to Tertiary strata prevailed until a comparatively late period. Prof. Ernst Haeckel, in his monograph on the Radiolaria, published in 1862, says "that the Radiolarians made their appearance for the first time during the Tertiary period"; and Ehrenberg, as late as 1875,¹ defined all the Polycystina-bearing rocks as Tertiary.

For a long time the Cretaceous rocks yielded but few remains of Radiolarians, and even as late as 1885 Dr. Rüst remarked on the poverty of Radiolarian remains in Cretaceous strata.² Since that date, however, chiefly owing to the patient and laborious researches of Dr. Rüst, a large number of species have been obtained from various rocks on the Continent, principally from the Lower Cretaceous.³

Prof. Sollas was the first to notice Radiolaria in the Cretaceous rocks of this country, and in his paper "On Greensand Sponges and Foraminifera"⁴ he says: "Polycystina of various genera also occur; forms resembling *Haliomma* may be noticed of somewhat frequent occurrence." Prof. Sollas promised a full description of these forms later, but I believe it has not yet appeared.⁵

In 1888 Dr. Rüst⁶ described two species—*Dictyomitra anglica* (Rüst) and *Dictyospyris chlamyden* (Rüst)—from flints of Senonian or Turonian age from England; but the locality is not given.

The object of this paper is to describe two fresh occurrences of Radiolaria in our Cretaceous rocks.

One is in the Fuller's Earth Rock Bed in the Lower Greensand, between Redhill and Nutfield, Surrey. This bed lies directly on

¹ Fortsetzung der mikrogeologischen Studien: Abhandl. der k. Akad. der Wissen. Berlin, 1875.

² Beiträge zur Kenntniss der fossilen Radiolarien aus Gesteinen des Sura: Palaeontographica, vol. xxi.

³ Beiträge zur Kenntniss der fossilen Radiolarien aus Gesteinen der Kreide: Palaeontographica, vol. xxxv.

⁴ GEOL. MAG., Vol. X, 1873.

⁵ It should also be mentioned that Dr. Wallich recorded the occurrence of several genera of Radiolaria in the interior of Chalk flints in 1883 (Ann. and Mag. Nat. Hist., July 1883, p. 52).—EDIT. GEOL. MAG.

⁶ Beiträge zur Kenntniss der fossilen Radiolarien aus Gesteinen der Kreide: Palaeontographica, vol. xxxv.