

of iron, probably the carbonate, was dissolved in the water, and precipitated by the carbonate of lime and magnesia as per-hydrate of iron.

In order to test the correctness of this explanation, I passed carbonic acid gas through water containing powdered grit, powdered limestone, and a mixture of the two; and since the stone that was stained was freely exposed to air and light, I was careful that the powders should be exposed in a similar manner. The powders were then allowed to dry and fresh water added. The process was repeated during several months, but in none of the three cases could I find a trace of iron in the liquid.

I am led to ask for a publication of my results, in the hope that some of your readers will suggest some other test experiments which may lead to the true explanation of the method by which the staining is produced.

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LLANDOVERY ROCKS IN THE LAKE DISTRICT.

SIR,—I notice that Mr. Hicks, in his last letter on this subject, is contented to meet his opponents on their own terms, and that he expresses his firm persuasion of the overthrow of their views solely by the evidence afforded by the Brachiopods and Trilobites which have been discovered in the disputed beds within the last few months. It may consequently be suspected that the Graptolites which swarm in these beds, but which have been so slightly alluded to and hurried out of sight, have not a word to say upon the question. I am still, however, inclined to think that a good case can be made out by the aid of the Graptolites alone; and that the view of the Lower Llandovery age of the Coniston Mudstones, grounded upon this opinion, which I have held for some years, and which was strongly insisted upon in a joint-paper on the Coniston Group by Professor Nicholson and myself, read at the Bristol Meeting of the British Association (1875), needs but little extra confirmation.

I presume that most palæontologists are willing to admit that, whether the various genera and species of the Graptolites are of equal systematic value with those of the Brachiopoda and Trilobita or no, they are at least as easily identified by those who have studied them, and that it is tolerably certain that they were correspondingly affected by the conditions which brought about the gradual evolution and extinction of the various forms of the latter groups, whose remains are now found upon the same horizons with them. If so, it is surely highly unphilosophical to refuse to allow full value to those points now known with a close approximation to certainty regarding the presence and range of the Graptolites which all would be willing to grant at once, where the other groups are concerned. Following here, therefore, the usual line of argument adopted when the latter are relied upon as indices of the systematic place of their containing beds, we observe—

Firstly—(a.) The Coniston Mudstones consist of a thin group of shales (black below, and grey or purple above), which reposes upon a limestone containing many of the very highest Bala fossils, and

which yields a very distinct assemblage of Graptolites (about 25 species), a few of which are confined to its lower beds, and a few occur only in its highest zones.

(*b.*) In the neighbouring Silurian district of South Scotland is found a bed of precisely similar lithological character (the Birkhill Shales), black below, and grey, purple and black above. In these shales perhaps every fossil of the Mudstones is represented; and, strange to say, they have a similar vertical distribution; the forms peculiar to the top beds of the Mudstones being also strictly confined to the highest bands of the Scotch deposit. Now these Birkhill Shales are said by the officers of the Scottish Survey to be imbedded in strata of Upper Llandeilo age.

(*c.*) The same beds, with nearly all the same fossils arranged in the same way, are continued into Ireland, where they emerge from below a great thickness of almost barren grits, regarded by the Irish Survey as of Bala age; while the black band itself is said to belong to the Llandeilo.

(*d.*) The characteristic Graptolites of the Mudstones can be collected in abundance in the highly prolific beds of Pomeroy, which yielded to Portlock the magnificent series of Irish fossils figured in his Report, and which have subsequently been looked upon as undoubtedly of Bala age.

(*e.*) The same group of Graptolites occurs in the Kiesel Schiefer of Thuringia—a band of black and grey shales which plunges below the great mass of the Middle Silurian rocks of that district.

(*f.*) Many of the most characteristic species (unmixed with earlier or later forms) swarm in the very lowest band only of Linnarsson's Upper Graptolite Schist of Sweden, which reposes immediately upon calcareous beds with Bala fossils.

Thus, on the assumption that the authoritative correlations made by the Scotch and Irish Surveys are correct, this especial group of Graptolites has hitherto been met with only in strata that (*i.*) underlie the chief mass of the Middle Silurian, (*ii.*) lie immediately above the Bala limestones, (*iii.*) are imbedded in the main Bala series, or (*iv.*) form a portion of the Upper Llandeilo.

Secondly—(*a.*) The Birkhill Shales aforementioned are separated from the true Upper Silurian of Scotland (with Wenlock fossils) by a massive series of rocks (the Gala group), containing many Graptolites, some of which are Coniston Mudstone forms, others peculiar, and others common to the Upper Silurian.

(*b.*) Similar rocks floor the counties of Down, Louth, and Cavan, and repose on the Mudstone equivalents already noticed. They contain also a similar mixture of Birkhill, Gala, and Upper Silurian Graptolites, but nowhere show any clear trace of overlying Upper Silurian strata.

(*c.*) Rocks of the same nature, and of great collective thickness, surmount the Thuringian Kiesel Schiefer, and contain some of the same transitional Graptolites in association with a mixed group of Lower and Upper Silurian Brachiopoda.

(*d.*) The lowest bed of the Upper Graptolitic Schist of Sweden,

containing the chief Mudstone Graptolites, is covered up by a second Graptolitic schist, with transitional forms, and that is followed in turn by a limestone containing a preponderance of Llandovery fossils.

(e.) The Colonies and the Band E. e. 1 (asserted by Salter to be of Llandovery age) of Barrande's Silurian Basin of Bohemia contain an admixture of the Mudstone Graptolites with transitional and Upper Silurian forms; the first-named making up, perhaps, about one-half of the total Graptolitic fauna.

We see, therefore, that the beds containing the typical Coniston Mudstone fauna are followed in Ireland, Scotland, Germany and Sweden, by rocks containing many new forms, and having a general fauna principally composed of an admixture of Lower and Upper Silurian species; and that the transitional and supposed Upper Silurian Graptolite-bearing zone of Bohemia, hitherto looked upon as the equivalent of the Mudstones, and sometimes instanced as proof positive of the possibility of their Upper Silurian age, is, on the contrary, of far more recent date.

Thirdly—(a.) None of the Graptolites of the Mudstones survive into the true Upper Silurians of the succeeding Coniston Flags.¹

(b.) All the corresponding Birkhill fossils have died out before we reach the Upper Silurians of South Scotland.

(c.) Not one of the Graptolites yielded by the Kiesel Schiefer proper of Thuringia occurs in the unequivocal Upper Silurian of the neighbouring district of Bohemia (Band E. e. 2 of Barrande).

(d.) None of the Mudstone Graptolites are met with in the Wenlock or Ludlow beds of Shropshire and Hereford.

The Upper Silurian beds here cited contain Graptolites in great abundance, so that the absence of the Mudstone forms cannot be explained away by reference to non-suitability of habitat or the like; while it must be recollected that the Graptolitic faunas of these widely separated Upper Silurians are practically identical. Hence on any view it is evident that the period of time which intervened between the close of the typical Mudstone epoch and the commencement of that of the true Upper Silurian was sufficiently lengthy to admit of the gradual dying out of all the Mudstone Graptolites and the contemporaneous evolution of their Upper Silurian successors. If this be true, the chief break in the Lake District is not between the Limestones and the Mudstones, but between the latter and the Coniston Flags. In Westmorland we may form some little idea of its magnitude by the marvellous change it wrought upon the Graptolites; and in Scotland and Germany by the thick and far-spreading masses of those Middle Silurian rocks, of which we have little or no trace in the Lake-district itself.

That the Coniston Mudstones are not of Bala age is tolerably clear from their position with reference to the Coniston Limestones; and if Mr. Aveline is right in his opinion that there is a slight physical break between the two groups, this may be regarded as demonstrated. Again, that they are not of Upper Silurian age is placed beyond doubt by the complete absence within them of Upper

¹ With one exception, *M. Hisingeri*, Carr.

Silurian Graptolites; and, finally, the fact that their equivalents are everywhere separated from the equivalents of the Wenlock Rocks by the main mass of the Middle Silurian, leaves us no choice but to assign them to the Lower Llandovery. CHARLES LAPWORTH.

St. ANDREWS, Sept. 9th.

SECTION OF BOULDER-CLAY, NORTH DOCKS, LIVERPOOL.

SIR,—The sections described by Mr. Mackintosh in the September Number of the GEOLOGICAL MAGAZINE are, as he says, well worthy of study. They were visited by the Liverpool Geological Society in June last: at that time the section showing the Lower Boulder-clay of Mr. Mackintosh was well developed. It was simply a clay containing more stones and of a harder nature than usual, separated from the clay above, which is more plastic and free from stones than is generally the case, by a seam of sand and gravel. Several of our members were rejoiced at having at last discovered that for which they had previously for years searched the neighbourhood in vain, viz. the veritable Lower Boulder-clay. I ventured to doubt if the section before us was sufficient evidence to support the tripartite division of the Boulder-clay now in fashion; and I expressed the opinion that the distinction would not be maintained over any considerable area, and that the lower clay was simply a local variation of the upper; in fact, that the deposit was one and the same. A short time since I again visited the Docks, this time in company with Mr. Bristow, Mr. Aveline, and Mr. De Rance. The latter gentleman, who is well acquainted with the excavations, was desirous of showing us a section of some curiously contorted gravels, and took us to the exact site of the previous Lower Boulder-clay section, but—though certainly not to my astonishment—both contorted gravels and Lower Boulder-clay had disappeared. The fact is, the beds are thrown about so irregularly that there is no dependence to be placed on their continuity. A few yards more or less of excavation changes their character so, that what before appeared separate and distinct beds shade into one another by imperceptible gradations, thin out, or, as not uncommonly happens with beds of sand or gravel, stop short off with a square end. My friend Mr. De Rance, if my memory serves me, also expressed the opinion that there was no Lower Boulder-clay in the dock. So far as the Boulder-clay deposits about here affect the question, I have arrived at the mature conviction, after long study, that between the red sand or rock on which they rest and the surface they are an unbroken series of marine deposits, laid down during the subsidence of the land and its subsequent re-elevation, and that for an explanation of the curious manner in which they are bedded we must look to the varying directions of the tidal currents as affected by the degree of submergence at the time, and the contours of the then land.

4, SOUTH JOHN STREET, LIVERPOOL, Sept. 12th. T. MELLARD READE.

ERRATUM.—In Mr. BONNEY's letter, p. 377, lines 30, 31, from top of page, for "therefore it is to be applied," read "it is *not* therefore to be applied."
Dr. OLDHAM begs us to delete, at p. 384, the letters C.B. after his name. We apologize for the error. EDIT. GEOL. MAG.