

Transactions

OF THE

BANFFSHIRE FIELD CLUB.



The support of The Strathmartine Trust toward
this publication is gratefully acknowledged.

www.banffshirefieldclub.org.uk

THE INTERSTITIAL OR CEMENTING SUBSTANCES IN THE ELGIN SANDSTONES.

Mr William Mackie, M.A., M.D., read the following paper on this subject:—

In addition to affording a ready explanation of the process by which beds of originally incoherent sand may be transmuted into masses of solid sandstone, the occurrence of cementing substances in elastic rocks raises many interesting problems regarding the former extension of rock systems over areas far beyond their present limits, as well as regarding the former existence

of formations which have long since vanished, and of which, indeed, these cementing substances now present in other rocks may be the only record. As frequently, I think, they indicate some peculiar chemical condition or state of concentration of the waters of the particular basin in which the sandstones were deposited; while from their effect on weathering they may also give rise to interesting, and, it may be, peculiar illustrations of rock sculpturing under the influence of surface agencies.

On the whole, I think the question of cementing substances in clastic rocks, and the problems they raise, have up to the present not received from geologists the attention they deserve; and the present paper may be taken as a tentative rather than a final attempt to solve some of the questions raised by the grouping of cements observed in the Elgin sandstones.

It would be advantageous, perhaps, to indicate first of all the general nature and character of these cementing substances. I shall then take up their general distribution in the Elgin sandstones, interweaving with the facts just sufficient theory to make those facts intelligible. Then some interesting examples of multiple as well as localised cements will be shortly discussed, and the succession of events of which they seem to be the records as briefly described.

From the accompanying table it will be seen that the cementing substances fall into four classes:—

- I. Hydrated Oxides of Iron=The Ferruginous Group.
- II. Salts of Lime and Magnesia=The Calcareous Group.
 - Carbonate of Lime=Calcite.
 - Sulphate „ =Gypsum.
 - Fluoride „ =Fluorspar (Cumington).
 - (Carbonate of Magnesia and Carb. of Lime=Dolomite).
 - Sulphate of Barium=Barytes (Covesea).
- III. Quartz=Siliceous Cement.
 - (Glaucosite=Ferro-Siliceous) (Ashgrove and Lossiemouth Oolite).
- IV. Hydrated Silicate of Alumina, &c.=Felspathic Cement.

In the Lower Old Red rocks the predominating and most widely distributed cement is, of course, ferric hydroxide. But locally, in addition to the ferric hydroxide, it is all but co-extensive with the Lower Old Red rocks, and it has never, so far as I know, been doubted that it has been deposited on the grains contemporaneously with the deposition of the beds themselves. Its presence must, therefore, point to some condition of the waters of the L.O.R. lake in which they were deposited. The ferruginous, in the form of ferric hydroxide, there occur enormous quantities of carbonate of lime, reaching to as much as 30 per cent. of the entire rock in some of the analyses of L.O.R. sandstone I have made. It is difficult to believe that such quantities of carbonate of lime could have been deposited otherwise than contemporaneously, and in some cases, as for instance over the Orcadian area—with which, however, we are not at present concerned—there is every probability that it was so deposited. But the particularly local distribution of the calcite cement in the Elgin area may, I think, be taken as indicating a different origin. Apart from the case of the Orcadian Old Red, which we have just discounted, the occurrence of calcite is limited to an area in the east of Morayshire and the adjoining parts of Banffshire.

The L.O.R. rocks from the Lossie at Birnie eastwards along Glen Rothes, the slopes of the Brown Muir, and Findlay Seat, in the beds which crop out along both sides of the Spey, along to Tynet, Portgordon, and Buckie, the Old Red rocks are strongly charged with carbonate of lime. To the west the quantity present is either small or it is entirely absent. At Piperhill in Nairnshire occurs the only instance I know of at present of a L.O.R. rock showing rims of secondary quartz around its constituent grains. In the L.O.R. of Inverness-shire, around Foyers, for instance, carbonate of lime is either absent or occurs in very small quantity. The mass of red rocks on the opposite shore of Loch Ness, which pass under the conglomerates of Meal Fourvounie, and which probably for that reason are among the earliest manifestations of the L.O.R. in the north of Scotland, show no calcite in their composition. Further north, at Tara-

dale, I have a record of 6.34 per cent. of carbonate of lime—a quantity not so phenomenally large as to require any particular explanation. In this connection it may also be stated that in some of the larger outliers of the L.O.R. in Aberdeenshire there is practical absence of carbonate of lime.

To pass to the Upper Old Red rocks, it may be remarked that in the beds which immediately succeed the L.O.R. in the Elgin area, the ferruginous cement is widely distributed, and here also the quantity of calcite may be simply phenomenal as at Scaat Craig, where, according to one analysis, it reached 42.45 per cent. It is also present in large quantity at Milton Bræ, to the south-west of Elgin, where the sandstone, from its fossil contents as well as the beautiful rounding of its constituent grains—a condition never yet observed in undoubted L.O.R. rocks—has been shown to belong to the U.O.R. division, and to be of the same age as Scaat Craig. In the rocks on the Findhorn, and again around Nairn, considerable quantities of calcite occur. I note Kingsteps 6.25 per cent., Delnies 13.6 per cent. Higher in the series comes a bed of rough limestone, seen in section near Elgin, and again at Cothall on the Findhorn. Its presence may be taken as indicating that the waters of the U.O.R. lake eventually became surcharged with carbonate of lime; and the occurrence of the enormous quantities of carbonate of lime in the earlier beds of the series would appear to suggest either premonitions of the onset of these conditions during the period in which they were themselves deposited, or that the limestone bed, by perfiltration at a period subsequent to its deposition, became the source of the carbonate of lime present in the underlying beds. The waters of the U.O.R. lake may have extended more widely; and, as a matter of fact, we know that they did extend more widely than the present out crop of the limestone beds would indicate, and by implication the limestone beds themselves must have extended more widely than they do now, and in their former extension over the area now occupied by the lower beds of the U.O.R., as well as the adjoining beds of the L.O.R., would ample explanation of the presence

of carbonate of lime in these local beds of the U.O.R. and the L.O.R. be found.

On the negative side this contention is borne out by the practical absence of carbonate of lime from the sandstones of the U.O.R. which overlie the limestone beds. At Newton the occurrence of carbonate of lime in some of the beds, and its entire absence in others, may be taken as indicating its contemporaneous deposition in the beds in which it does occur.

In the upper divisions of the U.O.R. we have the first indication of a wide-spread infiltration of secondary quartz. It is absent at Newton, but present in sandstones of like facies in the Millstone, Cardenhill, and Sweethillock quarries further to the west. In the latter two it is typical, and surrounds the grains in relatively broad bands, which almost completely fill up the interstices between the grains of what are really very rough sandstones. At these three localities, as well as at Newton, there is another peculiarity. The surfaces of the grains of sand are covered with large numbers of minute oblong crystals.

In the first three they have been subsequently overlaid with secondary quartz, but at Newton the quartz is absent. These minute crystals I at first considered to be—and I believe recorded as—sulphate of lime. From their extreme minuteness it is of course impossible to decide with certainty. But several considerations make it probable that they are sulphate of barium:—(1) They are too insoluble to be sulphate of calcium; (2) they are never seen to be twinned; and (3) I have been able to separate a trace of barium from some specimens of Newton sandstone. In this connection, and for another reason to be stated afterwards, special interest attaches to the occurrence of sulphate of barium, green fluor-spar, and a sulphide of iron as vein-stones in this quarry. I exhibit a specimen showing all three together. Celestine, that is sulphate of strontium, is stated by Heddle in his "Mineralogy of Scotland," on the authority of Greg, to occur in sandstone near Elgin, marked doubtfully Newton quarry.

In the uppermost or Rosebrae division of the U.O.R. rocks carbonate of lime is now entirely

absent; but as we shall see there is reason for believing that that or some other relatively soluble cement was originally present in isolated patches in these sandstones, just as it occurs now at Spynie in rocks of Reptiliferous age. The cement of the Rosebrae division is siliceous, but the quartz rims are not continuous, except at Laverock Loch, somewhat farther north. The secondary quartz comes on outside the scanty coating of ferric hydroxide. In a quarry of brick-red sandstone by the roadside to the south of Findrassie, and in beds of very similar facies exposed along the shore westwards from Stotfield and on Stotfield links, and understood to be of U.O.R. age, the grains have first been deeply covered with ferric hydroxide, and then completely sheathed in secondary quartz.

At Bishopmill, where the cement is mainly ferruginous, with some slight indications of secondary quartz, a colourless anisotropic cement substance has been seen in irregular fragments in a number of specimens that have been examined. A sulphate has been detected, but up to the present no barium. Calcium is always present in sufficient quantity to unite with all the sulphuric acid present. Barium sulphate, however occurs as a veinstone in this quarry also.

In the Reptiliferous generally the cementing substance is quartz, secondary in some cases to ferric hydroxide, which, as we shall presently see, there is remarkable evidence to show is itself secondary in point of time to the deposition of the sandstones. In the wind-accumulated deposits of Cutleshillock the quartz is in the form of discontinuous points, except along one linear band, where it is continuous. At Quarrywood there is little or no secondary quartz, and the cement is ferruginous, probably with the addition of some felspathic. And in this connection, it may be interesting to state that pockets of an almost chemically pure kaolin, evidently of secondary origin, are to be found in the sandstones of this quarry. An analysis of a typical sample is subjoined in the appendix.

In the Spynie rock, which is the hardest and most durable of the local sandstones, the secondary quartz occurs in broad rims which inter-

lock very closely, so that a microscopic section seems to show the original grains embedded in a clear continuous paste. Here there has also been deposited at separate points throughout the body of the rock crystalline carbonate of lime, and where the carbonate is present the quartz rims are absent. The evidence is, therefore, complete that the carbonate of lime was deposited before the secondary quartz. Towards the periphery of these carbonate of lime areas, a thin quartz rim may, however, occasionally be seen to come between the grains and the carbonate of lime. This would indicate that the calcite areas continued to be added to after the deposition of the quartz had commenced.

It is very interesting to note that secondary quartz is a feature of all the rocks belonging to this period. It is least developed at Findrassie, but even there it is not altogether absent. In the sandstones of the coast range, which extends from Covesea to Burghead, there has been a previous infiltration of ferric hydroxide, which, as we shall see, has itself been deposited at a period subsequent to the deposition of the sandstones themselves. The hydroxide has been followed by the quartz, and this again by another period of infiltration of ferric hydroxide.

For the sake of completeness it may be noted that secondary quartz is also a feature in the small patch of greenish sandstone of Middle Oolite age, faulted against the Reptiliferous at Lossiemouth. The component grains are here decidedly angular, and the green colour is evidently due to large numbers of small, dark, yellowish-green, highly refracting crystals, which I somewhat doubtfully refer to glauconite. The occurrence of secondary quartz in this sandstone, if it is to be presumed that the infiltration of quartz in the Elgin sandstone is all to be ascribed to one period—and there is no reason I know of for taking a different view—would decisively fix it down to a date posterior to the Middle Oolite.

So far we have had to do with general cementing substances extending continuously over wide areas; but, perhaps, some of the most interesting features of cements fall to be considered in connection with the localised cements, or the substances which have been laid down in discrete

areas, sometimes it may be through extensive masses of sandstone. A peculiarity of these localised cements, which so far as my observation has yet gone holds throughout the Elgin sandstones, is that in the nuclei of all these discretely cemented areas, the cementing substance has uniformly been deposited directly on the sand grains and by implication antecedent in time to the continuous or generalised cements. Thus in the Reptiliferous of Covesea, and extending westward from the Lighthouse for about a mile to just under the cottages at Old Covesea, the sandstone shows innumerable nodules, which are found on examination to be impregnated with sulphate of barium. Within the tideway these nodules, in consequence of their being more resistant than the general body of the sandstone, stand out in rounded knobs over the rock surfaces; whereas on the high cliffs, where the denudation has latterly been purely subaerial, the nodules, by some process of peripheral weathering towards the explanation of which I have as yet no clue, eventually tumble out, the cavities from which they have fallen being subsequently much amplified, and thus leave the peculiar fretted or pock-pitted appearance which is well shown in the photograph of a cliff near Covesea Lighthouse which I exhibit.

To the naked eye a section of one of these nodules shows, first, a central glistening white surface; then a dark purplish ring, deeper at some points than others, and consisting, as it turns out, to be of a sulphide of iron. This dark ring is followed towards the periphery by an irregular white ring, and that again by an irregular reddish brown ring of ferric hydroxide, while outside this again comes finally an irregular wavy border of glistening white.

Under the microscope in the central white area the sulphate of barium—for it is that which gives the glistening white appearance—is seen to directly envelope the grains of sand. Then the purple band seen under the microscope as blotches of sooty black directly envelopes the grains, the barium sulphate coming on outside the dark masses. In the middle white ring the sulphate again directly surrounds the grains; then the ferric hydroxide comes on, and has

been deposited directly on the grains, the sulphate of barium being again outside the hydroxide, and, finally, in the outer glistening border the quartz may be seen to come in above the ferric hydroxide, the barium sulphate in this area mostly coming on outside the ferric hydroxide and the quartz rims. Lastly, where the infiltration ceases, we have a coating of ferric hydroxide outside the secondary quartz, but entire cessation of the deposit of barium sulphate.

The interpretation of these facts is not, I think, far to seek. The barium sulphate in the nucleus of the nodule has been deposited first, and it may be presumed shortly after, if not almost contemporaneously with, the deposition of the sandstone. It has been added to in succeeding periods, during which there was infiltration of ferric sulphide, ferric hydroxide, quartz, and again ferric hydroxide, but a process well known in crystallisation, that is to say, the slow deposition on crystal surfaces of fresh substances of the same kind from a solution in which the crystals are immersed. In fact, in these nodules the barium sulphate may be slowly extending its boundaries by this process even now; and when one remembers that the solubility of barium sulphate is only about 1 in 400,000, one may form a rough idea of how long it has taken such a nodule to grow.

The occurrence of barium sulphate in quantity in sandstones is not a fact altogether new to science. Emeritus Professor Clowes, of Nottingham, as long ago as 1885, and again as recently as 1899, has described deposits of barium sulphate in upper Triassic rocks near that city: and the presence of the same substance in rocks of the same age in a distant and presumably isolated area of deposit becomes for that reason doubly interesting.

But another substance which has not been described as occurring in the Trias of England is to be found fairly widely distributed through sandstones of the same age some miles further west at Cumingston. I show you a smooth surface of a piece of sandstone from the quarry near that village. It exhibits a large number of glistening white patches, many of them as you will see showing a roughly square outline. The

substance that has crystallised in these patches is calcium fluoride or fluorspar. As it is the first time, so far as I am aware, that this substance has been described as occurring widely disseminated through the body of a sandstone, a short account of the circumstances of its discovery may not be out of place. As long ago as 1894 I was struck with the number of irregular, colourless, isotropic fragments that occurred among the sand grains of this quarry, when these were examined in polarized light. I find in a paper written in the beginning of that year that they are put down as "colourless garnets"; still they had manifestly a refractive index much too low for garnet. In the following year fluorine in quantity was discovered in these sandstones by the application of a test well known to chemists, which consists in heating the dry and powdered sandstone with strong sulphuric acid in a dry flask, and passing the evolved gas through a perfectly dry tube into water, when a copious precipitate of gelatinous silica was obtained according to the equations:

$$2\text{Ca F}_2 + \text{SiO}_2 + 2\text{H}_2 \text{SO}_4 = \text{Si F}_4 + 2\text{Ca SO}_4 + 2\text{H}_2 \text{O}.$$

The Silicon Tetrafluoride on coming in contact with water giving $3\text{Si F}_4 + 2\text{H}_2 \text{O} = 2\text{H}_2 \text{Si F}_6 + \text{Si O}_2$.

An analysis of an average specimen of this sandstone appears in the appendix.

In the centre of these nodules the fluoride is deposited directly on the grains of sand. In many this arrangement holds throughout. In others again towards the periphery ferric oxide and quartz rims occasionally come between the fluoride, and the grain showing again that the fluoride has been added to during subsequent geological periods. Outside these areas the sandstone shows ferric hydroxide overlaid by continuous quartz rims, and a coating of hydroxide again comes on outside the quartz. Around many of these fluoride areas a dense layer of ferric hydroxide has been laid down, showing unmistakeably that the wave of inflowing hydroxide has been subsequent to the deposition of the bulk of the fluoride. But altogether, apart from the evidence revealed by the microscopic, there is abundant evidence in the arrangement

of the ferric hydroxide in circinate or even concentric lines to show that it must have been deposited at a period long subsequent to the deposition of the sandstone.

The sequence of events, geologically speaking, is here manifestly the same as obtains at Covesea in the case of the barium sulphate nodules, and the same, or at least a similar explanation, is therefore indicated. First of all, two, if not three, important facts are to be noted regarding these two interesting substances, barium sulphate and calcium fluoride. In the first place, in the nuclei of these nodules they have both of them been deposited directly on the sand grains. They must, therefore, have been deposited at a very early period, if not actually contemporaneously with the sandstones. In the second place, they are very insoluble substances; and, in the third place, they are both present in sea water, and would naturally be expected to be present in relatively large quantities in any large body of water that had undergone concentration by evaporation, and also to be the first to crystallise out of these waters as evaporation went on.

We have, therefore, in the presence of these substances in the sandstones, I think, indicated important evidence regarding the geographical conditions of the time. An inland sea or lake, the waters of which were being gradually concentrated under what have aptly been called "desert conditions," would fully meet the circumstances of the case. In such a lake the more insoluble substances in its waters, such as barium sulphate and calcium fluoride, would be the first to crystallise out, and in consequence would be deposited among and around the grains of sand under its waters. Then, as evaporation went on, in the order of their insolubility would come all the other salts dissolved in its waters, till finally sodium chloride—common salt in solid form—would be thrown down. As far as I can make out, the barium sulphate around Nottingham occurs in beds which are elsewhere associated with the presence of sodium chloride; but I am not aware that a similar explanation has been offered in their case. Only a little stretch of imagination is necessary to extend the deposition of salt to the Covesea area, and

to bring on salt beds immediately above the rocks of the coast range; but, if ever they did occur in that position, they have long since vanished under the denuding agencies of later times. So must also have the beds from which the ferric hydroxide and the secondary quartz, now seen as cement in these sandstones, were no doubt derived. The occurrence of the same substances as we find in the sandstone of the coast—viz., barium sulphate, calcium sulphate, calcium fluoride, sulphide of iron, whether distributed through the mass of the sandstones or existing as vein stones in the neighbouring older U.O.R. rocks, probably mark the extension of the Triassic lake over the adjoining U.O.R. area, and the derivation by perfiltration from its waters, or subsequently from the rocks deposited in them of what are identically the very same substances as we find in the Reptiliferous rocks themselves.

Before concluding this paper, I should like to refer to some peculiarities of weathering in some of the sandstones which are referable to the presence of these cementing substances. The peculiarity of the barium sulphate nodules in this respect has already been referred to. In the case of the calcium fluoride nodules there occurs what might be called a negative variation in the form of white spots in the sandstone, similar in every respect to the others, but in which no fluoride is now found. It would appear that it had been originally deposited in these areas, but at an intervening period only to be broadly fixed as posterior in date to the deposition of the ferric hydroxide and secondary quartz, it had been re-dissolved and carried away, thus leaving the areas in which it was originally present without any cement whatever. Exposed to the atmospheric agencies, the sand grains in these areas tumble out, and exhibit a pitted surface of the sandstone as the result.

This is by no means the only instance where such negative areas occur. The same sort of pitting on weathered surfaces of Rosebrae sandstone have been observed; and I was surprised to find them on recently quarried blocks from a quarry towards the eastern end of the same ridge in a sandstone, which, as it occurs above

the pebble band—here said to be double—may be taken to be of Reptiliferous age. I have already said that those sandstones are cemented by discrete points of secondary quartz. Granting now that there had been, as, indeed, actually obtains in the neighbouring quarry at Spynie, a previous deposit in discrete spots of carbonate of lime—or for that matter any other relatively soluble cements—which would necessarily prevent the deposit of secondary quartz at these points, and that the carbonate of lime or other hypothetical cement had been subsequently removed, one can easily see how these original areas would thus be left without cement, and thus give rise on exposure to the appearances observed. We have some reason, therefore, for thinking that even in the Rosebrae division of the U.O.R., just as in the other rocks of that age, there was once carbonate of lime, that it has vanished, and given rise to the appearances we see.

I shall refer to only one other curiosity. At Kingsteps quarry there is a vein of copper ore. I have been able to determine from samples supplied me by Mr Taylor, Lhanbryde, that the original ore is the indigo sulphide CuS , known by the name of Covellite. The vein is bordered on each side by a band impregnated by green malachite, as shown by the subjoined analysis. The peculiarity is that carbonate of lime, which is universal in its occurrence in these sandstones, does not appear within the limits of the vein. Beyond the limits of the vein, however, the carbonate of lime is associated with malachite. The specimen I submit, which was evidently taken from some distance from the vein, contains over 5.5 per cent. of malachite, the presence of which may be readily demonstrated by pouring some ammonia on some of the powdered sandstone, when the supernatant liquid becomes deep blue from solution of the malachite in the ammonia.

In conclusion, I would beg to state that the foregoing theories are not to be accepted as by any means final. I simply state them as conveying to my mind the best and most probable interpretation of the facts that has occurred to me after thinking over those facts from time to time for several years.

APPENDIX.

<p>1. Analysis of soft white substance occurring in pockets of the Sandstone in the quarry at Quarrywood.</p>	<p>2. Nodules in Reptiliferous Sandstone, Covesea, chiefly centres.</p>
<p>Silica, 44·99</p> <p>Alumina and trace of Ferric Oxide, 34·79</p> <p>Lime, 2·32</p> <p>Magnesia, 1·13</p> <p>Potash, 1·23</p> <p>Soda, 1·69</p> <p>Chlorine, 1·12</p> <p>Water of Constitution, 13·90</p> <p>Moisture, 1·03</p> <p>Insoluble Residue, 57</p> <hr/> <p style="text-align: right;">99·77</p>	<p>Silica, 61·61</p> <p>Alumina, 2·60</p> <p>Ferric Oxide, 05</p> <p>Sulphide of Iron, 69</p> <p>Lime, 15</p> <p>Magnesia, trace</p> <p>Potash, 50</p> <p>Barium Sulphate, 32·42</p> <p>Calcium 1·07</p> <p>Soda, trace</p> <p>Loss on ignition, 91</p> <hr/> <p style="text-align: right;">100·04</p>

3. Nodules in Covesea Sandstone, chiefly from purple areas.

Silica,	53·83
Alumina and Ferric Oxide,	5·51
Barium Sulphate,	36·82
Calcium	1·67
Sulphide of Iron,	1·38
Lime,	25
Alkalies,	not estimated
And less (by dif.),	54

100

4. Average Sample of Cumingston Sandstone containing Fluoride of Calcium.

Silica (by dif.), ..	69·39 %
Alumina and Ferric Oxide,	1·99
Calcium Fluoride, ..	25·88
Lime,	91
Magnesia,	trace
Potash,	34
Soda,	25
Loss on ignition, ..	1·24

The Fluorine was estimated by Fresenius' absorption method, as well as by precipitation as Calcium Fluoride — the results being practically identical.

100

5. Nairnshire Copper Ore.

(a) Centre of Veins.		(b) Margin of Veins.	
Sand and Silica,	58·54	52·35
Copper,	25·97	Copper Oxide,	32·40
Sulphur,	11·65	1·46
Alumina and Ferric Oxide, ..	46	48
Lime,	trace	36
Carbonic Acid,	1·11	7·73
Water, &c.,	1·85	Not estimated

Results show that Copper exists at the centre mainly as Copper Sulphide (CuS = Covellite, which is a mineral new to Scotland), and as Malachite at the margins.

The interest of the paper was much enhanced by diagrams and numerous geological specimens which were handed round among the company.

Mr Wallace, Inverness, spoke of the originality of the paper, and said this was not the first time Dr Mackie had ably dealt with the Elgin Sandstone, and they found him now embarking on a new phase in the study of sand veins. He proposed a vote of thanks to Dr Mackie for his valuable contribution, and the motion was cordially carried.