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XI. *On the Structure and Arrangement of the Tesserae in a Roman pavement discovered at Cirencester in August 1849.* By JAMES BUCKMAN, F.L.S., F.G.S.*

THE object of this paper is to point out the nature of the materials of which the party-coloured floors so beautifully wrought in ancient Roman dwellings are composed, as also to offer some remarks upon their principles of arrangement.

The tesserae of Roman pavements may be said to be formed out of two classes of materials, the first of which, consisting of portions of various coloured rocks, may be termed *natural*; the second, of stained or coloured terra cottas and glass, being *artificial*.

The natural tesserae furnish but few colours, and those of a sober cast, hence these will be found forming shadings to figures entering largely into the composition of borders, or filling up the groundworks of the designs. They consist of portions of natural rocks from various localities, those belonging to the district where the pavement is found, as far as I have observed, always contributing their share.

The Cirencester pavement presented the following :—

Colours.	Rocks.
1. White, composed of	Hard fine-grained Oolite.
2. Light yellow	Pebbles of the Wiltshire Drift, and Oolite.
3. Gray	The same as No. 1, altered by heat.
4. Slate colour or black ...	Limestone bands of the Lower Lias.

No. 1 occurs as a bed of compact fine-grained stone of about 2 feet thick in nearly all the freestone quarries of this district, where it is distinguished under the name of the Limestone bed; its geological position is about the middle of the freestone rocks of the Great Oolite; it is well exposed at Trewsbury quarry, at the Acman Street Station, and at the smaller Sapperton tunnel, and was no doubt obtained by the Romans from the quarries once worked by them in the vicinity of the Querns.

2. The tesserae, of a yellowish or nankeen hue, appear to have been made of portions of the pebble-drift with which parts of the neighbourhood of Cirencester is so thickly strewn. Stray pebbles of this may be found in almost every field to the south of the town, whilst at Somerford Kaynes, and other places, it enters largely into the composition of the gravel beds which are there worked. It is probable that this drift is the debris of that tertiary rock known in Wiltshire as Sarsen stone, of which the huge stones of Abury Camp constitute the more enduring monument.

3. This, though differing so much in colour from No. 1, yet

* Read to the Cotswold Club, Jan. 22, 1850.

seemed so identical in lithological structure as to induce me to try to ascertain from experiment whether or not they were the same, when, on roasting a portion of the rock No. 1 in the fire for a few minutes, it gradually assumed the colour of the gray tesserae, the change no doubt being due to some alteration in the chemical conditions of the iron with which the stone is slightly charged.

4. The dark colour of the lias entered largely into the composition of these pavements, as much of the outline of the design and the darker bands of the border ornaments are composed of this stone, which, judging from an Ammonite found in one of the tesserae, was obtained from some one of the thin layers of argillaceous limestone with which the clay-beds of the third division of the lower lias in the vale of Gloucester are separated, and no doubt the stone in question was brought from that locality.

The *artificial tesserae* found at Cirencester entered for the most part into the construction of the finer and more important parts of the details of the figures and designs ; they consist of—

Colour.	Substance.
1. Black	} Terra cotta or baked clay.
2. Light red	
3. Dark red	
4. Brilliant ruby-red ...	Glass.

1. This is a much darker shade than that of the lias, and was consequently used in those portions of figures where bold relief was required ; it seems to be composed of a dark-coloured clay, only slightly, if at all burnt ; as the tesserae are very fragile, this would almost lead to the conclusion that these were not artificially coloured but made of a clay containing a large quantity of protoxide of iron, which is black, and they were consequently burnt in smother kilns, or the black would change to red by the protoxide becoming peroxidized. The identity of constitution of these tesserae with black pottery is very apparent.

2 and 3. The two reds are made from clays containing more or less of iron, and perhaps this substance may have been added in these and in the instance above noticed, where it was desirable to deepen the tint ; of course the red is due to the peroxidation of the iron salts.

4. In only one medallion of the Cirencester pavements has glass been made to play a part, and that is just when the transparency and brilliancy of colour of this substance were of the utmost importance to the composition.

An examination of the pavement itself will show that the medallion which symbolized Spring, represents a fine female head crowned by what appears a chaplet of olive-green and verdigris-coloured leaves. Now on studying this head attentively, I was

surprised at seeing these two colours intermixed apparently in a most inharmonious manner; and as the verdigris-green was so different from any other colour I had met with, it suddenly struck me that it was a mere coating to the tesseræ, resulting perhaps from chemical decomposition, and on scraping the surface with a knife I was gratified to find that the verdigris only covered up a glass of an exceedingly rich ruby tint. I then obtained a small portion for a chemical analysis, which was kindly undertaken for me by Dr. Voelcker, the College Professor of Chemistry, the results of which are so interesting that I must beg to lay it before the Club in his own words.

Examination of red-coloured Roman glass (Cirencester).

"The red glass which had undergone a partial decomposition was coated with a white crust, which itself was covered with a green substance. The latter on examination proved to be carbonate of copper; the white crust dissolved with effervescence in nitric acid, leaving gelatinous silicic acid behind, and was found to consist principally of carbonate of lead and silica. The glass, after having been treated with nitric acid and thus been deprived of the white and green coatings, exhibited a bright red colour; it was now transparent, not very hard, and easily flexible when exposed to a moderate heat. On analysis the following substances were detected, as—

Oxide of lead.

Oxide of iron.

Protoxide of copper.

Lime.

Alumina.

Silica.

"The red colour of the glass undoubtedly is due to protoxide of copper, which was present probably in combination with alumina in considerable quantities. It is well known that the ancients were acquainted with the art of colouring glass red by means of copper, for Cooper informs us (*Annales de Chimie*, série 1. tom. lxxiii. p. 20) that he detected in an antique red glass protoxide of copper, and Klaproth likewise ascribes the red colour of an antique glass to the presence of copper, which he considers to be contained in the glass in the state of protoxide. This gentleman found exactly the same constituent parts as those found by me in the Cirencester glass; it has further been ascertained that all the red glass in antique mosaic church windows is coloured red by copper. Gold, which likewise imparts a beautiful red colour to glass, is never met with in Roman glass, and it appears that the property of gold and its combinations was unknown to the Romans, for we do not find any traces with the ancients which could justify the supposition of their being acquainted with the art of making the purple and rose-coloured or

ruby-glass which at present is manufactured in great perfection in Bohemia, where a preparation of gold, generally chloride of gold, is used for that purpose by the glass manufacturer. The application of gold preparations in the preparation of red glass, comparatively speaking, is of recent origin, for it appears that before the 17th century the use of gold preparation for this particular purpose was unknown. In the 17th century we find the first reference made to the use of gold for colouring glass red by Cassius, who discovered and recommended a new combination of gold, which, to the present day, is known under the name of Cassius gold purple.

"Copper thus appears to have been the material with which the ancients were in the habit of colouring glass red. Various methods of applying copper were in use, and though metallic copper is capable of imbuing glass with a red colour, no doubt on account of the protoxide of copper which is found in almost every sample of copper, in most cases it was first subjected to operations which tended to generate protoxide of copper. Frequently also peroxide of copper (black oxide) was used for the same purpose, but in this case the glass mass received an addition of substances, as tartar, charcoal, soot, iron, protoxide of iron, which substances at a red heat combine with part of the oxygen of the black oxide, and thus become the means of reducing the latter to red oxide of copper.

"This important action of iron seems to have been known to the ancients, for both Cooper's and Klaproth's analyses of antique red glass referred to above, as well as my own of the Roman glass found in Cirencester, exhibits, besides oxide of copper, oxide of iron. Later the art of colouring glass red by means of copper was lost entirely, and many persons of our days even denied altogether the possibility of producing a red glass with copper. Very generally all red glass was supposed to contain gold.

"The importance of the subject induced the Society of Arts of Berlin to offer a prize for a method of manufacturing red glass by means of copper. The prize was gained by D. Engelhardt of Zinswider, who gave several directions of manufacturing red glass, and who succeeded in making a beautiful red glass with protoxide of copper and without using gold at all." (*Vide Verhandl. des Gewerbevereins*, Berlin, 1828, S. 15.)

From this analysis it will be seen that the Romans imparted this red tint to glass by a very ingenious method, and it was the substance used for this purpose, namely copper, which covered over the tesserae as the surface of the glass had become decomposed in the form of a carbonate of that metal.

This fact is curious in its bearing upon the pavement as a work of art; as so harmoniously are the colours arranged in all the

figures that it may almost be taken for granted that, as in this instance, when there is an exception in this particular, it is due to some subsequent change having taken place in one or other of the colours. In the case before us our first tracing was coloured with the verdigris-green: it was unsatisfactory; but on making a new tracing and colouring it according to our amended observations, it at once became harmonious in colour, and assumed an intelligible form, though all our colouring will not enable us to convey the idea of ruby-gemmed flowers like the substance used, the transparency of glass contributing much to the general effect.

XII. *The Effect of Pressure in Lowering the Freezing-Point of Water experimentally demonstrated.* By Professor W. THOMSON, Glasgow*.

ON the 2nd of January 1849, a communication entitled "Theoretical Considerations on the Effect of Pressure in Lowering the Freezing-Point of Water, by James Thomson, Esq., of Glasgow," was laid before the Royal Society, and it has since been published in the Transactions, vol. xvi. part 5†. In that paper it was demonstrated that, if the fundamental axiom of Carnot's Theory of the Motive Power of Heat be admitted, it follows, as a rigorous consequence, that the temperature at which ice melts will be lowered by the application of pressure; and the extent of this effect due to a given amount of pressure was deduced by a reasoning analogous to that of Carnot from Regnault's experimental determination of the latent heat, and the pressure of saturated aqueous vapour at various temperatures differing very little from the ordinary freezing-point of water. Reducing to Fahrenheit's scale the final result of the paper, we find

$$t = n \times 0.0135;$$

where t denotes the depression in the temperature of melting ice produced by the addition of n "atmospheres" (or n times the pressure due to 29.922 inches of mercury), to the ordinary pressure experienced from the atmosphere.

In this very remarkable speculation, an entirely novel physical phenomenon was *predicted* in anticipation of any direct experiments on the subject; and the actual observation of the phenomenon was pointed out as a highly interesting object for experimental research.

* From the Proceedings of the Royal Society of Edinburgh, February 1850.

† It will appear also, with some slight alterations made by the author, in the Cambridge and Dublin Mathematical Journal, Nov. 1850.—W. T.