

Further Notes on Tideswell Dale Quarry.

BY JOHN WARD.*

IT is several years since I was in Tideswell Dale Quarry; but I remember it well, for it was then that I first made my acquaintance with "Spheroids." They particularly attracted my attention, for I almost at once began to doubt the usual theory of their origin—as due to the cooling and contraction of the rock in the process of solidification. Since then the occasional examination of the phenomena elsewhere, in the same rock (Toadstone) of the district, has only tended to strengthen my conviction.

I do not dispute the possibility of structures known under this name in igneous rocks, to arise from such causes as the theory implies. I have a photograph of greenstone at Cader Idris, which at the first glance is remarkably like the rock containing spheroids, at Tideswell. But upon closer inspection wide differences will be noticed between them. The spheroids of Tideswell consist of rounded cores (A, Fig. 5), each enveloped in a series of zones or shells (BB) (giving the appearance of a stony onion to the structure); sometimes there are as many as 14 or 16 of these zones, and the diameters of these spheroids range from two or three to nine inches. At Cader the "nodules" are much more irregular in shape, and there are no traces of such shells, in

*Mr. Fletcher also supplies us with the following further notes on Tideswell Dale Quarry and igneous rocks, by Mr. John Ward, which were written to him in the form of a letter commenting on his own notes.—ED.

fact, the tendency is to a *radiate* structure by means of more

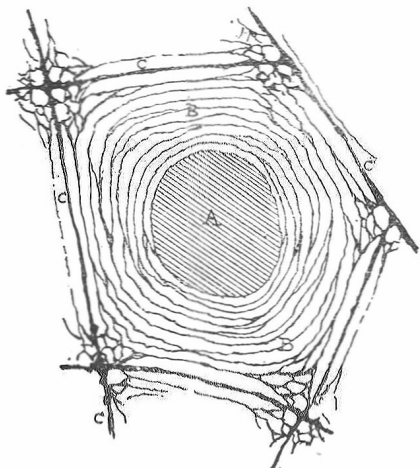


Fig. 5.

or less distinct cracks arranged in that manner, and more pronounced towards the centres of the nodules. Another wide difference is in the jointing of the two rocks, and the relation of the spheroids to them. At Tideswell, the jointing is precisely as in those parts of the same rock where spheroids are absent—an irregular arrangement of cracks (CCCC), without any ap-

parent order, breaking up the rock into irregular polyhedral masses, each being the seat of a spheroid (when present), the subordinate (or spheroidal) system of jointing of which, gives rise to the nucleus and its succession of concentric shells. But at Cader only one system obtains—the rock-joints; and it is their peculiar curvy arrangement that break the rock up into these nodular masses—just as it is the peculiar geometrical arrangement of the rock-joints which give rise to prismatic structure in basalt. Hence, while it is right to speak of these latter as *Nodular* (I prefer this name to “Spheroidal,” in this case) and *Prismatic structures*, I deem it more correct, in the former case, to speak of the rock as *Spheroidiferous*.

We will not enter into the difficult subject of rock-joints—sufficient it is for us that the jointing of the two varieties of Toadstone, above mentioned, is identical. How came the *Spheroids*?

1. The *Toadstone* above mentioned: as yet I have found only one variety of this rock to be spheroidiferous; and, in this, as already intimated, the presence of spheroids is by no means the rule. This variety is a dense,

homogeneous, and hard Diabase, of a black-grey colour, tinged with green; fracture conchoidal and dull; and sound when struck metallic.

2. In each case where I have observed spheroids, the rock containing them has not only occurred near the surface (as in our quarry, where the spheroidiferous variety is found at a higher level, and near the land surface, and the other variety lower down), but under circumstances that lead to the conviction that this proximity to the surface has obtained for an immense period of time—a period comparable with that during which a considerable depth of the valleys of the district has been excavated. This proximity with the surface means that, for this length of time, the rock has been in close relationship with the gases and moistures that operate from the surface, and which, where the underlying rocks are susceptible to their mechanical and chemical energies, do so mightily a work of rock-disintegration and metamorphosis. Diabase being a complex rock of igneous origin, and containing a large percentage of potassium and sodium salts, is highly susceptible to decomposition or alteration in presence of aerial or humid re-agents. And in every case of Spheroidiferous variety of the above that I have seen, some such process has taken place,—the cores being always of *unaltered* rock; but the enveloping shells of a *looser texture*—so friable, sometimes, as to crumble into a coarse powder between

the fingers, and the colour is decidedly brownish. This change, which is undoubtedly chemical, may often be discerned in the superficial parts of stray exposed blocks of this stone, as for instance, in walls. I found some good examples in the *debris* of this quarry—blocks of the unspheroidal variety, which showed signs of having been exposed

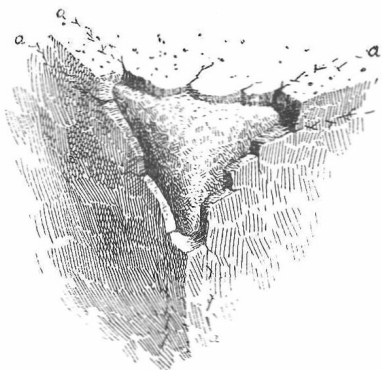


Fig. 6.

for some considerable time. They could be instantly detected by their brownish hue, or by a gentle blow of the hammer—a blow quite insufficient to break the unaltered stone—when a part of the altered material would “shell” off, leaving the sub-angular nucleus of unaltered stone exposed, which, if entirely stripped of its “shell,” would be found to approximate in shape to the original block (Fig. 6).

What this chemical change consists in I cannot say; but, probably, the change of colour is due to the raising of ferrous into ferric salts. The fact that such chemical change has taken place is beyond dispute, and that is sufficient for us. *How* the change came about is more readily answered. It was, undoubtedly, the result of the chemical absorption of some constituent or constituents of the atmosphere or the vegetable soil, or of both, which is more probable. Whatever this re-agent, or set of re-agents, may be, it must penetrate the rock by means of the *joints*, for the material is impervious to liquids or gases; and hence it must operate upon each block at its surface. I have seen a good example to the point in the peculiar ashy Toadstone of Ashover, where the discoloration due to chemical change follows the fissures and leading joints, sometimes for many feet below the natural surface. When a film of altered material is formed upon such a block, all further chemical change will depend upon the perviousness of this film to the re-agent: but as the altered material in our present subject is of so loose a texture, we need not hesitate to conclude that the re-agent would slowly pass through it to the surface of the unaltered part. But it would greatly retard the work of chemical change.

From what has been said, it will be difficult to escape the conclusion that the formation of these spheroids is in some way due to this subsequent work of chemical change in the rock: and this conclusion will be strengthened as we proceed.

3. Is this work of chemical change, invading each block from its superficies, competent, at any stage of its progress, to leave a *rounded* nucleus of unaltered material? It is. Imagine a cube of our rock immersed in some re-agent capable of producing a

similar change in its material, as we have above noted. Now, it is obvious that when once a film is formed, this re-agent can only reach the surface of the unaltered part by passing through it; and it is equally obvious that in so doing the re-agent will tend to reach this surface by the shortest "cuts." For instance, the part or area of the surface of the unaltered part, *a*, in Fig. 7 (which

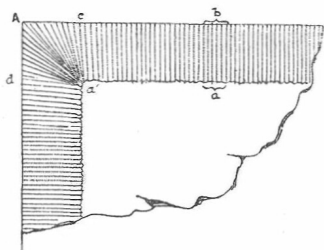


Fig. 7.

represents a section of a part of our cube) will draw its supply of re-agent from the outer surface at *b*, immediately superjacent to it; and these two corresponding areas, *a* and *b*, of the two surfaces, when situated in the central region of any of the sides of the cube, will be equal in size, or approximately

so—that is, a square inch at *a* will draw its supply of re-agent from the square inch of outer surface at *b*, immediately above it. But the case is otherwise, in this latter respect, in the regions of the angles of the cube, as *d* in the section; for it is manifest that instead of *d* drawing from an outer area equal to itself, it will draw from a strip in breadth equal to its own diameter, and extending from *c* to *A*, and from *A* to *d*—a surface immensely greater. But the contrast becomes still greater if we suppose *d* to be immediately under one of the "corners" of the cube; in that case, instead of supplies of a *breadth equal to its own diameter* converging upon it with an angle of nearly 90° , they will pour on to it *from all directions* within that angle. What will be the result? The greater the supply of re-agent, the greater the amount of chemical change, and the more rapid the recession of the surface of the nucleus acted upon. Hence a rounded nucleus must at length be the result. But when this is accomplished, the broader surface which the nucleus presents to the outer angles, combined with the thicker "shell," will tend to neutralise these differences, the surface of the former receiving a more equitable supply of re-agent throughout.

I have seen a good example of the above at Mount Sorrel.

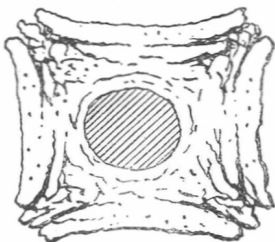


Fig. 8.

There in the sub-soil may be observed *rounded* blocks of granite of various sizes, packed in masses of disintegrated granite. Similar examples in other materials frequently occur, one particularly (Fig. 8) was excellent—a cubical lump of sodium had been left in a loosely corked bottle, with this result:—its section presented a mass of the oxide, containing a small ball of the metal in the centre.

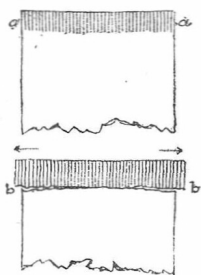
4. We now consider the concentric zones of our spheroids. Is this theory of subsequent chemical change competent to account for them? It is, I think. They may, if this change be complex—the work of many re-agents—be caused by variations in the proportions of these re-agents, due to varying seasons; hence giving rise to zones in the altered materials of slightly differing textures or proportions of constituents, which, although not obvious at first, may ultimately rupture along the lines of weaker material.

But a more satisfactory explanation is to be found in the combination of the following two circumstances:—The expansion of the altered material, and the resistance offered to this expansion on account of the closely packed condition of the rock, each block having its own expansion resisted by that of its neighbours.

That expansion does take place I had ample proof in the vicinity of the quarry, where many of the stray blocks already noticed had a line of more or less distinct cracks round each side, about one inch or more from its edge (Fig. 6, *a, a*); the rest of the surface being free from them. I can only account for them as the result of unequal expansion between the thicker part of the crust in the vicinity of the angles and the thinner upon the sides.

When a film of altered material (as *a a*, Fig. 9) is forming upon a body, it is free to expand in a direction *away* from the latter,

unless, indeed, this expansion be resisted by another body pressing upon it; but *sideways* it is otherwise, for as soon as the film begins to



Figs. 9 and 10.

form, its expanded particles, excepting those near the edges, are squeezed together laterally. Nevertheless, the cohesion which the film has with the unaltered material is able at first to overcome this state of lateral stress; but as the film increases in thickness, so is the number of its altered particles multiplied; and hence also this lateral stress, which is exerted by the particles—the cohesion re-

maining a constant quantity. Hence a time must come when this cohesion of the film with the unaltered material is no longer able to hold in check this stress in all such places where the film has an opportunity of responding to the expansion of the particles, a rupture being the result (as *b b*, Fig. 10).

We must now apply this, under certain modifications, to our spheroids. Turn to Fig. 5 again, and observe that the “shells” are not continuous all round the nucleus, but *overlap*, somewhat like the petals of a garden rose. This almost explains itself:—

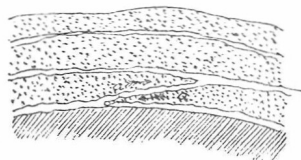


Fig. 11.

A film forms, and at length attains to such a thickness that the resultant state of lateral stress must be relieved in one of two ways—the envelope of film *as a whole may be thrown off* from the nucleus, or it may be *sheared obliquely* where it is weakest

or thinnest—the *one part sliding over the other laterally* (Fig. 11, *a a*). The former cannot take place on account, partly of the closely packed condition of the rock offering resistance to all expansion *away* from the nuclei, and partly of the unequal thickness of the film itself. When a film has thus separated, a new one is formed beneath it, to separate in due course from its parent stone in like manner, and the process may go on, till at length no unaltered material is left.