A Note on Cone-in-Cone Structure.

By Professor T. G. Bonney, D.Sc., LL.D., F.R.S., &c.

[Read November 20th, 1894.]

THE structure called cone-in-cone attracted my attention when I was working at certain forms of jointing and spherulitic structures in rocks,[1] and has been studied in a desultory fashion ever since. Moreover, the Museum of University College possesses some good specimens of cone in-cone obtained by the late Prof. Morris, and I received a present of others, which had been used by Mr. W. S. Gresley for his suggestive paper[2] when he left England for America. But though I formed some general conclusions on the subject, I abstained from writing, because I felt doubt concerning one point of importance, and had never seen a good example of cone-in-cone in the field. Both these obstacles were removed in the summer of 1892, so I venture to add a few words to the valuable paper of my friend, Prof. G. A. J. Cole,[3] not by way of criticism, but of confirmation and supplement. My conclusion, arrived at independently, is practically identical with his, and with that originally advocated by Dr. H. C. Sorby,[4] viz. that the structure is primarily and essentially due to crystallisation, which has started from a number of independent centres, either on or near to one surface of the bed, and has proceeded inwards, as spherulites attempted to form themselves, but produced sheaf-like growths from being crowded together. A similar process occurs, as I have already[5] described, in the devitrification of glass.

---

[1] *Quart. Jour. Geol. Soc.*, XXXII. (1876), p. 140. *Geol. Mag.*, 1877, p. 499.

[2] *Geol. Mag.*, 1887, p. 17. A very interesting paper by the same author appeared in the *Quart. Jour. Geol. Soc.* for Nov. 1894, p. 731, after this note had been sent to the Secretary of the Mineralogical Society. It brings forward additional evidence in support of the "crystallisation" theory, and practically anticipates some part of my note. But I leave it as written, since the conclusions were formed independently.

[3] *Min. Mag.* X. p. 136.

[4] *Brit. Assoc. Rep.*, 1859, pt. 2, p. 124.

[5] Presidential Address to the Geological Society, 1885. *Quart. Jour.* XLI. *Proc.* p. 95.

It is beautifully illustrated in a specimen which I obtained in 1892 from the upper part of the Wealden group in Sandown Bay, Isle of Wight. It formed part of the top "beef" bed (*f* of Prof. Judd's section[1]). This bed, above an inch in thickness, overlies a limestone "crowded with Cyrena and a few oysters." A slice cut so as to exhibit the upper bed and part of the lower shows the latter to be a somewhat "dirty" limestone containing numerous fragments of bivalves (probably for the most part *Cyrena*), with some of gasteropods (? *Paludina*), many valves of *Cyprides*, single and double, and mineral grains, chiefly quartz, the last being more plentiful in some bands than in others. From the top of this bed the crystalline "brushes" diverge upwards (the mineral being generally calcite, but perhaps sometimes ankerite[2]). The organic fragments, such as the convex sides of *Cyrenæ* and rather notably of *Cypris* valves, with occasionally (I think) a mineral grain, serve as *points d'appui* for the apices of these cones of diverging crystallites. When any two come together the line of junction is clearly indicated, especially when the nicols are crossed, and the structure of each sheaf of crystallites is rendered more conspicuous, but sometimes this line is made yet more distinct by a thin film of dark mud, probably extruded, as Prof. Cole suggests, during crystallisation. Fine lines, apparently cleavage planes, may be seen making angles of from 20° to 30° with the axis of the crystallites, and pointing downwards. Similar lines, pointing in the opposite direction, may be occasionally noticed. In the lower band the crystallites in the interior of the *Cypris* cases not unfrequently exhibit a radial structure, to which Dr. Sorby has already called attention. It may be noted also that the prismatic layers in the molluscan fragments are replaced, partially or often wholly, by granular calcite, but the nacreous layers are less affected. Probably the former were originally aragonite. This remarkably interesting and beautiful example confirms the evidence afforded by other specimens in my possession, similar to those described by Prof. Cole, and convinces me that he is right in attributing the cone-in-cone structure primarily to crystallisation.

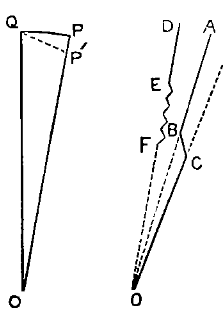
But we have also to account for the peculiar conical fracture which gives the name, and the fact that the surfaces of the cones are sometimes covered with approximately horizontal striations. The former may be thus explained. A half-spherulite may be regarded as consisting of acicular crystallites diverging from a centre and arranged symmetrically

[1] *Quart. Jour. Geol. Soc.* XXVII. (1871), p. 220.

[2] In the specimens from the Coal Measures which I have examined, the mineral is very often chalybite.

about a common axis, like a series of conical shells with a gradually increasing vertical angle. The rock itself is made up of a series of cones, representing portions of such groups of shells. Suppose it affected by a set of uniform strains due to contraction, such as would be produced in drying: if its material were perfectly uniform, it would break into vertical hexagonal prisms; but inasmuch as it has the structure just described, the surfaces of these cones will be surfaces of weakness (especially if they are parted here and there by films of extruded mud), and will determine the direction of fracture. Thus groups of cones will be developed, each consisting of one or more shells with a common apex and axis, and forming, at the outside of the bed, sets of concentric circular cracks generally two or three in number.

But the surface of rupture sometimes travels towards the axis, so as to produce a spiral crack on the outside. Of this I venture to offer the following explanation. Suppose P Q, two adjacent points in the circular base of one of these cones; let each be attracted towards the point O, its centre (corresponding with the end of the axis), and the conditions be such that fracture takes place at P slightly before it does at Q. On yielding let P move to P′. The effect of this is that Q is now also pulled slightly in the direction of Q P′, and has a tendency to move, not only along the radius O Q, but also slightly in the direction of P′. So the crack passes a little within the circle P Q and takes a spiral course. If the strains caused P to move in the opposite direction, the crack would travel outwards.



In regard to the other structure, the ribbed external surfaces, my view of their cause practically agrees with that put forward by Prof. Cole. I have already spoken of the tendency to form conical shells, and of the cleavage planes which exist in the rhombohedral carbonates (particularly in calcite) composing these masses. These planes also are surfaces of weakness, symmetrically disposed in consequence of the mode of growth of the aggregated crystallites.[2] Thus when a fracture occurs it may occasionally flash outwards, as shown at B C in the line A B C O, or turn in and out, as at E F in the line D E F. Both these forms may be found,

[2] They are indicated in the illustrations to Prof. Cole's paper, Figs. 1-3, pp. 140-141.

but the first is more usual. Sometimes these ribs are marked by carbonaceous crests or covering films; commonly they are not straight lines, but somewhat arched, with convexities towards the base of the cone. This may be the explanation: the development of the spherulite would probably include times of pause; these would produce surfaces of slight discontinuity in the form of spheres, and along these there would often be extrusion and deposition of carbonaceous material, which would make them more distinctly surfaces of weakness. When the axis of the cone of fracture was longer than a radius of the sphere (which would be, I think, the general tendency), these surfaces, in section, would arch upwards. The explanation, I admit, seems rather far-fetched, but after a good deal of consideration I am unable to devise a better.

Thus the cone-in-cone structure, as Professor Cole states, is primarily due to crystallisation, and is the result of a tendency to form "spherulites," though in a sedimentary instead of in an igneous rock. Its relation to the ordinary micro-columnar structure called "beef" is undoubtedly very close; the latter, indeed, may be regarded from the mathematician's point of view as the limit of the former, when the number of centres of independent crystallisation becomes infinite. But the developments of the cone-in-cone structure, its existence in short *as cone-in-cone*, is due to contraction subsequent to this crystallisation, and thus the mechanical cause is not less essential than the chemical one for its formation.