The brecciation of mineral-veins.

(*With Plates IV–VI.*)

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EXAMINATION of a series of examples of vein-breccias demonstrates that while many have readily explicable characters in common, others differ from ordinary types, and exhibit peculiarities calling for special investigation.

Characters distinguishing vein-breccias from volcanic breccias.—Owing to their situation along zones of fracture or within fissures that have served for the passage of waters charged with mineral matter, the primal constituents of vein-breccias are rarely devoid of signs of alteration, and the cementing material is of secondary origin. In this, among other respects, they differ from volcanic breccias, such, e. g., as the slate-ash rock of Glenridding, Ayrshire, the components of which are all clastic and were simultaneously deposited.

When a volcanic breccia has been subjected to the action of gases, moisture, and mineralizing agents, changes in both cement and included fragments may take place sufficient to render a hand-specimen scarcely distinguishable macroscopically from a vein-breccia. Thus the volcanic breccia at St. Anthony's Chapel, Edinburgh, consists now of partly eroded and much chloritized lapilli cemented by calcium carbonate. It is evident that the original mass was percolated by a fluid such, for instance, as that which lined the vesicles of an andesite at Penmaen, west of Pwllheli, with chlorite, and filled the interior spaces with calcite. Many brecciated mineral-veins can be shown to have been subjected to like changes.

The agency of water in the formation of vein-breccias.—With regard to the origin of brecciated mineral-veins, the question of paramount importance is the part played by underground waters. Shearing and fracture of a rock do not necessarily result in brecciation, as Dickson[1] shows in his account of the pyrrhotite deposits of Rossland, British

[1] C. W. Dickson, Trans. Amer. Inst. Min. Eng., 1904, vol. xxxiv, p. 36.

Columbia, where, in his opinion, dynamic movement doubtless took place under an immense load.

The relationship of water-supply and earth-movements in the formation of vein-breccias.—The earth-movements that have been productive of vein-debris commonly appear to have prepared a way for the passage upwards of cementing material. A specimen of vein-breccia in the Museum of Practical Geology, No. 375, from Ogo Gyfwr, Anglesey, indicates the repeated fracture of lode-quartz, and consequent occupation of many of its cracks by chalybite. Another specimen, No. 374, from Esgair Hir mine, Cardiganshire, originated in the erosion of fragments of slate by waters carrying abundant chalybite. This process was continued by a solution of quartz, which mineral enringed or (as at A, fig. 1) completely replaced them.

Change in the composition of the cementing material of vein-debris can often be shown to be consequent on the reopening of a fissure. In the Perran lode, near Marazion, Cornwall (fig. 2), first a breccia was formed of polygonal pieces of clay-slate with abundant quartz-cement. Later on, chalybite in solution was introduced along a rift betwixt this breccia and one wall of the lode, investing and seaming parts of both.

Messrs. Spurr and Garrey[1] state that in many cases the veins in the Georgetown mining district, Colorado, 'have the nature of rubble-filled fissures in which angular fragments of the wall rocks have been cemented together by ore, thus forming a breccia. By subsequent movements . . . the veins have sometimes been reopened and the ore-cement, above mentioned, brecciated in turn and recemented by pyrite, siderite, . . . or quartz'. The refissuring of the rhyolite-quartz-calcite-breccia of the Original Bullfrog vein, Nevada, ushered in the fresh deposition of quartz with much replacement of rhyolite and calcite thereby.[2]

Lode-material from Restormel mine, Cornwall (fig. 3), establishes that rising waters charged with silica and doubtless also carbon dioxide[3] there attacked massive chalybite in cleavage-directions, converting it into a breccia-like aggregate of rhombohedral fragments with septa formed of well-crystallized quartz, by which their shape is still outlined. Soon after the access of oxidizing agents to the lode the supply of quartz ceased, a slight ferruginous tint being imparted to that last formed. The

[1] J. E. Spurr and G. H. Garrey, Bull. U. S. Geol. Surv., 1904, No. 260, p. 111.

[2] F. L. Ransome, Bull. U. S. Geol. Surv., 1910, No. 407, p. 99.

[3] To the action of some such solution may be ascribed the juxtaposition in certain basalts—that of Rhuda-nan-Gall, Mull, e. g.—of amygdales that are composed exclusively of chalcedony and of calcite.

chalybite was then partly dissolved away, partly transformed into limonite and goethite, rhodochrosite where present being similarly transformed into manganite and pyrolusite. In the midst of a patch of goethite may be detected a few lenticular crystals of chalybite that have remained intact. The formation of goethite ($Fe_2O_3 . H_2O$) later than limonite ($2Fe_2O_3 . 3H_2O$) may signify diminution in the supply of water to the lode-cavity.

Crush-Breccias.

An important class of vein-breccias consists of those formed along the whole extent of a rock that by crushing has been rendered readily permeable to mineralizing waters. For these the term crush-breccias is distinctly appropriate. When metalliferous, they illustrate the dictum of Emmons[1] that ore-deposits are to a large extent actual replacements of crushed country-rock, the vein-materials being substitutes therefor and not mere infillings of open cavities.[2]

Illustrations of the modes of origin and characters of crush-breccias.— Some veins in the Georgetown mining district, Colorado, described by Messrs. Spurr and Garrey[3] afford a good insight into the mode of origin of crush-breccias. They consist entirely of zones of crushed, pulverized, and altered country-rock, differing little from the wall-rock except in being slightly more silicified and kaolinized. For the circulation of underground water these have served as channels in which retardation of flowage has been favourable to the deposition of ore.

The inception of the conglomerate-breccias of the Vermilion Range, Minnesota, as Messrs. Smyth and Finlay[4] have shown, was due to the fracture of the original massive rocks into roughly rhomboidal blocks by lateral compression.

The Foxdale lode in the Isle of Man rarely takes the course of a simple fissure, but is 'a belt of disturbed "country", with more or less parallel fractures . . . containing brecciated rock, with vein-stuff and ore generally in ribs but occasionally also brecciated.'[5]

[1] S. F. Emmons, Trans. Amer. Inst. Min. Eng., 1888, vol. xvi, p. 808.

[2] According to A. M. Finlayson, Quart. Journ. Geol. Soc., 1910, vol. lxvi, p. 310, replacement has played only a minor part in the formation of the important deposits that have yielded the bulk of the lead and zinc veins of Great Britain.

[3] J. E. Spurr and G. H. Garrey, loc. cit., p. 113.

[4] H. L. Smyth and J. H. Finlay, Trans. Amer. Inst. Min. Eng., 1895, vol. xxv, pp. 630–633.

[5] G. W. Lamplugh and W. W. Watts, Mem. Geol. Survey, 'Geol. of the Isle of Man,' 1903, p. 509. The brecciated vein-fillings of the Foxdale, Brow

The Grassington lead-mines, Yorkshire, have furnished a vein-breccia that is simply sandstone of which the polygonal segments are demarcated by a cement of galena precipitated from percolating lode-waters (fig. 4). In lode-stuff from Cronebane mine, Co. Wicklow, we note that slightly disrupted blocks of soft killas have been reunited by seams of galena (fig. 5).

At Sudbury, Ontario, where crushing, shearing, and slickensiding are notable features, the ore-bodies are 'replacements along crushed and faulted zones with only minor indications of open cavities'.[1] The second generation of pyrite in the Witwatersrand auriferous conglomerate, South Africa, has been proved to be a replacement of quartz.[2]

In the west of England, vein-breccias consisting of courses of fractured slaty rock in various stages of silicification and of replacement by quartz are far from rare. A specimen from near Sourton, Devon, e. g., shows patches of Culm-measures slate isolated by crystallized quartz, the encrusting rings of which must have grown thicker centripetally while the rock slowly underwent dissolution (fig. 6).

A frequent final result of the action of underground waters on the inclusions in a breccia is such a vein-stone as that from Wheal George, near Dittisham, in Walkhampton parish, Devon (fig. 7), namely, quartz-rock largely made up of spheroidal or ovoid aggregates of radiating crystals. In a specimen from Peak Hill, in the same parish (fig. 8), rapid and perhaps one-sided solution of a nucleus of rock has allowed the final crystallization of quartz straight across a central cavity.

Fissure-Breccias.

In the class of brecciated mineral-veins distinguishable as fissure-breccias, the materials cemented together consist of country-rock dislodged from the walls of open fissures and sometimes also of portions of pre-existing deposits therein.

Assigned modes of production of fissure-breccias.—For the origin of these breccias assigned causes are movement of the walls of veins, overweighting of portions of the walls by accretions thereon, loosening of the bases of mineral-crusts and deposits by decomposition of rock, and molecular pressure occasioned by the crystallization of minerals.[3]

(Leadhills), and Rampgill (Nenthead) lodes, are regarded by A. M. Finlayson, loc. cit., p. 289, as proof of movement since primary ore-deposition.

[1] C. W. Dickson, loc. cit., p. 63.

[2] R. B. Young, Trans. Geol. Soc. S. Africa, 1909, vol. xii, p. 96.

[3] See A. W. Stelzner and A. Bergeat, 'Die Erzlagerstätten,' 1904, p. 535,

Emmons[1] regards the fall of fragments into the cavity of a lode as of rare occurrence. Those usually found he considers to be the product of the rubbing or dragging of one lode-wall against the other. He takes the view—on which the consensus of experienced rock-drillers would be of interest—that under the enormous pressure productive of rock-fractures the space between the walls of a fissure must by attrition have been more or less completely filled with rock-fragments and finely comminuted material. Percolating waters, while converting the latter into impure clays, would effect the rounding of the coarser clastic constituents of the fissure-contents.

The substitution of ore and other vein-stuff for the disintegrated and decomposed material in a fissure-cavity no doubt sufficiently explains the occurrence in many lode-breccias of dispersed, rounded or eroded rock-fragments. Without careful scrutiny of the circumstances of their formation, it may be impossible to discriminate betwixt these breccias and those resulting from the passage of mineral-laden waters through rock broken up *in situ*, or crush-breccias.

Illustrations of the modes of origin and characters of fissure-breccias.—Good examples of vein-breccias that have imperfectly filled fissure-cavities are those of Strontian, in Argyllshire, and Wheal Phoenix, Cornwall (fig. 9), consisting respectively of an aggregate of rock-fragments held together by brewsterite and of lamellar portions of crystallized lode-quartz having their free surfaces encrusted with cuprite.

What is really a fissure-breccia modified by the action of lode-waters is the stanniferous and cupriferous breccia-conglomerate of Relistian mine, Gwinear, Cornwall,[2] frequently described as a congeries of surface-pebbles of quartz and killas.

From J. Carne's[3] account of this lode-material we gather that it was a body of pebbles of some 12 feet cube, lying between the outer forks of a quadrifid argillaceous cross-vein (flucan), and commencing at a depth of 75 fathoms. Other pebbles distributed singly or in bunches occurred 4 fathoms above and 5 fathoms below where it was first discovered. Of its components Carne observes: 'The pebbles are generally composed of

and C. G. A. von Weissenbach, 'Abbildungen merkwürdiger Gangverhältnisse aus dem sächsischen Erzgebirge,' 1836, pp. 21–26.

[1] S. F. Emmons, Trans. Amer. Inst. Min. Eng., 1888, vol. xvi, pp. 822–823.

[2] Greg and Lettsom, 'Manual of the Mineralogy of Great Britain and Ireland,' 1858, p. 357, erroneously give the Wherry mine, Penzance, as the locality.

[3] J. Carne, Phil. Trans., 1807, vol. xcvii, pp. 293–295.

shist [*sic*], cemented in some parts by the same substance or chlorite, in others by oxyde of tin, which is generally crystallized, and in some of the crevices there is a little copper pyrites.'

If the formation of the Relistian lode took place long previous to the main denudation of the Gwinear district, the distance of any superficial detritus from the deepest location of Carne's pebbles must have been of far greater extent than his figures indicate. A significant, though negative feature of the lode-material is the lack of fine-grained debris of evident alluvial origin. This one would imagine to be more likely to pass freely into the deep recesses of a rock-fissure than surface-pebbles and sub-angular blocks mostly not less in size than tennis-balls, some being many inches in length.

In the specimens of this breccia-conglomerate at the Museum of Practical Geology the only visible quartz bearing the semblance of a pebble is that occupying a globular space apparently voided by a nodule of killas (A, fig. 10). This, presumably, is one of the 'few pebbles' noted by Carne as 'composed of tin in quartz coated with chlorite.' The other quartz within view is interstitial, and is unmistakably of later origin than the chlorite that has penetrated into and everywhere invested the killas nodules. The killas shows no signs of weathering 'at grass' or of exposure to impact sufficient to develop signs of cleavage. Rounding of the edges of the nodules, as if affected by a solvent, has been generally very complete. In some broken hand-specimens, moreover, the cleavage-planes of several adjoining masses of the chlorite-clad killas may be seen to be approximately parallel, as if they were portions of one original block that had been scotched, segmented, and finally rounded by a liquid erosive agent. Trevascus mine, it may be observed, has yielded a stanniferous vein-stone precisely like that of Relistian, except in the marked angularity of the fragments of killas united by chlorite: clearly no surface-weathering has affected its constituents.

Fallen portions of the hanging-wall of lodes, observes Moissenet,[1] being acted upon by water . . . would become globular, and would sometimes form the nuclei of spheroidal concretionary masses. Miners in the Furness and Frizington districts in the north of England in fact not infrequently come upon water-worn pebbles of haematite imprisoned in cavities (locally 'loffs') in water-courses following cracks or faults in iron-ore, very frequently at the junction of vein- and country-rock.

The 'pebbles' of the Relistian lode-stuff are evidently identical in

[1] L. Moissenet, 'Études sur les filons de Cornwall,' 1874, p. 75.

origin with the 'angular fragments of shist' observed by Carne at a depth of 65 fathoms. They may be safely regarded as having travelled no further than the walls of the lode in their immediate neighbourhood. The history of the rock can, in fact, be but little different from that of a conglomerate in a gold-bearing vein in the Remedios district, Antioquia, Colombia, South America. This 'in all the instances observed', says Halse,[1] 'was evidently formed *in situ*, and probably in the main by the sliding-down of the hanging-wall.' Angles of the larger fragments were 'taken off to some extent by attrition, the rounding process being completed by the later inflow of thermal waters, which also cemented the pebbles together, finally converting the whole into one solid mineral mass.'

The angular inclusions of fissure-breccias.—In British fissure-breccias the presence of definitely angular portions of country-rock is far from rare. Sir W. W. Smyth[2] remarked of the lode of the Cornelly or Townsend mine in the Isle of Man that it was vuggy and sometimes fragmentary, with sharp, angular country-stone. In a vein-stone from Allenheads, Northumberland (fig. 11) we find angular bits of slaty rock, each with an exterior ring of chalybite—clearly their first investment—dispersed in a quartz matrix. Sir H. T. De la Beche[3] specifies nine Cornish mines besides Relistian in which angular fragments of slate were noted in a basis of metalliferous minerals.

Speaking of the Menheniot, Lanreath, and St. Pinnock lead-lodes, Henwood[4] remarks that the metalliferous portions are now and then separated from the containing country-rocks by bodies of breccia, in which for the most part angular masses of slate are enveloped in successive secretions of quartz, all of more or less radiated structure.

A lead-lode breccia from Wheal Betsy, Mary Tavy, Devon, exhibits sharp-cornered bits of Culm-measures country-slate completely isolated from one another, as a series of parallel sections (figs. 12–15) proves, by crusts of well-terminated quartz crystals. The bits of slate must have been subjected to stress tending to open out cleavage-planes, for the edges of some are serrate, and here and there incomplete longitudinal cracks occupied by quartz are visible. Many indicate by their slight

[1] E. Halse, Trans. Amer. Inst. Min. Eng., 1906, vol. xxxvi, pp. 154–177.

[2] See G. W. Lamplugh and W. W. Watts, loc. cit., p. 517.

[3] Sir H. T. De la Beche, 'Report on the Geology of Cornwall, Devon, and West Somerset,' 1839, pp. 322–323.

[4] W. J. Henwood, Trans. R. Geol. Soc. Cornwall, 1871, vol. viii, Part I, pp. 712–713.

lateral displacement their former connexion with one another. The appearance of the breccia is such as would be produced by the gradual shifting of the quartz-covered fragmental slate into the lode-fissure, and the filling in of interstices by fresh deposition of quartz crystals.

The detachment and encrustation of angular shreds and strips of country-rock to form a breccia is well exemplified by the slate-quartz-barytes-veinstone of the cross dip-fault breaking the main fault between the Pre-Cambrian and Arenigs at Pont Bren, Aberdaron (fig. 16), and also by the similar slate-quartz-galena lode of the lead-mine near Pont Erwyd, North Wales (fig. 17).

Inferences from characters as to the provenance of angular inclusions.—The dispersal of apparently isolated angular bits of country-rock in breccias such as those just mentioned is a problem requiring elucidation. Their maintenance free in vein-cavities contrary to gravitation until enveloped in cement is no more thinkable than the fabled suspension of Mahomet's coffin in mid-air. Their frequently uneroded and fresh-looking, sometimes partly silicified condition negatives the supposition that they are necessarily the undissolved remnants of vein-debris. Waters capable of dissolving away finely comminuted rock would certainly leave on the coarser portions some definite signs of their destructive action.

The suggestion has been made that when the rock-fragments in fissure-breccias seen in section are seemingly not in contact, but swimming as it were in their matrix—*rari nantes in gurgite vasto*—they yet actually support and are frequently wedged into one another or are nipped between vein-walls.[1]

This contention, if approximately true of ore-bearing fissure-breccias, seems doubtfully relevant with respect to such rocks as the brecciated vein at Port Henry, on Lake Champlain, New York, described by Sterry Hunt,[2] consisting of elongated irregular fragments of hornblende-gneiss from the wall-rock 'completely enveloped in crystallized calcium carbonate'. It provides us, further, with no explanation of the origin and persistence in many fissure-breccias of a mosaic-like arrangement of what are clearly the constituent portions of cross-fractured angular bits of country-rock.

Of some specimens of vein-stone from Huelgoët, in France, it has, for example, been remarked that they contain slaty fragments apparently

[1] A. W. Stelzner and A. Bergeat, op. cit., p. 537; see also Pošepný on the structure of ring-ores, 'The Genesis of Ore-Deposits,' 1902, 2nd ed., pp. 64–65.

[2] T. Sterry Hunt, 'Mineral Physiology and Physiography,' 1886, p. 237.

separated from one another by slow degrees, and showing the exact way in which these formerly fitted together.[1] Such fragments, having been gradually parted from one another without, as a rule, much alteration of their relative positions, have clearly been prevented from falling far asunder by the interposition of a crystalline cement.

Seemingly Weissenbach's theory that the force of crystal growth—well exemplified in the disintegration of chalk fossils dried after saturation with sea-water, and in the breaking up of rock and mineral specimens by melanterite developed from contained marcasite by atmospheric oxidation and hydration—may be efficacious in providing the angular constituents of vein-stuff does not apply to the fragments in question. We may confidently assert that not until these were bound together by crystal growth as we now see them were they removed from the walls to the body of any vein. Dislocation loose into a fissure-cavity would have subjected them, under the action of gravity, to disarrangement sufficient to prevent any recognition of their relationship, even if, unlike the country-rock inclusions in a breccia from the Devon United mine, Peter Tavy, Devon (fig. 18), they had escaped attack by percolating solvent waters and consequent partial replacement by chlorite, felspar, quartz, and other minerals.

Facts suggesting that brecciation is sometimes independent of earth-movements.—Sir H. T. De La Beche appears to have arrived at the opinion that the degree of brecciation of a lode is dependent entirely on the amount of regional disturbance in which it has participated. The view, however, that the presence of angular fragments of country-rock in vein-breccias is always positive testimony to the shattering effect of earth-movements does not tally with the conclusions suggested by a consideration of characters presented by a goodly number of examples of mine-material.

The fractured appearance of some west of England vein-stones in which there has been considerable leaching-out of country-rock is in favour of the view that occasionally dissolution at a more rapid rate than replacement has occasioned falls of vein-stuff by the withdrawal of support (see fig. 19).

That there is another and more frequent cause of brecciation in mineral-veins, acting quite independently of earth-movements, seems to be indicated by the following facts:—

In the Tavistock district, Devon (see fig. 18), and in Cornwall—in the

[1] J. A. Phillips, 'A Treatise on Ore Deposits,' 2nd ed., by H. Louis, 1896, p. 86.

Trevascus mine, for example—the gangue of brecciated country-rock (either Culm-measures slate and shale or killas) may be found extending as thin seams or well-marked bands into the vein-walls, mostly along cleavage-planes, just as far as dislocation or contortion of those planes has been brought about.

When the banding and disturbance of the wall of a brecciated vein do not proceed far into its country-rock, it may with reason be questioned whether either those features or the formation of the breccia should be regarded as the results, direct or indirect, of earth-movements. It can scarcely be argued that the physical changes in the country-rock besides the brecciation of the vein within it might be due to the dragging and rubbing of one vein-wall against the other. The fact that affection of the country-rock is conterminous with the limits of the narrow areas laminated by the intrusive breccia-cement points pretty conclusively to the causation both of it and of the brecciation without differential movement of the vein-walls. Henwood,[1] moreover, has pointed out that thin included slices of rock ('horses') in lodes, i.e. masses lying apart from though 'jointed and cleaved uniformly with the immediately contiguous (*Country*) strata . . . are occasionally penetrated, from either side, by slender strings of the vein-stones'.

It can certainly not be maintained that the banding of killas and other fissile rocks just in the immediate vicinity of lodes is due to a segregation of minerals such as obtains in the foliation of gneiss, for these rocks, except as regards disturbance of the parallelism and cohesion of their original laminae, have generally undergone no marked intrinsic change.

The smallness of the mean percentage volume of the interspaces determined by Sorby to exist in slates—3·6 (Moffat) to 0·24 (Penrhyn)—is opposed to the conjecture that the abundant mineral bands often to be seen in the boundary walls of brecciated veins therein are deposits from absorbed water. Weissenbach, in support of his theory of the disruption of vein-rocks by crystalline force, adduces the breaking-up of loam and clay by the growth in them of crystals of gypsum and ice. Now, Sorby[2] reckons the volume of the cavities in but slightly compressed clays at 32 or 33, and in Tertiary clays at 28·8 per cent. Crystallization within a loam or clay saturated with moisture may, therefore, be regarded as the segregation of particles from a liquid thickened by admixture with

[1] W. J. Henwood, loc. cit., p. 712.

[2] H. C. Sorby, Quart. Journ. Geol. Soc., 1908, vol. lxiv, p. 228.

nearly twice its bulk of mobile foreign matter. We have here no criterion of the behaviour of solutions occupying the interspaces among the constituents of nearly compact rocks. We lack, also, evidence that rifts in such rocks would be gradually enlarged by accretions on mineral-deposits already filling them until extensive fractures had been produced. Continued accretion on the inner ends of crystals lining the walls of a rift would require the maintenance of a median passage for the free ingress of fresh supplies of the invading mineral—a condition doubtfully compatible with the exercise of disruptive crystalline force. Accretion on the outer ends or bases of the crystals would imply a porosity of the walls of the rift inconsistent with the characters of many country-rocks.

The supposition that unsupported fallen fragments and cleft and gaping masses of country-rock were kept in the positions in which they appear in breccias until the filling up of free spaces by secondary deposits is manifestly untenable.

Hydrostatic pressure regarded as a brecciating agent.—If we may accept the postulate that all spaces filled by the cementing materials of breccia were first occupied by solutions of the same, we have practically arrived at an explanation of the origin of those fissure-breccias whose structure, like that of some above described, gainsays the assumption that their fragmental inclusions were disrupted from country-rock or vein-stuff by earth-movements. The features of such breccias and of fissile rock-walls enclosing them are readily explicable as the results of the hydrostatic pressure and movement and usually also of the solvent properties of mineralizing waters flowing through deep fissures. Thus, while the deposition of cement-substance in rifts already formed was going on, the opening-out of fresh channels and the occasional quiet disruption of rock-fragments could be effected. Sorby[1] has shown that pressure may be an important factor in determining the solution of rock-constituents. Doubtless, too, its solvent action is greatly enhanced by high temperatures, which, moreover, by lessening the viscosity of water, promote its flow through capillary openings.[2]

It should, in addition, be noted that orogenic movements productive of new fissures, seasonal variations in the vadose or shallow underground circulation of water, surface denudation, and all other causes of relief of hydrostatic pressure would further brecciation by allowing of the

[1] H. C. Sorby, loc. cit., p. 224.

[2] C. R. Van Hise, 'A Treatise on Metamorphism,' Monogr. U. S. Geol. Surv., 1904, p. 1027.

regurgitation of fluid with its suspended particles out of the saturated wall-rock into the cavities of veins.

Testimony to the existence of considerable hydrostatic pressure *previous to the infilling of fissures* is afforded by the splitting and bulging of bands of cleavable rock occurring in Cornish and many other vein-stones, e.g. in auriferous chloritic lode-stuff from Greenwood, British Columbia (fig. 20). The latter shows also the commencement of contortion of country-rock at the point of intrusion of quartz.

A specimen of jasper-breccia in the author's possession (fig. 21) evidences the fragmentation along cleavage-directions and the subsequent silicification of dark-coloured country-rock by the flow of a clear solution of quartz.

Other good examples of the fission of a soft rock by lode-waters are the quartz-chalcopyrite-killas-breccias of Fowey Consols and Wheal Tolgus, Cornwall (Nos. 295 and 250, Coll. Mus. Pract. Geol.).

Conclusions.

Brecciated mineral-veins may be classed as those in which the material cemented is (1) rock fractured *in situ*; (2) fragments of the walls or of the contents of veins dislocated into fissures by regional disturbances; (3) similar fragments shifted from their original positions by the hydrostatic pressure and the solvent action of water flowing at great depths.

Owing to the variety of influences to which the contents of mineral-veins may be subjected, very careful consideration may be necessary in order to determine whether any particular brecciated portion should be referred to one or more of these three classes.

[*Explanation of Plates*, p. 136.]

Explanation of Plates IV–VI.

Fig. 1. Vein-breccia from Esgair Hir mine, Cardiganshire (Coll. Mus. Pract. Geol., No. 374): actual size, 10 × 16·4 cm. (p. 125).

„ 2. Vein-breccia from the Perran lode, near Marazion, Cornwall: actual size, 9·5 × 16·0 cm. (p. 125).

„ 3. Breccia-like lode-material from Restormel mine, Lostwithiel, Cornwall: actual size, 8·0 × 11·5 cm. (p. 125).

„ 4. Vein-breccia from Grassington lead-mines, Yorkshire (Coll. Mus. Pract. Geol., No. 346) : actual size, 17·5 × 24·0 cm. (p. 127).

„ 5. Vein-breccia from Cronebane mine, Co. Wicklow, Ireland (Coll. Mus. Pract. Geol., No. 347) : actual size, 21·0 × 21·0 cm. (p. 127).

„ 6. Vein-breccia from near Sourton, Devon: actual size, 8·5 × 11·2 cm. (p. 127).

„ 7. Quartz-rock (an altered vein-breccia) from Wheal George, near Dittisham, Devon: actual size, 15·0 × 18·5 cm. (p. 127).

„ 8. Quartz-rock in vein-stone similar to No. 7, from Peak Hill, near Dittisham, Devon: actual size, 4·0 × 4·5 cm. (p. 127).

„ 9. Quartz-cuprite-fissure-breccia from Wheal Phoenix, Cornwall (Coll. Mus. Pract. Geol.) : actual size, 17·4 × 27·4 cm. (p. 128).

„ 10. Breccia-conglomerate from Relistian mine, Gwinear, Cornwall (Coll. Mus. Pract. Geol., No. 385): actual size, 22·0 × 29·0 cm. (p. 129).

„ 11. Slate-chalybite-quartz-fissure-breccia from Allenheads, Northumberland (Coll. Mus. Pract. Geol., No. 378) : actual size, 14·0 × 18·0 cm. (p. 130).

„ 12. Lead-lode breccia from Wheal Betsy, Mary Tavy, Devon: actual size, 4·3 × 7·8 cm. (p. 130).

„ 13. Lead-load breccia from Wheal Betsy, Mary Tavy, Devon (section parallel to No. 12) : actual size, 6·5 × 9·7 cm. (p. 130).

„ 14. Lead-lode breccia from Wheal Betsy, Mary Tavy, Devon (section parallel to No. 13) : actual size, 6·3 × 10·0 cm. (p. 130).

„ 15. Lead-lode breccia from Wheal Betsy, Mary Tavy, Devon (section parallel to No. 14) : actual size, 5·7 × 10·0 cm. (p. 130).

„ 16. Slate-quartz-barytes-breccia from Pont Bren, Aberdaron, North Wales: actual size, 8·5 × 15·0 cm. (p. 131).

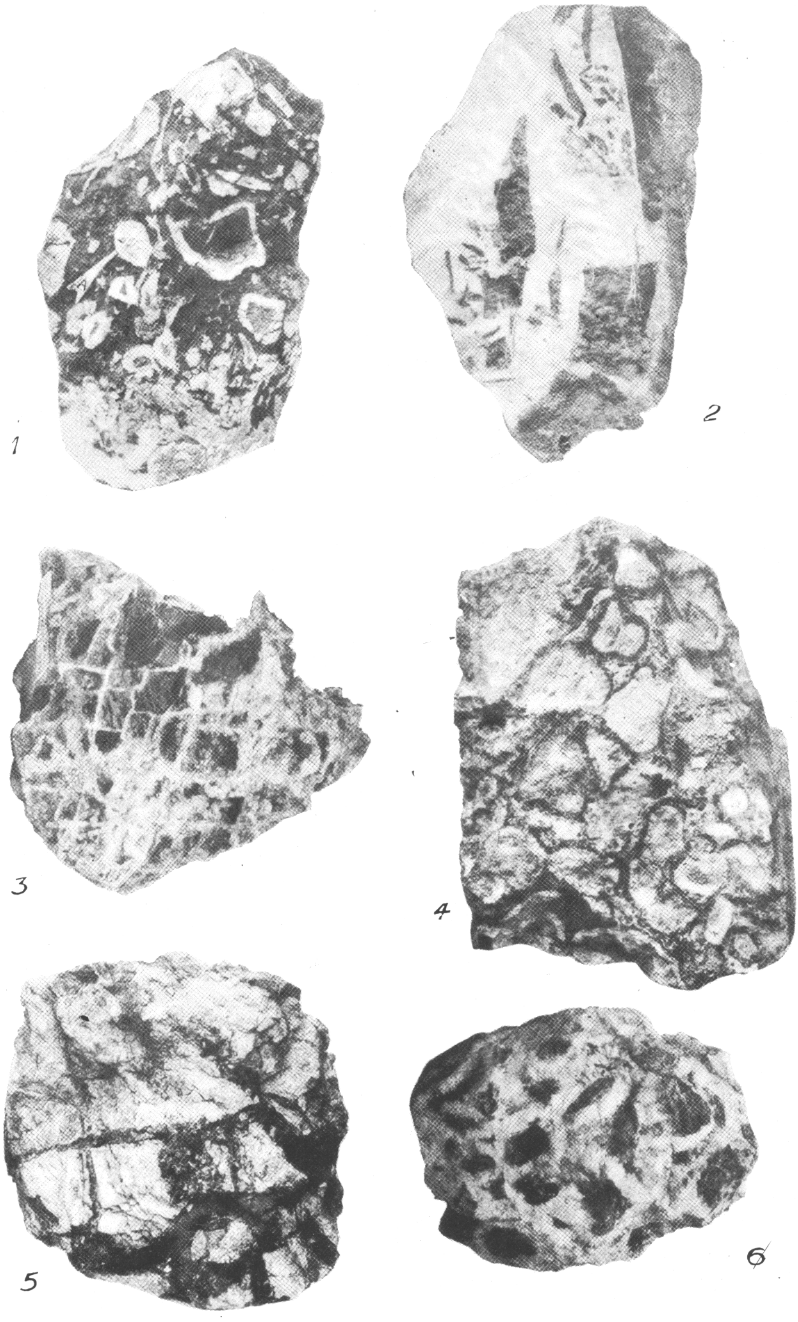
„ 17. Lead-lode slate-quartz-galena-breccia from Pont Erwyd, North Wales: actual size, 7·0 × 9·8 cm. (p. 131).

„ 18. Junction of vein-breccia and country-rock, Devon United mine, Peter Tavy, Devon: actual size, 8·8 × 14·0 cm. (p. 132).

„ 19. Slate-quartz-breccia from near Sourton, Devon: actual size, 8·5 × 11·9 cm. (p. 132).

„ 20. Quartz-chlorite-killas-vein-breccia (transverse section), from Greenwood, British Columbia: actual size, 5·0 × 11·0 cm. (p. 135).

„ 21. Green and white jasper-breccia, from India: actual size, 6·3 × 15·5 cm. (p. 135).



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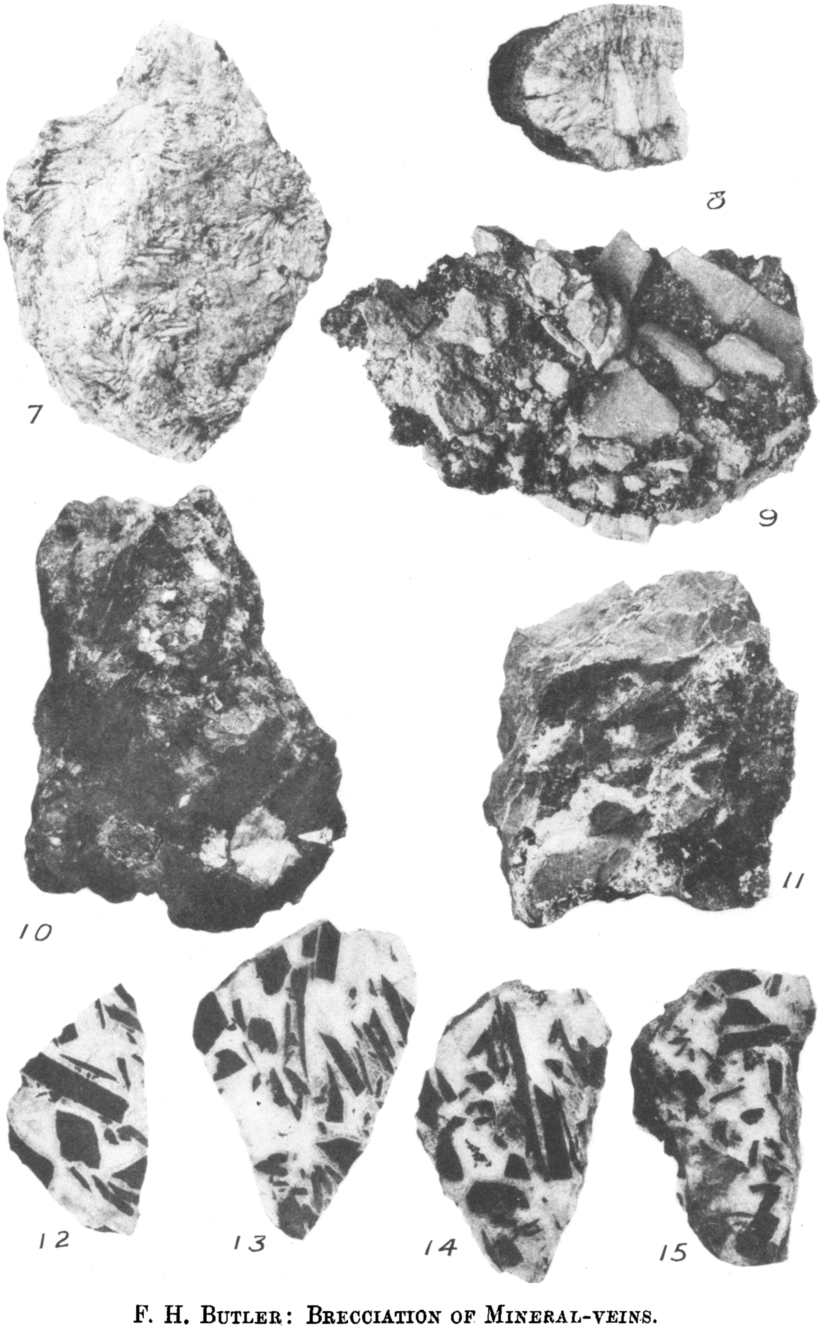

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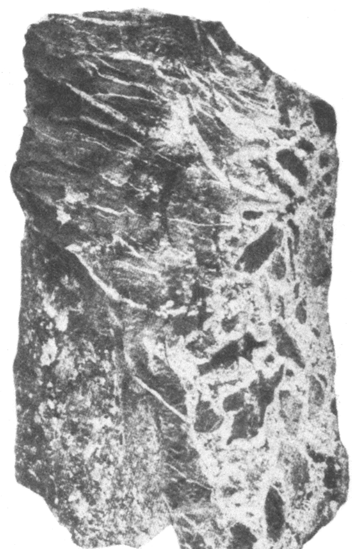

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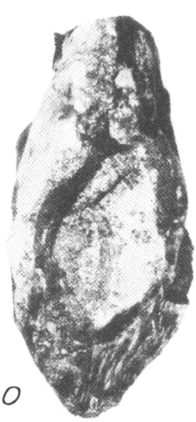

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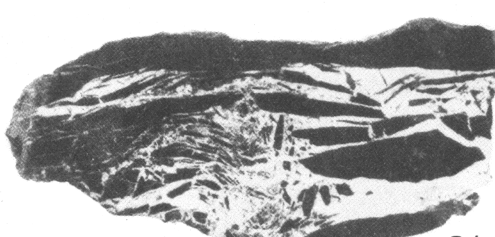

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