Curvature in Crystals.

(*With Plates VII and VIII.*)

By L. J. Spencer, M.A., Sc.D., F.G.S.

Assistant-Keeper in the Mineral Department of the British Museum.

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THE following notes were prepared at the request of Dr. J. E. Stead, F.R.S., the well-known metallographer. Several years ago he had obtained in a tin-antimony-arsenic alloy[1] some remarkable crystals having the form of segments of spherical shells (fig. 3, p. 272 below), and he naturally wished to learn if anything of the same kind was known amongst minerals. The notes contain no new data, but merely collect together facts already known to mineralogists. They may perhaps be of some use to metallographers in calling attention to the various habits of growth met with amongst minerals, since distortions and irregularities of crystalline growth are so frequent amongst metals.

The text-books on crystallography and mineralogy deal mainly with the ideal symmetrical development of crystals, and, as a rule, give only brief accounts of 'the imperfections of crystals' or crystals as they are actually developed. This branch of the subject has consequently been somewhat neglected, and much remains to be learnt respecting it. There is, however, much scattered literature relating to the matter, and several references to more recent papers will be found in the Mineralogy volumes (1–14, for 1901–14) of the 'International Catalogue of Scientific Literature' under the headings 'Irregularities in

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[1] Specimens were shown at the Royal Society's Conversazione in 1906, and the complete description is given in the paper 'The ternary alloys of tin-antimony-arsenic', by J. E. Stead, with notes by L. J. Spencer, Journ. Institute of Metals, London, 1919, vol. 22 (no. 2 for 1919), pp. 127–144, 10 pls.; reprinted [from the uncorrected proofs] in Engineering, London, 1919, vol. 108, pp. 663–667 [Min. Abstr., vol. 1, p. 231]. In the discussion (pp. 145–148) on this paper Prof. Carl A. F. Benedicks offers an ingenious explanation of the curvature of the spherical shells, basing it on differences in the dilatation-coefficient corresponding with variations in chemical composition of the lamellar mixed crystals during growth.

crystals, variation in angles, vicinal faces, character of faces', and 'Twinning, gliding-planes, &c. Regular grouping of crystals'. A whole treatise could in fact be written on this subject, and many beautiful illustrations could be reproduced. The present disjointed notes indicate no more than the salient points, while some of the explanations are quite conjectural and are offered for criticism. Many of the examples are taken from the British Museum collection of minerals, and several illustrations will be found on the 91 plates of R. Brauns's '*Mineral Kingdom*', *English translation* by L. J. Spencer, 1908–12. A number of examples of curvature of faces and contortion of crystals are figured by L. Bombicci in his mineralogical text-books (1862, 1889) and in various papers presented to the Academy of Science of Bologna (1872–99).

The curvature of crystals is evidently of many different kinds and due to as many different causes:—

Curved crystallites—the *trichites* of F. Zirkel (1873)—are the most primitive form of curved crystals. These are hair-like and feathery forms occurring in glassy igneous rocks, and are well shown in micro-sections of the pitchstone of the Island of Arran (figured by S. Allport, Geol. Mag., 1872, p. 1; J. J. H. Teall, 'British Petrography', 1888, pl. 34; Brauns, pl. 59).

Similar structures in a more advanced stage of development are the feathery microlites of felspar, augite, &c., also occurring in volcanic rocks (J. P. Iddings, 'Rock Minerals', 2nd edit., 1911, pp. 58–59, 214–215, figs. 16–20 and 24–28). These are also common in the silicate fusions made with the view to the artificial production of rocks and minerals. Similar forms are often produced by crystallizing various artificial substances on microscope-slides (O. Lehmann, 'Molekularphysik', 1888–9, vol. 1, pp. 375–385, figs. 184–192; 'Flüssige Krystalle', 1904, pp. 123–126, figs. 363–379; H. A. Miers, Min. Mag., 1908, vol. 15, pl. 1). Mention may also be made of the frost patterns on window-panes and on muddy pavements, which may be either rectilinear or curved and frond-like. A large series of beautiful photomicrographs of frost and ice crystals are given by W. A. Bentley, 'Studies of frost and ice crystals', Monthly Weather Review, 1907, vol. 35; reprinted U.S. Weather Bureau, 1908.

In all these instances there has been hurried crystallization, which moreover has been hindered by viscosity and surface-tension. Such conditions are conducive to twin-growths in crystals; and it is probable that the curvature is a result of twinning in the endeavours of the this connexion mention may also be made of the spherulitic and orbicular or spheroidal structures in igneous rocks, and the problematical 'cone-in-cone' and other concretionary structures in sedimentary rocks.

The forms of aggregation above mentioned are usually exhibited by minutely crystallized material, but larger crystal individuals may be aggregated in much the same fashion. For example, we may have radiating, more or less globular aggregates of quite large crystals of quartz, sheaf-like aggregates of stilbite, warty groups of prehnite, fibrous and columnar bundles of tourmaline, rosettes ('iron-roses') of platy crystals of haematite (Brauns, pls. 2 and 28). In many of these cases the individual crystals are grown together in not quite parallel position. The deviation from parallelism between adjacent crystals may be only small, but if this slight difference is repeated in the same sense through a long series of small individuals a curved surface will result (text-fig. 1). Such sub-parallel grouping of crystals is of very frequent occurrence. Examples are the barytes and dolomite groups shown in pl. VIII, figs. 11 and 12.

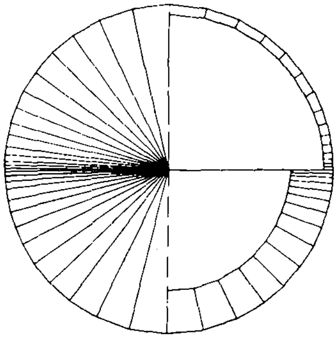


FIG. 1.—Approximation to a curved surface produced by the radial aggregation of a large number of small, individual crystals.

Almost all crystals, however small and perfect, show signs of being built up of smaller individuals; and on the goniometer the faces give scattered reflections of the signal-image, isolated areas and spots on different parts of the crystal usually helping to produce this effect. With larger crystals such irregularities increase, and the faces are often quite rough and uneven from this cause. In fact, it is not always easy to decide whether we are dealing with a single crystal or an aggregate of crystals; and they may pass insensibly into the forms mentioned above.

In the cases just considered there is a lack in continuity in the crystal-structure; and the material if examined in polarized light will be seen to be built up of differently orientated portions. We will now pass to the consideration of cases of curvature in a single homogeneous crystal. Here again the curvature may be of different kinds and due to different causes.

crystals to find constantly fresh directions of growth when they have been hindered in their original direction.

Capillary habit is of frequent occurrence amongst minerals of many kinds, and these fine, hair-like crystals may not only be bent and twisted, but may form matted, woolly, felted, or even compact aggregates (e.g. jade). Many such minerals are suggested at once by their names, e.g. chalcotrichite or plush-copper-ore (from θρίξ, τριχός, hair), halotrichite or feather-alum, plumosite or feather-ore (from *pluma*, a feather), pilolite or mountain-leather, mountain-cork, &c. (from πῖλος, felt), ptilolite (from πτίλον, down), erionite (from ἔριον, wool), and crocidolite (from κροκύς, κροκύδος, the flock or nap on woollen cloth). Other fibrous minerals of the same character are hair-salt or alunogen, hair-pyrites or millerite, hair-zeolite (including mesolite, natrolite, &c.), asbestos and other asbestiform minerals. In most of these cases the fibrous habit is characteristic of the particular mineral; but chalcotrichite affords a peculiar instance of irregular development. Crystals of cuprite are, as a rule, well and equably developed, but in the chalcotrichite variety they become enormously elongated in the direction of an edge of the cube. The same also happens in the case of kalinite or potash-alum, which is easily crystallized artificially as well-developed regular octahedra, but is usually found in nature as an efflorescence of bent and twisted, silky hairs.

Aggregations of crystals give rise to a great variety of indeterminate forms usually with curved surfaces. These are of extremely common occurrence in the mineral kingdom, and are described as globular (e.g. wavellite, calcite, sphaerite, sphaerocobaltite, sphaerosiderite, sphaerostilbite, bismutosphaerite, &c.), botryoidal (e.g. prehnite, hydrodolomite, andrewsite), mammiform (e.g. psilomelane, malachite, arsenic, &c.), reniform (e.g. kidney-iron-ore, menilite), warty (e.g. vanadinite), nodular (e.g. zinc-blende), amygdaloidal (e.g. agate), stalactitic (e.g. calcite, chalcedony, limonite, marcasite, &c.), coralloidal (e.g. aragonite), oolitic and pisolitic (e.g. calcite and aragonite), vermicular (e.g. chlorite), dendritic or arborescent (e.g. native copper, pyrolusite, bismuth), leafy (e.g. gold), wiry (e.g. silver, often curiously twisted, Brauns, pls. 6 and 7), mossy (e.g. copper), plumose (e.g. mica). Such forms are, of course, due to growth under a variety of conditions. For instance, flat dendritic forms are due to confined growth in a rock-crevice and are met with in a great variety of minerals (Brauns, pl. 2, showing dendritic iron-pyrites and wollastonite). Stalactites, on the other hand, have grown freely in cavities from dripping solutions. In

Interfacial oscillation.—A step-like repetition of two adjacent faces on a simple crystal may give rise to the rounding of an edge or to wider surfaces marked by striations parallel to that edge. Here the curvature is cylindrical with the edge in question as axis. A common example of this is seen in crystals of iron-pyrites with the cube and the pentagonal-dodecahedron *e* (210) in combination. Calcite crystals are very often much striated and rounded between the faces *r* (100) and *e* (110); and when these are the only forms present the crystals may be lenticular. Prismatic crystals of beryl are always striated parallel to the prism-edge, due to oscillation between the faces *a* $(11\bar{2}0)$ and *m* $(10\bar{1}0)$: this is sometimes carried so far that the crystals are cylindrical. The same happens even more frequently in prisms of tourmaline, though here, corresponding with the hemimorphic development, the curvature is about three axes which do not coincide with the central axis of the crystal. Diamond crystals showing stepped areas and curved, striated surfaces due to oscillation between adjacent octahedron faces, are figured by A. von Fersmann and V. Goldschmidt, 'Der Diamant', 1911, pl. 5, &c. Striated zones are, in fact, of common occurrence on crystals of very many substances, and on the goniometer they frequently give a continuous band of reflected images. How far this reflection is due to the scattering of light from the striated surface or to simple reflection from vicinal faces it is not always easy to decide.

Vicinal faces are perhaps the most common cause of the curvature of the surfaces of simple crystals. A progressive succession of such faces with small angles between small adjacent faces would give rise to a curved surface (Sir H. A. Miers, 'Mineralogy' 1902, p. 248, fig. 391; see also Miers, Phil. Trans. Roy. Soc. London, 1903, ser. A, vol. 202, p. 459). Good examples are afforded by the lenticular crystals of gypsum and phacolite (so named from φακός, a lentil); and by crystals of diamond, of which many good illustrations are given by A. von Fersmann and V. Goldschmidt, 'Der Diamant', 1911. The name cyrtolite (κυρτός, curved) was applied to a variety of altered zircon on account of the marked curvature of the pyramidal faces.

In some minerals certain faces with very simple indices are rarely developed and then only as rounded surfaces approximating to the true position; e.g. the basal plane on quartz and witherite (pl. VIII, fig. 8). Such rounded surfaces may be observed on the edges and corners of most crystals. The reflection of a spot of light from these surfaces gives a pattern ('light-figure') conforming with the degree of symmetry of the crystal. They are usually regarded as the results of corrosion, and similar forms ('prerosion faces') may be produced artificially by placing a crystal in a suitable solvent. The small pits and flat hillocks ('etch-figures', '*etch-hills*', '*etch-shields*', &c.) *produced on the faces of crystals* by corrosive liquids are also bounded by curved surfaces with the complex indices of vicinal faces.

Very similar forms may, however, also be developed during the period of growth of crystals ('hills of growth', 'hopper-shaped' crystals, &c.); and it is not always easy to decide with a given crystal whether such forms are the result of corrosion or of growth. 'Hills of growth' may sometimes be seen to consist of a pile of thin, flat plates, their edges forming, as it were, contour-lines on the curved surface.

Vicinal faces, and perhaps sometimes a consequential rounding of the surface, are also developed on crystals that have undergone a molecular transformation. Such crystals, which are characterized by their 'optical anomalies' (e.g. boracite, leucite, &c.), have grown and acquired their external form at a temperature at which one modification of the substance is stable; at another temperature the material changes over into another modification stable under the new conditions.

Bent crystals.—Subsequent to their growth, mineral crystals may be broken or bent by earth-pressures. Prismatic crystals of tourmaline (pl. VII, fig. 2), beryl, quartz, actinolite, gypsum, chlorite, &c., are sometimes bent in this way. Fibrous minerals of various kinds occurring as a filling in rock-crevices, and with the fibres arranged perpendicularly to the walls, frequently show a curved or zigzag bending of their fibres, due to a differential movement of the rock-walls. For example, the South African crocidolite and pseudo-crocidolite (or 'tiger-eye'); and gypsum (satin-spar), see W. A. Richardson, Min. Mag., 1920, vol. 19, pp. 82, 92, fig. 1 c.

A prism of smoky-quartz from Mursinsk, Urals, in the British Museum collection (pl. VII, fig. 5) is sharply bent with the two portions of the trigonal axis approximately at right angles. Brauns figures (fig. 4, pl. 2 a) one quartz crystal bent round another; see also A. Lacroix, 'Minéralogie de la France', 1901, vol. 3, pp. 37, 71. An enormous group of gypsum crystals, from Reinhardsbrunn in the Thuringian Forest, presented to the British Museum in 1847 by the Prince Consort, shows good examples of bending in the large prismatic crystals. Bent crystals from the same locality are shown in pl. VIII, fig. 10, and by Brauns, pl. 80; here the bending is due to secondary twinning along glide-planes. Curiously-twisted crystals and rosettes of gypsum are found in large quantities in the Mammoth Cave of Kentucky, and are known as 'oulopholites' (from οὖλος, a corn-sheaf, and φωλεός, a cave).

'These cave flowers are unfolded by pressure, as if a sheaf were forced through a tight binding, and the crystal fibres curl outward from the centre of the group' (Encyclopaedia Britannica, 9th edit., 1883, vol. 15, p. 449). A good example of them, from Roth Rocks, Indiana, is in the British Museum collection (pl. VIII, fig. 7). Similar forms from limestone caves in France are figured by Lacroix, 'Minéralogie de la France', 1910, vol. 4, p. 209.

The bending or plastic deformation of crystals is in fact a common phenomenon; and is due to secondary twinning or simple translation, induced by pressure along certain planes known as glide-planes. The characteristic striations on the cleavage-planes of stibnite and kyanite are due to this cause; and the secondary twinning which may be produced artificially by pressure in calcite is well known. Crystals of rock-salt, ice, gypsum, and many other minerals can be bent, by the application of pressure in a certain direction. S. Ichikawa has figured blade-shaped crystals of gypsum from Japan bent artificially into the forms of propeller-blades and hoops (Amer. Journ. Sci., 1917, vol. 44, p. 66, figs. 4 and 5). Glide-planes also exist in many native and artificially-produced metals. Day and Allen (The Isomorphism and thermal properties of the feldspars. Carnegie Inst., Washington, 1905, Publ. No. 31, pls. 25, 26) give figures of felspar cleavage-fragments bent under a load at a temperature of 1200° C. The 'liquid crystals' of certain carbon-compounds (e.g. para-azoxyanisol, ammonium oleate, &c.) are so highly plastic that they are deformed by their own surface-tension at ordinary temperatures, and they present spherical and rounded outlines.

Twisted crystals.—Perhaps the most striking instance of curvature in crystals is that presented by the twisted crystals of smoky-quartz from the Swiss Alps. These crystals have a spiral twist about one of the horizontal, digonal axes, the screw being a right-handed one in right-handed crystals, and a left-handed one in left-handed crystals. These have been described in detail and well figured by G. Tschermak (Über gewundene Bergkrystalle, Denkschriften Akad. Wiss. Wien, 1894, vol. 61, pp. 365–400, with 5 pls.; see also Brauns, pls. 2 and 2 a), and are regarded by him as twin-growths in which the twin-axes are perpendicular to vicinal faces approximating in position to the basal plane. A crystal of quartz, from Baveno, Piedmont, with a spiral twist about the vertical, trigonal axis is figured in Brauns, pl. 2 a.

Stibnite crystals sometimes have a spiral twist about the vertical (digonal) axis: figures are given by Miers ('Mineralogy', 1902, pp. 333, fig. 462), L. Bombicci (Mem. Accad. Sci., Bologna, 1886, ser. 4, vol. 7,

p. 129), and T. Wada ('Minerals of Japan', 1904, pl. VII 2), and a specimen in the British Museum shows a much more violent twisting (pl. VII, fig. 4). G. Friedel ('Leçons de Cristallographie', 1911, p. 265) suggests that the helical twist is here due to the glide-planes present in stibnite. Excellent examples of spirally-twisted crystals of cromfordite (= phosgenite, $PbCO_3 . PbCl_2$) from Cromford in Derbyshire are preserved in the British Museum collection. Here the twist is about the vertical, tetragonal axis. One specimen (pl. VII, fig. 1) shows a twisted crystal of prismatic habit projecting freely into a cavity and attached in parallel position (at its base) on another earlier-formed crystal of cromfordite of tabular habit which shows no twist. A helical twist is also occasionally shown by bent prisms of gypsum. A bent and twisted chlorite crystal represented in Dana's 'System of Mineralogy' (4th edit., 1855, p. 294; 6th edit., 1892, p. 653) is rather suggestive of a ram's horn, and there are good examples from Nordmark, Sweden, in the British Museum collection (pl. VII, fig. 6).

There does not appear to be any connexion between these twisted crystals and the screw-axes postulated in the geometrical theories of crystal-structure. Such screw-axes have been compared by F. M. Jaeger ('Lectures on the principle of symmetry', Amsterdam, 1917) with the spiral arrangements in plants.

Twisted crystals of another kind with a double curvature are well-known in the saddle-shaped crystals of dolomite (Miers, 'Mineralogy', 1902, p. 402, fig. 545). A similar effect is also seen in the crystals of the plagionite-semseyite group of minerals, which form a morphotropic series ranging in composition from $5PbS . 4Sb_2S_3$ to $9PbS . 4Sb_2S_3$. Here the habit of the crystals is the same for different members of the group, but the angles vary slightly with the chemical composition. In a compound crystal built up of smaller crystals of different composition there would be a lack of parallelism, and distorted and twisted surfaces would result. I have also suggested (Min. Mag., 1899, vol. 12, p. 68) that the same explanation may hold good in the case of the twisted crystals of dolomite, or rather 'brown spar' (since pure dolomite, $MgCa(CO_3)_2$, yields very sharply developed crystals). Here the compound crystals may be built up of smaller elements containing carbonates of calcium, magnesium, iron, and manganese in varying proportions, and consequently differing slightly in their crystal-angles. The same may also perhaps happen in some other isomorphous groups of minerals. For example, a barrel-like curvature is quite common in crystals of pyromorphite, mimetite (Miers, 'Mineralogy', 1902, p. 515, fig. 656), and vanadinite, the varieties polysphaerite and campylite (from καμπύλος, curved) being so named on this account. M. Amadori and E. Viterbi (Mem. Accad. Lincei, Rome, 1914, vol. 10, p. 405) have recently found that the interior and exterior portions of pyromorphite crystals from Wheal Alfred, Cornwall, differ slightly in composition.

If this explanation is a correct one, we should expect to find twisted crystals in such a large isomorphous group as that of the felspars. Curvature of any kind is, however, rarely shown by the minerals of this group, although zonal and parallel growths are common. There are curious coral-like aggregates of albite from Pike's Peak, Colorado. Twisted crystals of adularia with zonal enclosures, and somewhat resembling those of 'brown-spar', are found in Switzerland; the best example of this is one from Mompe-Medel, Disentis, recently presented to the British Museum collection by the Rev. J. M. Gordon.

Cylindrical (?) and Spherical (?) Crystals.—The curious case of kylindrite (from κύλινδρος, a roll) is considered apart, as it does not appear at first sight to fall into any of the groups considered above. This mineral is a sulphur-salt of tin, lead, antimony, and iron with the formula $Pb_3FeSn_4Sb_2S_{14} = 3PbSnS_2 + SnFeSb_2S_8$ (G. T. Prior, Min. Mag., 1904, vol. 14, p. 26). It has the appearance of consisting of tightly wound rolls of foil, with a smooth surface and brilliant metallic lustre. The ore consists of large numbers of these rolls with a more or less radial grouping. It has been found only at Poopó, near Oruro in Bolivia, but there in some quantity. The rolls have a diameter of a few millimetres up to 1 cm. and reach a length of 3–4 cm. They flake off in concentric cylindrical shells with all the appearance of a perfect cleavage, very similar to that of the allied minerals franckeite and teallite. These cylindrically-curved cleavage-flakes are perfectly bright and smooth, and show no visible signs of being built up of smaller elements (text-fig. 2).

In this connexion reference may be made to the 'cylindrical cleavage' of gypsum and anthophyllite described by G. Friedel (Bull. Soc. franç. Min., 1902, vol. 25, p. 102; abstract in Min. Mag., vol. 13, p. 396). A possible explanation is that kylindrite crystallizes in thin lamellae, like franckeite and teallite, but that here they are aggregated around an axis and consequently bent cylindrically. A somewhat similar case is afforded by the lamellar crystals of ice described by L. L. Fermor (Min. Mag., 1914, vol. 17, p. 150), which are wound spirally around the vertical, hexagonal axis, though here, as the faces of the hexagonal prism are distinctly developed, the form is not cylindrical.

In cylindrical aggregates such as stalactites of calcite, limonite, &c.,

the concentric layers of material are built up of acicular crystals radiating normally from the axis. I have been unable to find any examples of cylindrical aggregates in which these acicular crystals possess a good cleavage perpendicular to their length; nor (besides kylindrite) of cylindrical aggregates of lamellar crystals with platy cleavage and arranged concentrically on the surface of the cylinder.

Spherical aggregates of crystals possessing a platy cleavage are, however, met with, but here a radial grouping is much more common than a concentric arrangement. Examples of radiating spherical aggregates of lamellar crystals with platy cleavage are pyrophyllite, zeophyllite, gyrolite (γυρός, round), faröelite, tyrolite, &c. The 'pudding granite' of Vermont contains balls of muscovite with a grouping of the scales roughly parallel to the surface. Balls of howlite, a calcium silico-borate from Nova Scotia, consist of a similar aggregate of pearly scales. The chloritic minerals chamosite, berthierine, bavalite, of importance as ores of iron in Lorraine, Switzerland, and Brittany, have an oolitic or pisolitic structure in which the balls are built up of concentric layers of minute scales (A. Lacroix, 'Minéralogie de la France', 1895, vol. 1, figs. on pp. 400 and 401). Mica sometimes forms radiating aggregates of fibrous or columnar crystals in which the cleavage is perpendicular to the length

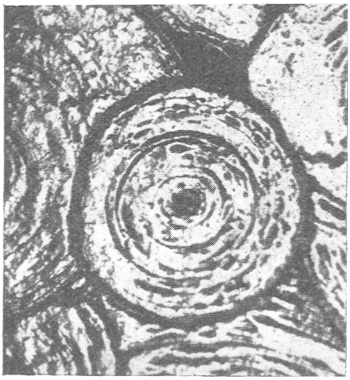


FIG. 2.

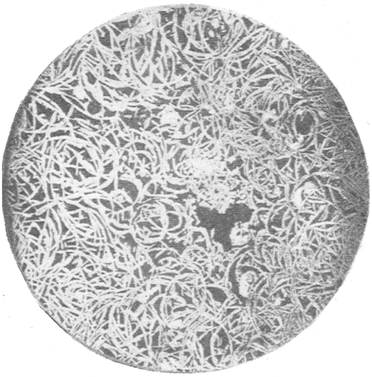


FIG. 3.

FIG. 2.—Kylindrite from Bolivia. Photomicrograph of a polished and etched section perpendicular to the axis of the rolls. × 13. (J. E. Stead, photo.)

FIG. 3.—Tin-antimony-arsenic alloy (artificial). Photograph of polished and etched surface showing sections of spherical shells. × ⅔. (J. E. Stead, photo.)

of the fibres. Such aggregates show bright and smooth cleavage-surfaces with spherical curvatures; e. g. muscovite from Kimito in Finland, Branchville in Connecticut, Stow in Maine (pl. VIII, fig. 9), and Arsuk in Greenland, and lepidolite from Auburn in Maine.

A similar structure is shown by the isolated balls of crystallized native arsenic found in large quantities at Akatani, prov. Echizen, Japan (T. Wada, 'Minerals of Japan', 1904, p. 7, fig. 1; S. Ichikawa, 1917, see Min. Abstr., vol. 1, p. 65). These consist of radially-grouped crystals with the apices of rhombohedra projecting like spikes from the surface. The tips of the crystals can be readily cleaved off parallel to the basal plane, which is tangential to the surface of the sphere. On breaking open the balls, they show, towards the centre, a well-marked spherical cleavage. This, though bright, is not perfectly smooth, and is readily seen to be composite, owing to the comparatively large size of the crystals even near the centre of the balls. Apart from the coarseness of the crystallization, this is exactly similar to the curvilaminar structure with shelly separation commonly shown by native arsenic and by allemontite ($SbAs_3$); here we have the limiting case in which the separate individuals are no longer recognizable. The same structure is often shown by artificial graphite from pig-iron, and it is also seen in a specimen of graphite from Franklin, New Jersey, in the British Museum collection. Similar also is the structure shown by the new mineral villamaninite (Min. Mag., 1920, vol. 14, p. 19), in which can be traced all stages from crystals with slightly rounded cube-faces to aggregates showing bright spherical surfaces. (Compare also the 'iron-roses' mentioned above on page 266.)

Quite apart from any consideration of theories of crystal-structure, the supposition of cylindrical and spherical crystals leads to a *reductio ad absurdum*; and we are referred back to the forms of aggregation considered earlier. It thus seems most probable that this is the correct explanation of the cylinders of kylindrite and the curious spherical shells of the tin-antimony-arsenic alloy (fig. 3, p. 272) described by Dr. Stead.

Explanation of Plates VII and VIII.

Photographs of mineral specimens in the British Museum collection, taken by Mr J. H. Leonard, B.Sc.

Fig. 1.—Phosgenite (= cromfordite) from Wallclose mine, Cromford, Matlock, Derbyshire. Prismatic crystal with helical twist about the vertical axis, in parallel growth (at the base) on an untwisted crystal of short-prismatic habit. (B.M. 59296. This specimen, acquired with the Greville collection in 1810, was early figured by J. Sowerby, 'British Mineralogy', London, 1811, vol 4, p. 175, plate 399.) × 2. (p. 270.)

Fig. 2.—Tourmaline from Chesterfield, Massachusetts. Green prisms embedded in white quartz, bent by earth-movements. One crystal was fractured and the transverse slices slid over one another. (B.M 60234.) $\times \frac{2}{5}$. (p 268.)

Fig. 3.—Sal-ammoniac from Zwickau, Saxony. Curved, skeletal (dendritic) crystals on black shale with coal. (B.M. 1908, 123.) $\times \frac{2}{3}$.

Fig. 4.—Stibnite from Hungary. Crystal with helical twist about the vertical axis. (B.M. 51906.) Actual size. (p. 270.)

Fig. 5.—Quartz (smoky-quartz) from Mursinsk, Urals. Crystal bent by side pressure. (B.M. 83415.) $\times \frac{3}{2}$. (p. 268.)

Fig. 6.—Vermiculite from Nordmark, Sweden. Bent and twisted crystal embedded in matrix of vermiculite and magnetite. (B.M. 53444.) $\times \frac{5}{6}$. (p. 270.)

Fig. 7.—Gypsum from Roth Rocks, Indiana. Bundles of bent, white fibres. (B.M. 26257. Presented by Mr. W. N. Pearson in 1851.) $\times \frac{3}{4}$. (p. 269.)

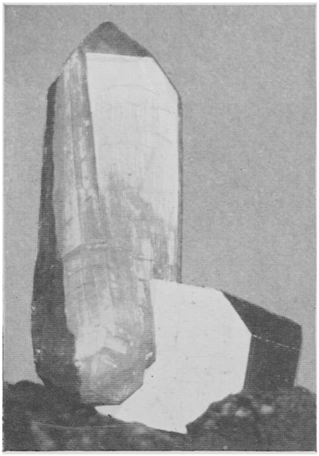
Fig. 8.—Witherite from Fallowfield mine, Hexham, Northumberland. Hemispherical aggregate of thin, platy crystals with curved basal planes. (B.M. 1911, 209.) $\times \frac{1}{4}$. (p. 267.)

Fig. 9.—Muscovite ('blister mica') from Stow, Oxford Co., Maine. Hemispherical aggregates in pegmatite. (B.M. 55484.) Actual size. (p. 273.)

Fig. 10.—Gypsum from Friedrichroda, Gotha, Germany. Transparent crystal bent by secondary twinning along glide-planes. (B.M. 19752.) Actual size. (p. 268.)

Fig. 11.—Barytes from Mowbray mine, Frizington, Cumberland. Sub-parallel aggregation of prismatic crystals. (B.M. 85623.) $\times \frac{1}{2}$. (p. 266.)

Fig. 12.—Dolomite from Simplon tunnel, Switzerland–Italy. Sub-parallel aggregation of rhombohedra. (B.M. 1905, 139.) $\times \frac{3}{4}$. (p. 266.)



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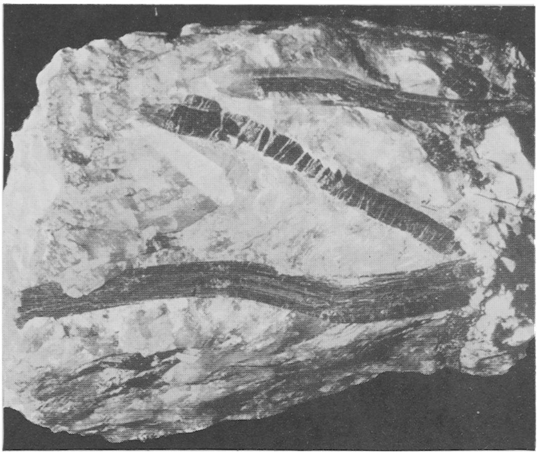

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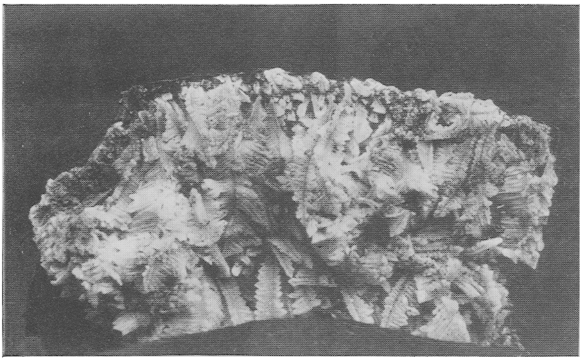

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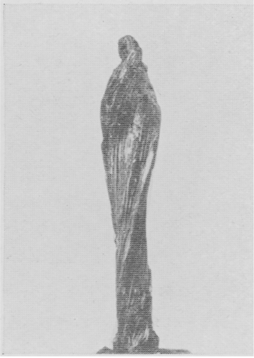

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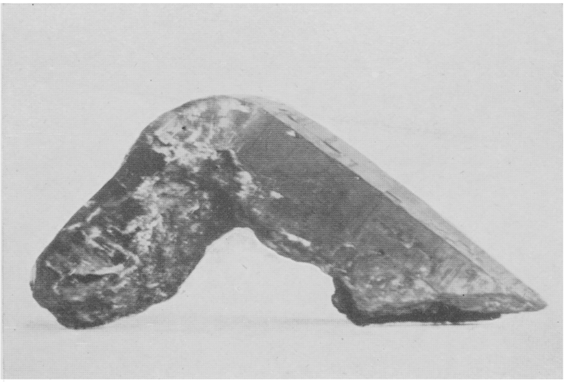

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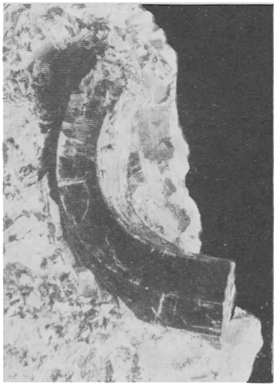
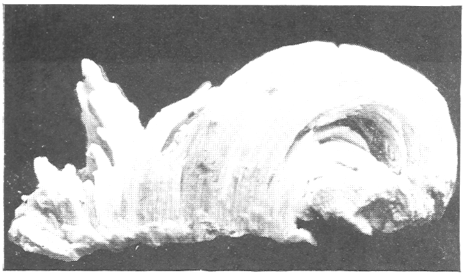


6

L. J. SPENCER: CURVATURE IN CRYSTALS.



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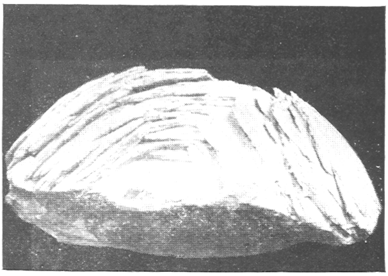

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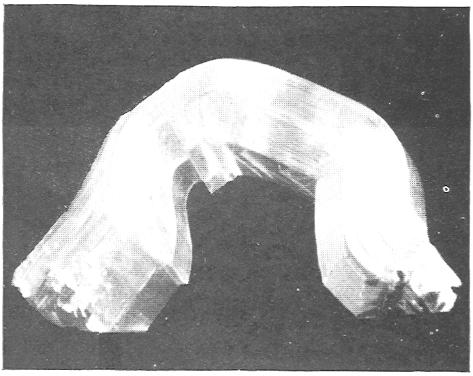

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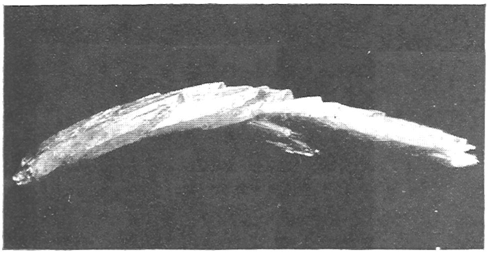

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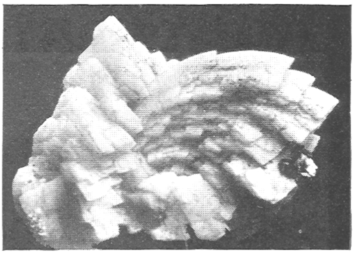

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L. J. Spencer: Curvature in Crystals.