Different habits of fluorite crystals.

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ALTHOUGH a considerable amount of work has been published on the occurrence and crystallography of fluorite, comparatively little has been done on the variations in habit of the crystals. V. Goldschmidt's 'Atlas der Krystallformen' (vol. 4, 1913) gives 160 drawings with references for different forms and combinations of fluorite, but very few attempts have been made to explain the different habits observed. Experiments on the artificial growth of crystals by different methods, under varying conditions of temperature and pressure, and in the presence of foreign substances in the solution do not appear to have been made.

The three specimens now to be described seem to show that, though the cube may be the characteristic predominating form in a large number of fluorite occurrences, other habits may also have their importance, and, under other conditions of formation, may be the predominant form.

(1) *Fluorite of triakis-octahedral habit from Finbo, Falun, Sweden.*

This specimen was collected by myself in 1910 during the International Geological Congress excursion to the mines of central Sweden. I had noticed a small violet crystal at the bottom of a small deep cavity in a block of pegmatite. Having a pyramidal aspect, the crystal was at first thought to be amethyst, but the late Prof. P. Groth suggested fluorite, and when it was extracted by separation along an octahedral cleavage this suggestion proved to be correct. The crystal measures $3\frac{1}{2} \times 2\frac{1}{2}$ mm. and is bounded by faces of a triakis-octahedron (fig. 1). Being somewhat distorted by elongation in the direction of a trigonal axis the crystal has an unusual pyramidal appearance. A narrow dodecahedron face is visible on one edge, and a series of triangular ridges over one trigonal summit approximates to a rough octahedral face. Otherwise the crystal is entirely bounded by triakis-octahedron faces. These (*hhl*) faces are dull owing to fine striations parallel to the octahedral edges; but they are flat and have sharp edges. No accurate measurements could be obtained, but measurements made on the goniometer in the position of maximum illumination, after coating the faces with gum-arabic, showed that the form is (331).

Angle.	Observed.	Calculated for: (221).	(331).	(772).	(441).
$(hhl):(hh\bar{l})$	26—28°	38° 57′	26° 32′	22° 51′	20° 3′
$(hhl):(hlh)$	38—40°	27 16	37 52	40 59	43 20

Triakis-octahedra are very rare as independent forms for fluorite, the only case on record being that of crystals from druses in the Striegau granite in Silesia, described by von Lasaulx.[1] The form there was the triakis-octahedron (441). It accompanied much more numerous octahedral crystals, often modified by (441) and other forms. A number of triakis-octahedra have been observed as subordinate forms, for instance, (332), (221), (331), (772), and (441); but of these only (441) had, so far, been found unaccompanied by other forms. The triakis-octahedron (331) is thus new as an independent form for fluorite.

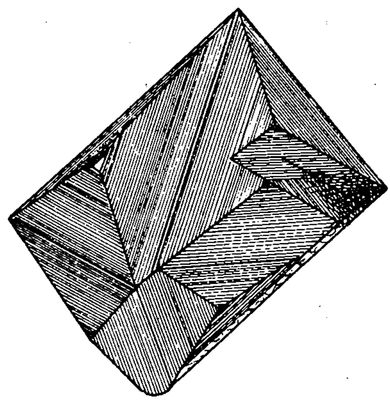

FIG. 1. Fluorite triakis-octahedron (331), from Finbo, Sweden.

But the chief interest of this crystal lies rather in its internal structure. The cleavage surface on one side allows one to see more clearly the inside of the crystal. The core is of almost colourless fluorite and of octahedral shape. On this octahedron, the triakis-octahedron seems to have been built up by addition of successive thin layers of more or less deeply coloured violet material, forming shallow triangular pyramids over the octahedron faces. The initial octahedral development seems, then, to have given way to a later phase, in which material was added almost exclusively normally to the octahedron faces. Continuation of this would probably have led to the development of dodecahedron faces, as the small face

[1] A. von Lasaulx, Neues Jahrb. Min., 1875, p. 134; also Zeits. Kryst. Min., 1877, vol. 1, p. 360.

actually present seems to suggest. The triakis-octahedron represents a transition-form rather than a stable independent habit. Such seems also to be the case in the Striegau specimens, where the independent (441) is found as a rare occurrence, accompanying numerous octahedra. Von Lasaulx mentions that the (441) faces are covered with fine striations. An independent dodecahedron was also observed by him.

Another interpretation of the habit of the Finbo crystal would be by corrosion of an original dodecahedral coloured layer. Bauhans and Goldschmidt[1] have shown that solution leads to a triakis-octahedron with curved faces as the final result. But, here, the flatness of the faces together with the fine striations point more to growth than to solution.

(2) *Fluorite of dodecahedral habit from Celerina, Engadine, Switzerland.*

This and the next specimen formed part of the Daimeries collection, a small portion of which I was able to secure, the larger portion having found its way to London. A. Daimeries, for many years professor of analytical chemistry in the University of Brussels, was a born collector and had accumulated several extensive collections of which, perhaps, the mineralogical one was the least important. Another of his collections, what he called his 'collection of worked stone', ranged from simple cobbles through all possible uses of stones and minerals up to fine cut gems. A number of specimens would have been interesting from a mineralogical point of view, but all were finally sold in Paris. His very extensive collection of flint implements has found a home at Louvain.

The specimen of fluorite to be described was collected by Daimeries himself during one of his numerous visits to the Engadine. It is composed of quartz and muscovite with gneissose structure, and seems to be part of the wall of a fissure whose surface cuts across the direction of foliation of the rock. A parallel, narrow fissure, represented by the under side of the specimen, is filled completely by a snow-white carbonate, calcite or dolomite, showing no natural faces.

The fluorite crystals are small, none being over 3 mm. diameter, but each is a perfectly developed dodecahedron, modified by subordinate octahedron faces. They are associated with minute pyrite

[1] H. Bauhans and V. Goldschmidt, Beitr. Kryst. Min., 1918, vol. 1, p. 219; 1924, vol. 2, p. 123. [Min. Abstr., vol. 1, p. 306; vol. 3, p. 171.]

crystals, cubes modified by (111), both growing on a layer of clear quartz crystals, themselves growing out of the milky quartz of the rock. That these quartz crystals are earlier than the fluorite and pyrite is shown by the pyrite crystals sometimes being aggregated round quartzes, and by fluorite crystals being transfixed by quartz prisms. Pyritous masses are enclosed here and there in the rock-mass.

The fluorites are nearly colourless with a tinge of violet. They are symmetrically developed and sharp-edged, but the dodecahedron faces are dull. The octahedron faces are brighter, but they show slight traces of corrosion. Internally, the crystals seem quite homogeneous without banding of any sort. The dodecahedron seems here to be the original habit. The only internal inhomogeneity observable is caused by very localized patches of pale-violet colouring matter, giving a violet tinge to the otherwise colourless crystals. The arrangement of these patches is an interesting one, for it is quite regular and observed in nearly all of the larger crystals. They are in the form of small clouds, suspended perfectly symmetrically in the direction of the fourfold axes, a little distance below each summit. Each crystal contains, therefore, six such small patches (fig. 2). Occasionally the patch is replaced by a minute opaque grain with a narrow halo of colouring matter round it.

(3) *Fluorite showing three distinct stages of growth.*

The label with this specimen gives 'Cumberland' as the locality, but this is very doubtful, since another very similar specimen is labelled 'Cornwall'. The specimen is a portion of a rather brecciated vein-filling with numerous cavities, mostly filled with clear, pale-greenish fluorite. Some of this is edged by zoned violet material. One surface, where the fluorite had space to crystallize without hindrance, is covered with large and small octahedral crystals edged by new growths of colourless fluorite and dotted over with violet patches. The nature of these successive growths deserves closer examination.

Wherever the pale-green fluorite is seen to emerge freely, it shows well-developed octahedral faces, sometimes with summits and edges slightly grooved by later corrosion. There is no doubt that this first generation of pale-green fluorite was of octahedral habit. This is now covered by a close-packed layer of very small quartz crystals, forming epimorphs of the fluorite octahedra.

Another stage of fluorite deposition then began. The conditions of deposition must have been different, for this later fluorite is of entirely different habit. It is formed entirely of colourless dodecahedra, free of any other forms. Yet this second layer is in contact with the earlier material, for the dodecahedra are invariably in strictly parallel position with the original octahedra. They form composite skeleton octahedra over the points and edges of the larger original octahedra, or else perfect dodecahedra enclose completely the smaller octahedra. In every case, one can see through the limpid dodecahedra a white granular layer of quartz over the faces of the original octahedra (fig. 3).

This dodecahedral stage was followed by yet another, again characterized by a different habit. The violet blebs that are dotted over the dodecahedral fluorites also show distinct crystal faces. They are cubes, sometimes modified by dodecahedra; that is, cubes with blunted edges. Their position on the older crystals is, also, a definite one. They have formed either over a trigonal summit of a dodecahedron or else over a fourfold apex. The dodecahedra seem to have been somewhat dissolved away in other parts. The shape of the cubes also varies according to their position. Those over the trigonal summits are normally developed symmetrical cubes showing fairly large dodecahedron modifications, whereas those on the fourfold apices are tabular and show only narrow modifications on their edges. Where two opposite dodecahedron faces have met in an edge, the new-formed cubes are then elongated in the direction of this edge; and in this case no modification of the edges is seen (top of fig. 3).

This specimen shows, then, the following stages of growth:

(1) Octahedra of clear, green fluorite.

(2) Period of deposition of quartz; no fluorite formed, but slight corrosion. Quartz epimorphs.

(3) Dodecahedra of colourless fluorite capping the fluorite of the previous stage and epimorphous over the quartz.

(4) Cubes of violet fluorite in parallel growth on the dodecahedral fluorite; cubes of tabular form over fourfold summits, and equably developed cubes with truncated edges over the trigonal summits.

Summary and Conclusions.

The specimens here described support the idea that there is a definite sequence in the stages of development of fluorite crystals characterized in each period by a definite habit. These stages probably represent progressively cooler periods of formation. The octahedral habit seems to be the earlier, higher-temperature stage. It would represent the normal habit under those special conditions, and not, as most text-books seem to consider, accidental exceptions to the universal cubic habit of fluorite.

Octahedral fluorite has been described from a large number of localities. One is struck, on reading through the descriptions, how

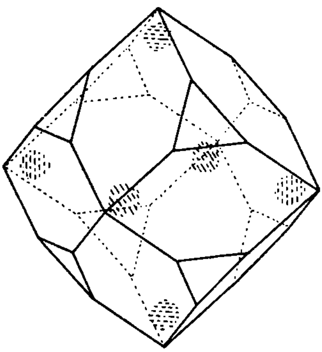

Fig. 2. Fluorite dodecahedron from Celerina, Switzerland.

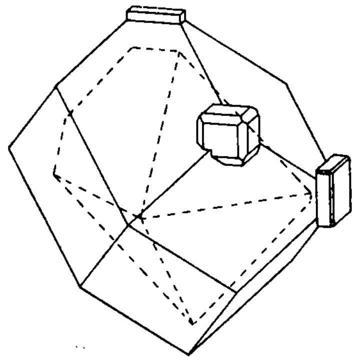

Fig. 3. Fluorite showing three successive habits.

often pale, usually greenish, colours are mentioned for these occurrences. This may have some connexion with the well-known fact that dark-coloured fluorite loses its colour on heating. Fluorites from cavities in granites and pegmatite are generally of octahedral habit. Most attempts at laboratory formation of fluorite, carried under relatively high temperatures and pressures, have also yielded octahedra.

On the other hand, the fluorites of mineral veins are often deeply coloured, and they are almost without exception of cubic habit. Colour is so irregularly distributed in fluorite that it can hardly be used as a criterion for general conditions during crystallization, yet, broadly speaking, deep coloration seems more typical of lower temperatures.

The dodecahedron, as an independent form, is much rarer than the octahedron, but it, too, seems to have its range of stability, a range that lies between those for the octahedral and the cubic types. The Celerina specimen does not give much help in elucidating this. It merely shows that the dodecahedron can occur as an independent form under certain conditions. The third specimen described gives us more precision. Other occurrences of dodecahedral fluorite, mentioned in mineralogical literature, also confirm the view that the dodecahedral stage lies between the octahedral and the cubic. Independent dodecahedra have been met with at Striegau accompanying the much more numerous octahedra; also, exceptionally, in the occurrences of pink octahedral fluorites of the Alps.

The only other dodecahedra I have been able to examine are the well-known deep-violet crystals from the Franco-Belgian frontier. These were also contained in the Daimeries collection. Two isolated dodecahedra, one large one from Foische, nearly 5 cm. across, and a much smaller, very dark one from Gymnée, show the same structure. Fractures show the inside to be homogeneous and somewhat zoned, the zoning following the directions of the dodecahedron faces. Small cube faces modify the dodecahedron. The outside is rough and corroded and a new growth of minute cubes can be seen.

The rare triakis-octahedra as independent forms seem, on the other hand, to be rather of the nature of accidental transition occurrences. They form a transition between the octahedral and dodecahedral habits.

Other transition stages are probably represented by the specimens in which cube, dodecahedron, and octahedron are associated. I have a specimen from Baveno, Italy, in which a sharp octahedron is in close contact with another crystal in which octahedron, dodecahedron, and cube are in equal development. On another specimen from Baveno, the octahedron and dodecahedron modify the cube.

Fluorite of distinctly cubic habit, such as that from typical mineral veins, is only rarely modified by the octahedron or the dodecahedron. The typical modifications here are four-faced cubes (*hk*0), and less frequently triakis-octahedra (*hhl*).

The only other forms that have been observed on fluorite as independent forms are four-faced cubes and (*hkl*) forms. But these are generally also modified by cube faces. They may be classed as accidental transition phases. The well-known Cornish specimens, from St. Agnes and elsewhere, are good examples of this. The four-faced cube, though predominant, has almost invariably well-developed cube faces in addition.

I have examined in detail a specimen from the Münsterthal, Baden, the typical locality for fluorites showing (*hkl*) as independent forms, and have come to the conclusion that the (*hkl*) form, though certainly well developed and occasionally almost obliterating the actual cube faces, is more generally subordinate to the cube. It may be that slower deposition under still later conditions than those required for the typical cubic development have favoured the fuller development of the (*hkl*) faces. My specimen shows older, large cubic crystals of typical vein habit. These have been completely covered by a coating of sulphide, marcasite or pyrite, and on this a second generation of fluorite has been deposited as small, independent, but closely-packed crystals, all showing in model-like regularity the combination of the cube with a (*hkl*) form. The sequence here is:

(1) Original cubic fluorite; irregular intergrowth of large unmodified crystals.

(2) Sulphide crust forming epimorphs of the cubes.

(3) Small limpid fluorites; (*hkl*) with (100) showing parallel orientation on only a few corners of the older fluorites, but generally quite independently orientated. This can also be looked upon as an epimorph of the original cubic fluorite.

Another frequent occurrence, mentioned in all text-books, is that of octahedra formed of piled-up tiny cubes. The specimen at my disposal shows a homogeneous core of pale-green fluorite having quite definite octahedral boundaries. On this a later growth of minute colourless cubes, all in parallel orientation, has continued the original octahedron.

Temperature has been suggested above as the probable main factor conditioning the habit of fluorite at different stages of growth. Too much weight must not, however, be given to this suggestion. The chief thing to be noted is that there seem to be three distinct habits, octahedral, dodecahedral, cubic, each predominant through a certain range of conditions. The fact that low-temperature quartz is found intimately associated with fluorites of octahedral habit, as well as with those of dodecahedral and of cubic habit, shows that the actual temperature range is not an extended one. Other unknown factors must also be of importance.