THE SIZE OF CRYSTALS

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In a recent paper, Palache[1] has given the dimensions of a number of large crystals of various minerals and has directed attention to the problem of the genetic factors that influence their growth. It would appear that a growing crystal would increase in size indefinitely if a continuous supply of material were brought to its surface. However, experiment has shown that growth may cease with the attainment of a critical size, regardless of the amount of material still available. Retgers[2] concluded that there is a distinct maximum in size for every crystal, varying somewhat with the conditions, beyond which it is incapable of further growth. Von Hauer[3] earlier observed that there is a certain limit to growth beyond which the crystals become markedly imperfect, developing a composite and fissured structure with surface excrescences and cavities. This limit was found to vary for different substances and under varying circumstances. A similar observation was made by Ord[4] for crystals of calcium oxalate and the phenomenon was likened by him to the property of liquids to form drops, but only drops of a certain limit of size for each kind of liquid.

Both Retgers and von Hauer found that upon addition of a small amount of a foreign substance, such as a metallic chloride or an acid, to the crystallizing solution the crystals resulting could grow perfectly to much larger sizes. In addition to the citations of these workers on this effect there may be mentioned the observations of Buchner[5] on the property of Mg, Cu and Fe chlorides to perfect and enlarge NaCl, KCl and NH_4Cl crystals; of Gibbs and Clayton[6] on the similar effect of lead salts on NaCl; of Ehrlich[7]

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[1] Palache, C., The largest crystal: *Am. Mineral.*, vol. **17**, pp. 362–363, 1932.

[2] Retgers, J. W., Ueber den Einfluss fremder Substanzen in der Lösung auf die Form, die Reinheit und die Grösse der ausgeschiedenen Krystalle: *Zeit. physik, Chem.*, vol. **9**, p. 278, 1892.

[3] Von Hauer, K., Krystallogenetische Beobachtungen: *Verh. der k. k. Geol. Reichsanst. Wien*, pp. 45, 57, 75, 90, 162, 296, **1877**; pp. 185, 315, **1878**; pp. 20, 181, **1880.**

[4] Ord, W. M., On the influence of colloids upon crystalline form and cohesion. *London*, **1879**, p. 125.

[5] Buchner, L. A., Ueber die Bildung durchsichtiger, dem Steinsalze ähnlicher Salzwürfel: *Jour. prakt. Chem.*, vol. **111**, pp. 259–266, 1871.

[6] Gibbs, W. E., and Clayton, W., The production of large, clear cubical crystals of sodium chloride: *Nature*, vol. **113**, pp. 492–493, 1924.

on the remarkable action of pectin in inducing such changes in NH_4Cl and other salts; and of Yamamoto[8] on the effect of a large number of metallic salts on the size and transparency of NaCl, KCl and NH_4Cl crystals. Addition of the foreign substance is frequently found to be accompanied by a change in crystal habit; borax, for instance, inducing the development of hemimorphic faces on magnesium sulphate in addition to perfecting the crystals (von Hauer).

Zwicky[9] has suggested in explanation of the phenomenon of size limitation in ordinary growth that the liberation of heat of crystallization or heat of fusion at a growth surface may cumulatively produce, through thermal stresses, a disordered mosaic surface which, at the attainment of a critical size, may become such as to prevent further growth. The observation of Stöber,[10] that large perfect crystals can be obtained from a melt by placing the axis of greatest heat conductivity of the crystal in the direction of heat flow, is of significance in this connection. W. H. Bragg has suggested that the regular fitting of molecules into a crystal may begin correctly enough, in the nuclear stage, but that errors of adjustment may creep in until the surface becomes somewhat disordered, and growth ceases because fresh molecules cannot slip into their proper places.[11] Von Hauer observed that the heterogeneous surface occurring at the maximum size is marked by a difference of angles in the composite parts, and said that a crystal may bear in itself a tendency to irregularity which becomes more conspicuous with continued growth. Retgers believed that the tendency for a size maximum is a property of the crystal itself and that its cause can not be sought in the properties of the solution.

Foreign substances apparently increase the transparency and perfection of crystals, and induce a larger size, by decreasing the

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[7] Ehrlich, F., Ueber die Beeinflussung des Krystallwachstums von Salmiak durch Pektin: *Zeit. anorg. Chem.*, vol. **203**, pp. 26–38, 1931.

[8] Yamamoto, T., *Bull. Inst. Phys. Chem. Res. Tokyo*, vol. **10**, pp. 52–60, 679–686, **1931**; vol. **11**, pp. 1083–1097, 1932.

[9] Zwicky, F., Secondary structure and mosaic structure of crystals: *Phys. Rev.*, vol. **40**, p. 74, 1932.

[10] Stöber, F., Kunstlicher Darstellung grosser, fehlfreier Kristalle: *Zeit. Kryst.*, vol. **61**, p. 299, 1925.

[11] Bragg, W. H., Cohesion and molecular forces: Alexander's *Colloid Chemistry*, vol. **1**, p. 266, 1926.

tendency for a mosaic structure, as was suggested by Oka,[12] for micro-composite NaCl crystals, but in what manner this would be accomplished is not evident. Slow growth, in general, enhances the size and perfection of crystals, as was brought out in this connection by Zwicky, and the effect of adsorbed foreign substances may possibly be by slowing up growth. This view is supported by the frequent occurrence of habit modification in such cases, and is not inconsistent with the fact that under other circumstances addition agents may cause the formation of fine grained aggregates or of skeletal growths, in place of normal crystals, as a result of an extreme hindering of growth.

The effect of magma-derived mineralizers in promoting crystal growth in certain geological processes may also include an action on the coarse structure of the crystals, of the nature described, in addition to the viscosity and chemical control that is generally ascribed to them.

A number of large crystals that have come to the attention of the writer are cited in the following table. The specimens are contained in the collection of The American Museum of Natural History, unless otherwise stated. Further instances have been mentioned by Spencer.[13]

SPECIES	LOCALITY	DESCRIPTION
Analcite	Fassathal, Italy	Trapezohedron; $a=7$ cm.
	Cape Blomidon, N.S.	Trapezohedron, implanted and distorted; longest dimens. = 11 cm.
Apophyllite	Poonah, India	$c=6$ cm., $a=7$ cm.
Aragonite	Cianciana, Sicily	Pseudo-hexagonal twin, implanted; $c=$ about 4 cm., distance across base ⊥ to side = 8 cm.
	Girgenti, Sicily	Pseudo-hexagonal twin· $c=5.5$ cm., distance across base ⊥ to side = 5.5 cm.
Axinite	Japan	8 cm. along (110) $(1\bar{1}1)$ edge (Takimoto).
	Medels, Switzerland	Elongated bent composite crystal; $b=9$ cm.
Bournonite	Neudorf, Germany	Tabular; 6×6×2 cm.
	Cornwall, England	Implanted distorted twinned crystal; longest dimens. = 6.5 cm., $c=2.5$ cm.

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[12] Oka, S., On the opacity of sodium chloride crystals: *Jour. Soc. Chem. Ind. Japan*, Supplem. Binding, vol. **35**, pp. 178–179, 1932; vol. **36**, pp. 141–143, 144–145, 1933.

[13] Spencer, L. J., Large specimens of spar from the Snailbeach Mine, Shropshire: *Nat. Hist. Mag. Brit. Mus.*, vol. **1**, p. 259, 1928.

SPECIES	LOCALITY	DESCRIPTION
Brookite	Magnet Cove, Arkansas	Stout pyramidal crystal; $c=12$ cm. Another specimen is a fragment of a much larger crystal.
Brucite	Texas, Pennsylvania	Merged crystal; 14×8×1 cm. Also a cleavage surface with longest dimens. =19 cm.
Calcite	Joplin, Missouri	Scalenohedron, one end implanted; $c=85$ cm. (meas. length.)
Cerussite	Dundas, Tasmania	Thick rounded prism; $c=12$ cm.
	Nertschinsk, Urals	Thick tabular crystal; 7×3.5×2.5 cm.
	Broken Hill, N.S.W.	Thin prisms; c from 8 to 13 cm.
Datolite	Westfield, Mass.	Implanted distorted crystal; 7×5.5×5 cm.
	Osceola Mine, Mich.	Implanted distorted crystal; 5.5×5×4.5 cm.
Dolomite	Alexander Co., N.C.	Rhombohedron 10 cm. on edge (Hidden and Washington).
	Stony Point, N.C.	Distorted rhombohedron; 9.5×7×6 cm.
Epidote	Untersulzbachthal, Austria.	Prism, both ends broken off; 25×3×3 cm.
Erythrite	Schneeberg, Saxony	Radiating needles; $c=5$ cm.
Fluorite	Westmoreland, N.H.	Octahedron, green; 21 cm. on edge.
	Cumberland, England	Cube, violet; 24 cm. on edge.
	Cumberland, England	Cube, violet; 13.5 cm. on edge.
	Weardale, England	Cube, violet; 11 cm. on edge.
	Cornwall, England	Cube, yellow-green; 12 cm. on edge.
	Jefferson Co., N.Y.	Cube, green; 13.5 cm. on edge.
Galena	Pitcher, Oklahoma	Cube; 13 cm. on edge.
	Galena, Illinois	Cube; 13 cm. on edge.
	Galena, Illinois	Distorted cube; 21×4×4 cm.
	Galena, Illinois	Distorted cube; 13.5×5.6×3 cm.
	Joplin, Missouri	Cube; 14 cm. on edge.
Gypsum	Fremont River Canyon, Utah	Single cleavage surface; 102×51 cm.
	Fremont River Canyon, Utah	Prismatic crystal; 122×22×14 cm.
Halite	Stassfurt, Germany	Irregular cleavage fragment; longest dimens. =23 cm.
Hematite	Sussex Co., N.J.	Parting surface; longest dimens. =11 cm.
Ilmenite	Froland, Norway	Stout, merged crystals; longest dimens. =14 cm.
Leucite	Wiesenthal, Bohemia	Trapezohedron; $a=6$ cm.
	Rocco Montina, Italy	Trapezohedron; $a=5$ cm.
Magnetite	Twin Peaks, Millard Co., Utah	"even larger than 3 in. in diam." (Patton)
	Twin Peaks, Millard Co., Utah	Implanted octahedron; 9 cm. on edge.

SPECIES	LOCALITY	DESCRIPTION
Matlockite	Derbyshire	Flat broken fragment; longest dimens. =10 cm.
Microlite	Amelia Court House, Va.	Octahedron; 6.5 cm. on edge
Monazite	North Carolina	$a=18.5$, $b=26$, $c=31.5$ cm. Wgt.=58$\frac{3}{4}$ lbs. (Schaller).
Phosgenite	Monti Poni, Sardinia	Distorted crystal; 5×4×2.5 cm.
Pyrite	Leadville, Colorado	Cube; 16 cm. on edge.
	Rio, Elba	Octahedron; 8 cm. on edge.
	Brockville, Ontario	Octahedron; 7.5 cm. on edge.
	Rio, Elba	Pyritohedron; $a=13$ cm.
	Summit Co., Colo.	(210) Pyritohedron, implanted; 6.5 cm. on short edges
Pyrrhotite	Freiburg, Germany	$c=5$ cm., $a=10$ cm.
Quartz	St. Gotthard, Switzerland	Dark smoky; $c=45$ cm., $a=25$ cm.
	Auburn, Maine	Pale smoky, distorted and broken; $c=70$ cm., $a=34$ cm. (meas.)
	Thunder Bay, Michigan	Amethyst, implanted, no prism faces; rhomb. edge =15 cm.
Rutile	Graves Mt., Georgia	Stout fourling, distorted; 11×9×7 cm. Another, part in matrix, has $c=13$ cm.
Scheelite	Japan	$c=33$ cm. (Wada).
Siderite	Pikes Peak, Colo.	Rhombohedron; 13 cm. edge.
	Carinthia	Composite rhomb., merged with others; 9 cm. on edge.
Spinel	Amity, Orange Co., N.Y.	"16 in. around base"; another crystal weighed 59 lbs. (Shepard).
Sulphur	Cianciana, Sicily	Broken crystal; 14×13×8 cm. (meas.)
Titanite	Eganville, Ontario	Wedge habit; 26×18×12 cm.
Witherite	Alston Moor, England	Rounded pyramidal crystal, incomplete; $c=8$ cm.(meas.)=13 cm. (est. for ideal).
Zincite	Franklin, N.J.	Embedded formless single crystal; greatest dimens.=5 cm. ⊥ to cleavage and 6 cm. across cleavage.