

tional space we defined and limits, if any, are probably to be found in the particular geochemical environment.

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On the shapes of dissolved crystals

DISSOLUTION often produces crystal morphologies quite different from those of growth. The normal (or pole) to a face on a growth form corresponds to a direction of slow growth. Despite statements to the contrary (Donaldson, 1985, quoting Bagdasarov *et al.*, 1974), the same direction should also be one of slow etch; and if dissolution has proceeded far enough, a vertex may be expected. Thus (I) faces in growth become vertices in dissolution.

A vertex on a growth form, however, results from factors involving the growth rates of several different crystallographic orientations, notably the normals to the three or more facets which meet at the vertex. The statement (II) that vertices on growth forms become faces in dissolution is not generally true. Donaldson (1985) is incorrect in suggesting that statements (I) and (II) are just different ways of saying the same thing.

If (I) and (II) were *both* true—faces becoming vertices and vertices becoming faces—then growth and dissolution forms would be dual figures. For example, the eight faces of the octahedron would become the eight vertices of the cube, and the six octahedral vertices would become the six cube faces. This is seldom observed in practice. For example, natural diamonds of octahedral habit become rounded rhombic dodecahedra by geologi-

cal dissolution (Moore and Lang, 1974). Here the propagation of kinks along $\langle 110 \rangle$ edges on $\{111\}$ monolayers seems to be the shape-determining process. The twelve edges of the octahedron eventually become the twelve (rounded) faces of the dodecahedral dissolution body. The eight octahedral growth faces do indeed become eight of the vertices of the rhombic dodecahedron, but note that the six vertices of the octahedron remain as vertices for the dodecahedron. Growth and dissolution forms are not necessarily dual figures (Moore, 1973).

Now the dual of the rhombic dodecahedron is the cubo-octahedron. Whilst it is true that the cubo-octahedron is a common growth form for *synthetic* diamond (Bovenkerk *et al.*, 1959; Litvin and Butuzov, 1969; Strong and Wentorf, 1972), it is rare for natural diamond (Moore, 1979, and for a general review of diamond morphology see Moore, 1985). When diamonds of combined cubic and octahedral habits are made in the laboratory, the relative development of the two forms can be varied by changing the temperature (Bovenkerk, 1961). The cubo-octahedron (of six square and eight triangular faces, and only twelve corners) is particularly favoured for sawing applications. This is a unique morphology between the cube and octahedron, in the middle of the spectrum of shapes

derived by the progressive truncation of the vertices of either extreme. Whilst statement (I) is generally true, statement (II) is valid only in special cases.

The observations on the etching of single crystal germanium spheres by Ellis (1954, 1957) and by Batterman (1957) are of interest since they succeeded in producing a number of different geometrical dissolution shapes, including the rhombic dodecahedron. Heimann (1975) shows a photograph of five such shapes; $\{110\}$, $\{hk0\}$, $\{100\}$, $\{hhl\}$, and $\{111\}$, all formed by the dissolution of germanium spheres in various acid mixtures. He also gives numerous other examples, lists nearly seven hundred references and reviews the theories of dissolution, notably those of F. C. Frank.

Contrary to earlier beliefs (particularly Goldschmidt and Wright, 1904) that after considerable etching the dissolution body would assume a definite shape (Endkörper), Frank's kinematic theory (1958, 1972) suggests that there is no unique terminal morphology independent of the starting shape. In general, the shape gradually changes throughout the dissolution process.

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Variations in a growth form of synthetic vaterite

VATERITE, a polymorph of CaCO_3 , is rarely found in nature but has been identified in the repair tissue of young gastropods (Mayer and Weineck, 1932), in gallstones (Phemister *et al.*, 1939; Rodgers, 1983), in the early carbonation of Portland cements (Cole and Kroone, 1959), in a carbonated hydrogel (McConnell, 1960) and in evaporite beds in the Antarctic (Browne, 1973). Its scarcity in nature compared with the other two polymorphs, calcite and aragonite, may be due to its instability in the presence of water. Hitherto, morphological description of vaterite has not been possible be-

cause the available material, both natural and synthetic, has been restricted to very small crystals (1-10 μm).

Previously, vaterite has been synthesized at room temperature by precipitation from a solution containing a calcium salt (e.g. Gibson *et al.*, 1925). In our work, which involved a series of experiments to study the distribution of selected trace elements between synthetic CaCO_3 and its parent solution, spheroids of vaterite (0.1-1.0 mm diameter) were observed amongst the crystalline products. The syntheses were made by the slow diffusion of CO_2