GENERAL MECHANISM OF PORPHYROBLAST GROWTH

Ostapenko G.T. (IMAG HASU)
ostap@imag.kiev.ua; Fax: (38 044) 424-10-20, phone: (38 044) 424-12-66

Key words: porphyroblast growth, crystallization pressure, pressure solution, fluid film

This presentation deals with physical and chemical aspects of space occupation by growing porphyroblast, as well as formation of its faces.

Petrographic studies demonstrate that space, occupied by a porphyroblast, is freed mainly through dissolution of a mineral matrix, hosting it. Besides, cases of mechanical drawing the matrix apart and dissolution in combination with pushing separate grains away or their capturing, were fixed too [1-3]. Events of drawing apart/pushing away may be regarded as proof of mechanical pressure on a matrix by growing porphyroblast, i.e. manifestation of crystallization pressure, first studied with the water-soluble ionic crystals at room temperature [4]. On the other hand, dissolution of the hosting matrix can be explained by the well-known effect of pressure solution.

Realization of the above two effects is possible in presence of liquid (or quasi-liquid) water film at the porphyroblast/matrix boundary. Film combines the following functions: 1) transfer of growing porphyroblast pressure to a matrix, thus leading to increase in chemical potential of the latter; 2) bringing of components to porphyroblast surface from the adjacent matrix volume; and 3) matrix dissolution and taking its constituents out of the porphyroblast/matrix boundary. The above parallel processes of growth and dissolution make the essence of porphyroblast formation at the expense of matrix dissolution [5].

Works by B.V. Deryagin and his school (specifically [6]), as well as other investigators [7,8] determined, that wedging pressure Π (after Deryagin) can develop at the boundary of fibers or plates of quartz and mica at room temperature in water films of less than ~50 nm thickness, reaching ~20-200 bar at ~1-5 nm thick fluid film.

Such Π values ensure development of crystallization pressure, which was proved by experiments with water-soluble crystals [4]. When temperature increases up to 65-70°C, thickness of water film on quartz decreases to monolayer [9].

As it was found by works [10,11], continuous fluid film, similar to volumetric fluid as to its characteristics, can’t form on boundary between quartz grains at much higher temperatures (450°-1080°) and pressures of 1-15 kbar. Nevertheless, rather large number of water molecules are adsorbed both on quartz surface (at its boundary with fluid) and at quartz/quartz grain boundaries, thus forming water layer of 0.04 mol/cm^2 density [11].

In this way, based on the above data one can assume, that either thin fluid films (one - two water monolayers), which characteristics differ from the volumetric fluid, or at least disturbed intergranular layers with dissolved water exist under metamorphic conditions at high temperatures and water fluid pressures too [12].

Experiments showing manifestations of crystallization pressure [13, 14] and dissolution under pressure [15] at high temperatures and water pressures indirectly prove existence of active quasi-fluid films or layers on grain boundaries.

As an example, let us consider growth features of andalusite porphyroblast formed as a result of the following metamorphic reaction:

muscovite + quartz = andalusite + potassium feldspar + water

Kinetics of the reaction was studied in [16]. The reaction rate was shown to be controlled by andalusite crystallization (from left to right) and dissolution (from right to left) rates. It was found, that andalusite dissolution/crystallization rates are lower than the same of quartz and muscovite [16], and, apparently, potassium feldspar. Therefore, during growth of andalusite porphyroblast formed from a nucleus in quartz/muscovite matrix, low crystallization pressure ΔP_s will develop at a contact with the latter (due to quick dissolution and carrying out of quartz and muscovite components through diffusion [5]).

In this case, ΔP_s will be much higher at face (001), quickly growing in C axis direction, than at face (110), growth rate of which in direction perpendicular to C axis will be 5 to 10 times less. It is possible, that quasi-liquid films at the above faces will be of different thickness too.

Extent of crystal faces development (degree of idiomorphism or idioblastesis [17]) is a very important and largely debated topic. Local manifestation of idiomorphism (development of limited number of faces) was mentioned too [17]. Based on thermodynamic analysis, which takes into account existence of fluid film or amorphous layer of viscous pseudo-liquid at the grain boundary, Ostapenko [18] formulated the following principles of idiomorphism: capability for idiomorphism of a certain F-face (i.e., its capacity to be flat) will be the more, the higher is it's surface energy in general and, at the same time, the lower is the same energy for the given crystal (that is, the more intense is anisotropy of surface energy). If irregularities (convexities or concavities) appear on such face, they will be the most unstable in respect to energy and that's why they will quickly disappear. Face (110) of andalusite complies with the above conditions of the highest degree of idiomorphism, the face (001) conforming to its lowest extent.

References

1. *Ferguson C.C., Harvey P.K.* // Geol. Soc. Amer. Bull., 1972. V.83. N. 2. PP. 38-39.
2. *Ferguson C.C., Harvey P.K., Lloyd G.E.* // Contrib. Mineral. Petrol., 1980. V.75. N. 4. PP. 339-352.
3. *Mish P.* // Geol. Soc. Amer. Bull., 1971. V.82. N. 1. P. 245-251.
4. *Хаимов-Мальков В.Я.* Рост кристаллов // М.:Наука, 1959. Т.2. СС. 5-26.
5. *Ostapenko G.T.* // Geochem. Int., 1985. V.22. PP. 56-68.
6. *Дерягин Б.В., Рабинович Я.И., Чураев Н.В.* // Изв. АН СССР, Сер. хим. наук, 1982, N 8. СС. 1743-1748.
7. *Pashley R.M.* // J. Coll. Interf. Sci., 1981. V.80. N.1. PP. 153-162.
8. *Pashley R.M.* // J. Coll. Interf. Sci., 1981. V.83. N.2. PP. 531-546.
9. *Ершова Г.Ф., Зорин З.М., Чураев Н.В.* // Колл. журн., 1975. Т.37. СС. 208-210.
10. *Holness M.B.* // Earth and Planetary Sci. Letters, 1992. V.114. PP. 171-184.
11. *Holness M.B.* // Earth and Planetary Sci. Letters, 1993. V.117. PP. 363-377.
12. *Rubie D.C.* // Mineral Mag., 1986. V.50. PP. 399-415.
13. *Ostapenko G.T.* // Geochem. Int., 1976. V.13. PP. 120-138.
14. *Зарайский Г.П., Жариков В.А., Стояновская Ф.М., Балашов В.Н.* Экспериментальное исследование биметасоматического скарнообразования // М.:Наука, 1986. 232 с.
15. *De Boer R.B., Nagtegaal J.C., Duyvis E.M.* // Geochim. Cosmochim. Acta, 1977. V.41. PP. 257-264.
16. *Schramke J.A., Kerrick D.M., Lasaga A.C.* // Amer. J. Sci., 1987. V.287. N. 6. P. 517-559.
17. *Kretz R.* // J. Petrol., 1966. V.7. N. 1. PP. 68-94.
18. *Остапенко Г.Т.* // Записки ВМО, 1986, Вып. 6. СС. 633-644.

Electronic Scientific Information Journal "Herald of the Department of Earth Sciences RAS" № 1(22)'2004
Informational Bulletin of the Annual Seminar of Experimental Mineralogy, Petrology and Geochemistry – 2004
URL: http://www.scgis.ru/russian/cp1251/h_dgggms/1-2004/informbul-1_2004/mineral-24e.pdf
Published on July, 1, 2004