Garnet crystal size distributions: Magmatic *vs*. fragmentation origin

(1 fig)

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Crystal size distributions (CSD) are commonly used to infer information on kinetics of crystal growth (crystallization and nucleation rates). Size distributions as displayed on plots size *vs*. frequency result from a variety of processes, which influence the shape and slope of the CSDs. These may include primary and secondary processes: Crystals in magmas were shown to crystallize either in open or closed system (Marsh 1988, 1998), each producing a negative loglinear correlation, the latter accompanied by downbending at small sizes ("humped" patterns). In an open system the loglinear pattern is achieved through continuous outflow of older crystals so that bigger crystals occur in smaller numbers. As soon as the system attains a steady state, the slope of the CSD corresponds to the residence time of a crystal in the system. In a closed system the nucleation rate increases logarithmically due to cooling until the diminishing amount of remaining melt inhibits a further increase. Leaving aside other processes, as crystal aggregation or Ostwald ripening, the original CSD may suffer from solid state deformations, which comprise crushing and comminution of crystals. This applies especially for polymetamorphic terrains as are the Western Carpathians. The CSD originated due to comminution shows a different pattern, which follows a power law and may be interpreted in terms of its exponent, a fractal dimension D (e.g. Shimamoto and Naghama 1992).

The primary CSDs developed both in open and closed systems, and clastic crushed crystals are illustrated and interpreted first on the example of granite cataclasites and pseudotachylytes from the High Tatras (Petrík et al. 2003). Then results are applied to garnet CSDs in magmatic and metamorphic rocks from the Veporic unit.

The detailed study and modelling of hematite CSDs from a Tatra pseudotachylyte (Fig. 1A–C) shows that majority of them have developed in an open system thus indicating a dynamic behaviour of short-living frictional melts. A steady state was approached within tens of seconds and resulted in characteristical loglinear patterns (Fig. 1B). In some places, as vein tips, melt flow stopped and open system CSDs were replaced by closed system CSDs with humped patterns (Fig. 1D). The pseudotachylyte is closely intermingled with mineral and lithic clasts, and cataclasite breccia. Here, in contrast to magmatic hematite, which crystallized from the frictional melt, original granitic minerals are seen in zones of crushing. A crushed apatite is shown in Fig. 1C, located close to the pseudotachylyte vein. Its CSD is almost linear in a log-log plot suggesting that it follows a power law with D = 3.09. Comminution was modelled by Sammis et al. (1985), see also Turcotte (1992) using a fractal cube, which is sliced so that two opposite cubes are retained at each scale. In this model no equal size blocks are in contact as it is assumed that one of them will break up. The fractal dimension of this cube is D = 2.585.

Garnets in magmatic rocks may be scattered or may form clusters. In the latter case their crystal sizes can readily be measured and their distributions obtained. A ca. 1 m thick pegmatite – aplite vein from the southern Veporic unit contains such clustered magmatic garnets, which are shown by Thöni et al. (this volume) to have Variscan age 339 ± 7.7 Ma. Textural parameters were calculated from about 600 grains using the program UTHSCSA Image Tool. 2D (N_A) data (longest axis) were converted to 3D (N_V) using $N_V = N_A/L$ where L is diameter or crystal length (average value for each class) with no additional unfolding technique, and a CSD histogram was obtained (Fig. 1E). The CSD is loglinear and its slope corresponds to $-1/G\tau$ where G is growth rate and τ is residence time. The CSD may be interpreted as originating from garnet nucleation in an open magmatic system.

A slightly different behaviour is recorded by small metamorphic garnets in the metagranite from the Veporic unit. This pre-Variscan granite was affected by a polyphase – Variscan and Alpine deformation and recrystallization (Janák et al. 2002). Metamorphic garnet forms coronas around relict biotite and or along the boundaries between biotite and plagioclase. Larger polygonal garnets have developed by a coalescence and coarsening of numerous small grains. Due to deformation, some garnets show grain-size reduction and fragmentation. The CSD obtained from about 600 grains is slightly concave up in semilog plot, and linear to slightly concave down in log-log space (Fig. 1F). Its slope corresponds to D = 2.93, a value higher than in the Sammis et al. model. The CSD may be interpreted as a mixed one showing influence both of negative exponential and power law relationship due to original nucleation followed by fragmentation. The D values exceeding 3, a theoretical maximum, are probably an artifact resulting from 2D to 3D conversion, which seems to overestimate the smallest sizes.

The CSDs provide valuable information on various garnet origins. The open system CSD of pegmatite garnets suggests crystallization in freely moving, low viscos-

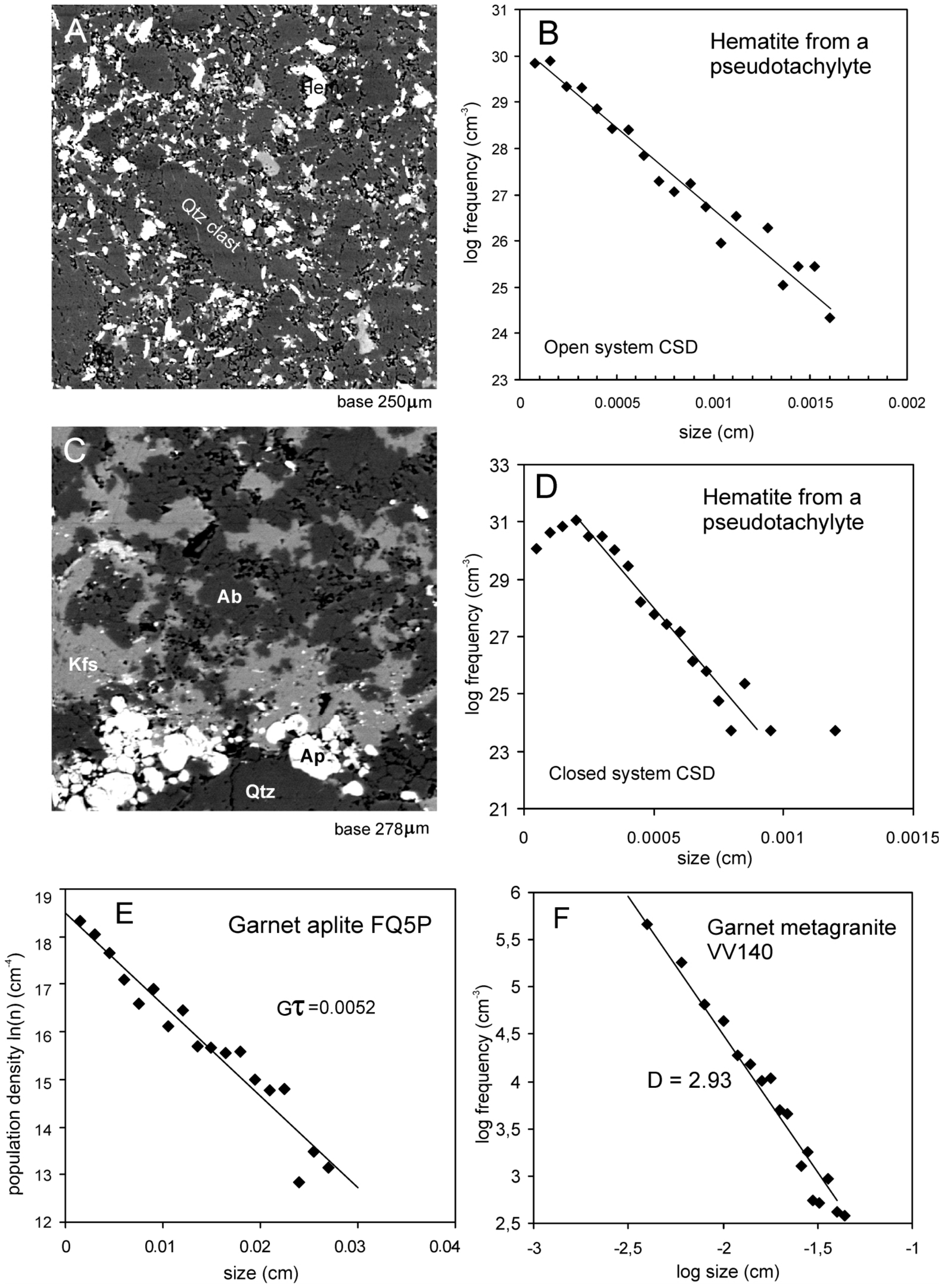

Fig. 1

ity H_2O-rich melt. There was enough time for nucleating garnets to develop a steady state CSD. In the absence of garnet data we used the plagioclase growth rate from a 1 m thick basaltic dike ($5x10^{-8}$ cms^{-1}, as compiled by Cashman, 1990). It gives the residence time $\tau = 29$ hours and total crystallization time 7 days for maximum garnet size 0.03 cm.

By contrast, small metamorphic garnets from the metagranite, which originaly nucleated to form pseudomorphoses or coronas around biotite, were subsequently fragmented due to deformation.

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