Nonlinear Processes in Geophysics

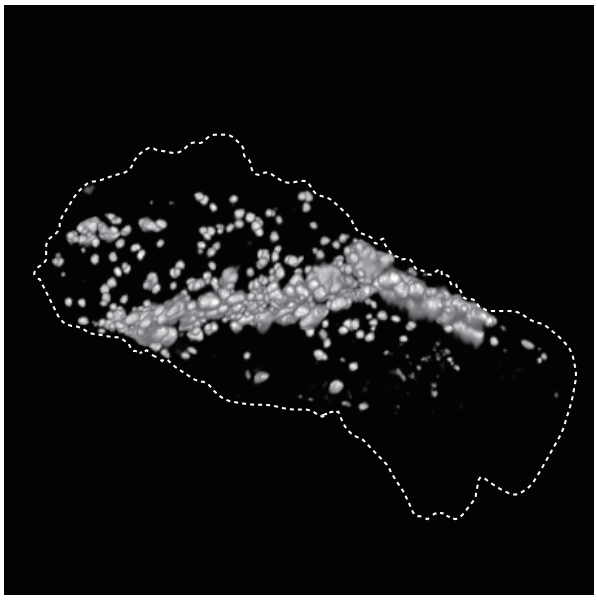
MS No: ngp-2014-53

MS Type: Research Article

Title: Multifractal analysis of mercury inclusions in quartz by X-ray computed tomography

Authors: T. Shibata, T. Maruoka, and T. Echigo

We are thankful to Dr. S. Tarafdar for referee's useful comments. We re-discussed our speculation of multifractal, and reply to them. Obtained fractal dimensions are 1.71 and 1.70 for the San Benito and Itomuka samples, respectively. The dimensions are lower than 2.5 in the diffusion-limited aggregation (DLA) of three-dimensional system shown by Muthukumar (1983). However, the mercury inclusions show dendritic structures (Figure A1) and these dimensions are similar to 1.66 and 1.89 in DLA and percolation theory for two-dimensional system, respectively. Therefore, we regarded the dendritic structures as products obtained by DLA processes under the constrained by available pores in quartz crystals, i.e., mercury inclusion could be constrained by (1) the available pores, (2) pore alteration by metamorphism in the quartz, and (3) migration of mercury into the pore.



Caption of Figure A1. Distribution image of the mercury inclusions in the San Benito quartz sample obtained with a micro-focus X-ray CT system. Mercury inclusions are

lighten and the quartz area is edged with a dotted line. This figure was added in revised paper (Figure 3) and uploaded to the journal web-page as a separate comment (AC C543)

Replies to specific comments

1. A 3D image is mentioned above and shown in Figure A1 that was added in revised paper (See the uploaded journal web-page as a separate comment (AC C543)).

2. *N(r)* in 1369:1 is the number of boxes in a box-counting technique. $P_i(r)$ in 1369:16 is the probability of being in the *i*-th box, and is defined as the measure of the *i*-th box of its size *r*, when the measure of the whole space is normalized to 1. To be more clearly, we rewrote the sentences in 1369:1 and 1369:16. The sentences in 1369:1 and 1369:16 were changed to "*N(r)* is the number of boxes in a box-counting technique" and "$P_i(r)$ is the probability of being in the *i*-th box, and is defined as the measure of the *i*-th box of its size *r*, when the measure of the whole space is normalized to 1", respectively.

3. Figure A1 shows the planar distribution of mercury inclusions in the host polycrystalline quartz. This three-dimensional distribution of mercury inclusions implies that these inclusions outline pre-existing cracks of the host. On the basis of the criteria for distinguishing primary, secondary or pseudo-secondary inclusions (e.g., Roedder, 1984), these mercury inclusions appear to be secondary inclusions. This observation suggests that the precipitation of mercury from hydrothermal fluids was after that of quartz crystals. We suggest that the fractal dimension of the mercury inclusion could be constrained by (1) the available pores, (2) pore alteration by metamorphism in the quartz, and (3) migration of mercury into the pore. Then, we have already mentioned the migration processes of 1370:22-1371:2, and 1371:13-21 in uploaded web-page as a separate comment (AC C543).

4. We show multifractal analysis and D_q is generalized dimension that shows fractal dimension of the *q*-th order moment of a distribution. The D_q for positively large *q* is measured in high densely parts, and the D_q for negatively large *q* is measured in low distribution densely parts. Therefore, the D_q with high-*q* characterizes the fractal dimension of the densely clustered parts, and D_q with low-*q* characterizes the fractal

dimension of scarcely distributed parts.

5. As the referee showed, this means that the distribution of mercury inclusion in the samples is heterogeneous. Then, to be more clearly, the caption of figure 4 in revised paper was changed to “Multifractal spectrum for the mercury inclusions in the San Benito and Itomuka quartz samples. The spectrum is the shape of a downward concave parabola. A wide opening parabola indicates heterogeneous distribution structures in the mercury inclusions. The opening size of parabola in the San Benito sample is larger than that of Itomuka sample, suggesting that mercury inclusions in the San Benito distribute the more heterogeneous than those in Itomuka”.