Nonlinear Processes in Geophysics

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

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We are thankful to Professor Robert P. Ewing for his useful comments. As the comments are precisely, we agree with the comments sincerely.

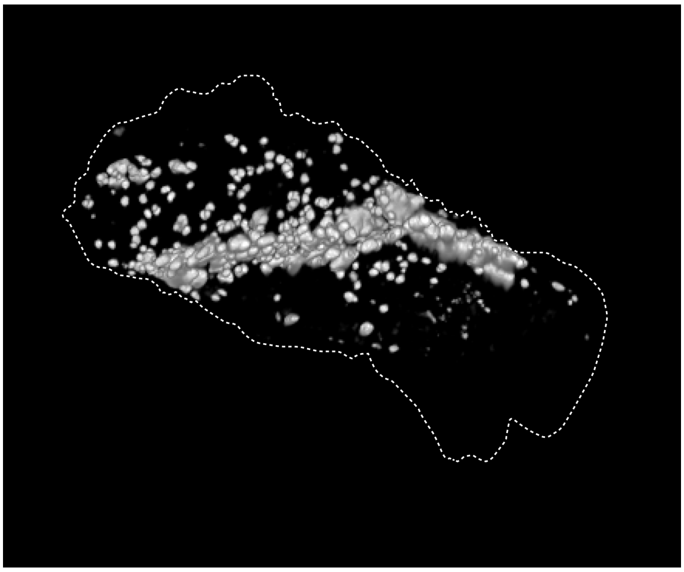
Response to overall comments:

We re-discussed the chapter 4 of "Results and Discussion", and rewrote our conclusion that included a new figure as Fig. 3 in order to be more clearly (1370:22-1371:2 and 1371:13-21, please see "Major change and English in the following pages"). As suggested by the reviewer, we changed the title from "Multifractal analysis of mercury inclusions in quartz by X-ray computed tomography" into "Inferring origin of mercury inclusions in quartz by multifractal analysis".

Response to scientific issues:

We agree with the reviewer's comments of inferring processes by which mercury inclusions migrate into the quartz. As suggested by the reviewer, the distribution of mercury inclusions could certainly differ from that of pores. Mercury inclusions presumably occupy only a part of primary pore spaces, because some pores could be closed by alteration and mercury inclusions did not arrive such pores. In addition, during crystal growth of the host rocks/minerals, mercury inclusions could be trapped in growing crystal faces. Thus, in this study, we attempted to analyze the spatial distributions of mercury inclusions quantitatively and then elucidate how the inclusions were trapped in the host rocks, e.g., primary, secondary and pseudo-secondary inclusions. We described some geological/mineralogical backgrounds of the analyzed samples and research objectives in the last paragraph of the revised introduction (1367:16-18, please see "Major change and English in the following pages").

As suggested by the reviewer, 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. The constraints are consistent with inference induced by geology and mineralogy. In the constraints, mercury migrations are defined by DLA or percolation processes. The different processes could lead to different results of patterns. The DLA process results in a dendritic pattern and the percolation process does in a loop pattern. Then, figure A1, which was Fig. 3 in the revised paper, gives an image of distribution of the mercury inclusion in the San Benito quartz sample. The distribution of the mercury inclusions could seem to be like a dendritic structure by DLA results, but not like a loop structure by percolation. Therefore, we understand that the distribution of the mercury inclusions would indicate the DLA process constrained by (3), as suggested by the reviewer. Then, we mentioned the migration processes in 1370:22-1371:2, and 1371:13-21 (please see "Major change and English in the following pages").



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.

Major change and English:

1366:9 and 1373:1 "mines": changed to "geological settings". Although the reviewer suggested us to use "geological formation" in these sentences, "geological formation" has other specific meaning in the field of stratigraphy and thus we used "geological settings" in the revised manuscript.

1366:10, "1.7 for the samples": changed to "1.70 and 1.71 for the San Benito and

Itomuka samples, respectively".

1366:12, "Then,": changed to "Given the fractal dimension and its implied mechanism, we conclude that".

1367:16-18, We described our research objective in order to make our story more clearly. The sentence was changed to "Here we observed mercury inclusions (liquid Hg^0) in quartz by the X-ray CT, and quantitatively analyzed their three-dimensional distribution using fractal and multifractal methods in order to elucidate how the mercury inclusions were trapped in the host rocks. The mercury ores in this study were formed by hydrothermal activities, and mercury precipitated from the hydrothermal fluids in the late stage of ore forming processes (Peabody and Einaudy, 1992; Dunning et al., 2005). Quantitative analyses of spatial distribution of mercury inclusions should give an insight into the detailed physical behavior of mercury during their migration and precipitation."

1367:21, "objective": deleted.

1368:19, "were": inserted before "analyzed".

1368:21-24, The sentences were changed to "Fractal and multifractal behavior is common in nature, and often the spatial distributions of mercury inclusions have fractal and multifractal properties. Because a fractal typically has a self-similar structure and scale-free properties, the degree of distribution of the inclusions follows a power law in the form".

1369:10, 1369:12 and 1370.6. "the": deleted.

1369:20, "then" : inserted before "the singularity".

1370:13-14, The sentence was changed to "We analyzed the mercury inclusion clusters in the quartz samples using the above equations in order to understand how the inclusions were incorporated into the quartz samples".

1370:22-1371:2, The sentences were changed to "Several studies have been performed using fractal geometry, which is controlled by the irreversible kinetic processes such as diffusion, aggregation and percolation (e.g., Zheng et al., 1998; Hunt and Ewing, 2009).

The San Benito and Itomuka mercury deposits occurred in hydrothermally altered rocks, which would have been formed by repeated hydrothermal activity in the Neogene/Quaternary age (Dunning et al., 2005; Sugimoto et al., 1972), and it is difficult to distinguish whether the mercury inclusions were primary, secondary or pseudo-secondary inclusions. However, as spatial distributions of mercury inclusions have fractal geometry, the mercury inclusions could not be trapped in growing crystal faces but controlled by diffusive processes. This result suggests that the fluids of mercury inclusions would be captured into quartz after its crystallization process. Hence the mercury-bearing fluids were not the primary fluid inclusions, but were trapped in cracks that already existed in the quartz samples.

In this condition, the fractal dimension of the mercury inclusion could be constrained by the available pores, pore alteration by metamorphism, and migration of mercury into the pore. These processes…"

1371:10, "D": deleted.

1371:13-21, The sentences were changed to "The mercury inclusion could be constrained by DLA models or percolation mechanism, which could lead to different structures. The DLA models and percolation mechanism result in dendritic and percolation structures, respectively (e.g., Zheng et al., 1998; Hunt and Ewing, 2009). Consequently, mercury inclusions were ramified like a dendritic structure, but not like a loop structure as illustrated in Fig. 3. Therefore, we assume that the mercury inclusions could migrate into the quartz by the DLA models rather than by percolation mechanism".

1372:13-14, The sentence of "Consequently, mercury inclusions ramified like a dendritical structure" was deleted.

1372:17, "We proposed to analyze of mercury inclusions" was changed to "We analyzed mercury inclusions".

1376 (Fig. 1 Caption) "binatized" changed to "binarized".

1378 A new figure was inserted as Fig. 3, and its caption was "**Figure 3.** 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." Figure 3 in the peer-review paper was changed to Figure 4.

1379 Figure 4 in the peer-review paper was changed to Figure 5, and the figure was inserted dot lines through q=0, D=1.70 and D=1.71.

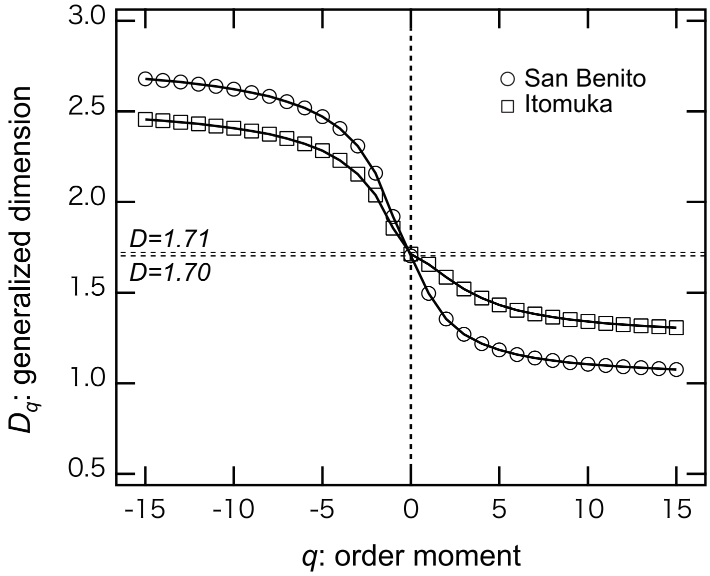


Figure 5.

We are deeply grateful to the reviewer for constructive reviewing the paper and encouraging us in the improvement of it. We hope now find that this paper becomes more clearly for the readers.