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Ar-Ar dating by fluid inclusions in hydrothermal quartz, compared with its field and microscopic observations

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The chemical evolution history of the ocean must have been one of the most critical factors to unravel the evolution of life on the Earth. However, this topic has not fully understood yet. Recently, de Ronde et al. (1997) and some studies try to estimate seawater composition during Archean and Proterozoic using fluid inclusions trapped in hydrothermal quartz correlated with pillowed basalt, which is expected to erupt in sub-seawater condition. Lowe and Byerly (2003) claims that the hydrothermal minerals used by de Ronde et al. (1997) were formed at far younger age (Quaternary) than expected age of eruption of the matrix lavas (3.2 Ga), based on the only field and microscopic observations. This problem must be solved by dating of the fluid inclusions trapped in hydrothermal quartz and comparing the age of pillowed basalt as a matrix in addition to field and microscopic observations. We carried out Ar-Ar dating of the fluid inclusions with stepwise crushing techniques at Guangzhou Institute of Geochemistry, Chinese Academy of Sciences.

Analyzed samples in this study are from 2.2 - 2.4 Ga Ongeluk Formation, Transvaal Supergroup, South Africa. Above Ongeluk Formation, two younger volcanic layers exist, one is mafic intrusions of the Malopo Farms complex formed at 2044 $\pm$ 24 Ma, the other is porphyritic andesite of the Hartley Formation formed at 1928 $\pm$ 4 Ma.

The analyzed samples are hydrothermal quartz with growth zoning texture, filling the primary shaped drainage cavities and interstitial spaces of lava flows of the Ongeluk Formation without quartz vein crosscut pillow of lava, suggesting the quartz had precipitated soon after eruption of the lava. We analyzed four of the most primary-rich samples (GU84, GU91, GU103a and GU103b), in terms of microscopic observations. However, secondary fluid inclusions are not excluded completely, in other words, argon gas extracted the quartz samples including some secondary fluid inclusions origin in the analysis.

Three samples, GU 84, GU103a and GU103b, yielded Ar-Ar isochron ages of 2688 $\pm$ 584 Ma, 1952 $\pm$ 279 Ma and 1967 $\pm$ 64 Ma Ar-Ar isochron ages, respectively. GU91 was also dated in the same manner as well, but failed to obtain a tight line of isochron with a diffused age (611 $\pm$ 517 Ma).

Comparing the age of the Ongeluk lava and younger two volcanisms with the results, the age from GU84 has a wide range of error, but is consistent with Ongeluk lava, GU103a has also a wide range of error, but is consistent with all three volcanisms, and GU103b has the narrowest range of error and is consistent with Malopo Farms complex and Hartley Formation, especially match with Hartley. Based on field and microscopic observations, it is unlikely to precipitate quartz with filling cavities 100-200 Myr after eruption of Ongeluk lava. Two probable mechanisms to explain the results, one is that fluid inclusions were re-equilibrated at younger volcanisms in terms of the argon with preserving primary textures. The other is that secondary fluid inclusion formed by younger volcanism driving hydrothermal circulations and that extracted argon gas in the analysis is mainly composed of the secondary inclusions. The secondary fluid inclusions have argon ratio suggesting younger age than primary fundamentally, suggesting that GU84 obtaining the oldest argon age is the most primary rich samples. Assuming that obtained younger ages than Ongeluk lava are resulted in argon gas from secondary fluid inclusions, the consistency with Ar-Ar age of GU84, the most primary-rich sample, and Ongeluk lava support that our field and microscopic observations are robust and that the primary fluid inclusions formed soon after Ongeluk lava eruption.

Keywords: fluid inclusion, Ar-Ar dating, quartz, seawater