Experimental results of fission track annealing by hydrothermal fluid in zircon

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Fission Track (FT) Dating and FT length analysis are one of the most reliable methods to measure geotime and geothermal history because it is known that FT age becomes younger only by heating. But nobody knows whether any environmental condition of heating, such as dry heating and wet heating, controls the effect to reduce FT length or not. In mineralogy, it is known that a little water existence accelerates crystal phase change dramatically. This is, we think, the most weak point of FT.

Therefore the aim of this study is to measure the reduction of zircon FT length through pure thermowater annealing and compare with dry annealing data of Yamada et al.(1995b).

As a result, no conspicuousness difference appeared between experimented Time-temperature range adopted in this study.

Geothermal history analysis using fission track length (FTL) is made widely useful as a relatively low temperature thermometer to measure paleotemperature elevation such as temperature distributions nearby faults (e.g. Tagami et al., 2001). But it is necessary to know accurate relation among temperature - time - FTL reduction to estimate not only qualitative cooling history but also quantitative temperature history. All previous experiments were done in the room pressure and dry atmosphere although many experiments had investigated this relation. In contrast with this, in mineralogy, they think water existence changes rate of the phenomenon at boundary among crystals or in the crystal. For example, it is known that a little water existence accelerates crystal phase change dramatically. Therefore, the aim of this study is to measure the reduction of FTL in zircon annealed hydrothermally and to estimate the water effect on the annealing rate of FTL in zircon.

At 20 degrees C pure water, the specific gravity of liquid phase is 0.998 g/cm3, the one of gas phase is 1.85x10^-15 g/cm3, and saturate vapor pressure is 0.023 atm. At 360 degrees C, each data is 0.575 g/cm3, 0.114 g/cm3, 163 atm. At 374.15 degrees C, both specific gravity values in agreement and the difference of liquid and gas phase disappears. This temperature is called critical point (CP), and the water temperature higher than CP is called super critical water. Super critical water has high reactivity such as large solubility of silica, resolution of dioxin, and so on. This is clearly different from reactivity of normal hot water and means the existence of particular nature of super critical state. Annealing by super critical water is suitable for natural conditions because CP temperature is 374.15 degrees C as mentioned above and saturated vapor pressure is 218.3 atm.

It is well known that the FT before etching is characterized by only a few atomic vacancies across its length direction, surrounded by a wide area where crystal lattice is distorted by coulomb power of high speed heavy ions created by nuclear fission. It is essence of annealing that distortion of crystal lattice in this area recovers. The effect of super critical water to the annealing rate is assumed to have the following two contrary factors derived from different mechanism.

1. Annealing is accelerated by action as catalyst.
2. Crystal lattice distorted area is etched by super critical water as solvent. In this case, annealing rate is to decrease or annealing does not occur.

The zircon grains shut into Platinum capsule with pure water for protection from pollution and loss are heated by using electric heater and Tuttle type reactor. This type of reactor can be used with keeping connection to pomp, pressure gauge, and thermocouple. In this point, this reactor is better than conventional reactors. Therefore, real time direct measuring of temperature and pressure in the reactor is characteristic of this one. Time needed to reach plateau temperature from start of heat is almost constant as about 2 hours in spite of different reached temperatures. Experimental annealing time is set as 100 hours through this study so that we can ignore annealing effect during this 2 hours. Temperature measurement was done with PR thermocouple put at within 1 cm from the sample in the reactor. Temperature is constant for 100 hours within +/- 5 degrees C. Pressure was kept as 1000 kg/cm2 due to machine limit.

Experiment was performed at about 450, 500, 550 degrees C. There is no conspicuousness difference appeared between this data and precise dry annealing data of Yamada et al.(1995b). There is also no difference of shape of annealed FTs, and so on. Therefore, the pure water does not effect annealing rate for conditions of this experiment. It is theme in the future to increase variation of conditions and estimation of natural ions.