Effects of allowable complexity and multiple thermochronometers on thermal history inversion

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Inverse Modeling

The objective of inverse thermal history modeling is to use measurements from one or more thermochronometric systems to infer details of the time-temperature history that a rock has experienced. However, of comparable importance in determining the nature and details of results is the set of candidate time-temperature histories that is tested. Candidate histories consist of a number of line segments or polynomial curves, specified with a limited number of degrees of freedom. Both the nature of the paths and the means by which they are specified are substantive implicit assumptions about the nature of the solution. Invariably, when more variation and flexibility are allowed in candidate time-temperature histories, a wider range of statistically permissible paths will be found. Thus, it is often tempting to simplify and restrict the range of possibilities considered in modeling in order to arrive at a cleaner solution; however, such clarity may be illusory. Although simple, a line segment is not a geologically probable path. The appropriate level of allowable complexity in thermal history modeling is not clear. Two avenues for improving thermal history modeling include simultaneous evaluation of data from more than one thermochronometer and test-driven modeling approaches.

Multiple Thermochonometers

Combining fission-track and (U-Th)/He data for multiple minerals can allow each to constrain the region of time-temperature space that it is most sensitive to, generally its partial retention zone. In beneficial cases these mutual constraints can lead to better-defined solutions. However, by increasing the number of variables involved we also increase the likelihood of error or unforeseen variablility and the effect of uncertainties in thermochonometer calibrations.

Test-Driven Modeling

Test-driven modeling is an approach that seeks to answer a particular geological question while allowing the level of complexity to be explicitly specified and controlled. Example questions include determination of cooling rates or the timing and extent of heating evnts. Complexity can be controlled by allowing progressively greater variation from linear sub-path segments and documenting the increase in the range of solutions found.

Water-rock interaction in Kusatsu-Shirane volcano area (Japan) studied by long-term changes in water chemistry of hot springs

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Long-term changes in water chemistry since 1960s were investigated for major acidic hot springs around Kusatsu-Shirane volcano, Gunma, Japan. These hot springs can be classified into two groups based on their locations. The first group consists of hot springs located in the eastern foot of Mt. Kusatsu-Shirane (Kusatsu hot springs), and the second group those located in the western foot (Manza hot springs). While the hot springs in the two groups are all acidic, there are differences in water chemistry between the two.

Fig. 1 shows Si – Al – Fe ternary plots of the hot spring waters belonging to the Kusatsu hot spring group. The chemical compositions of those hot springs can be plotted along a single curved line (dotted line in Fig. 1). Kagusa hot spring, which is one of the nearest hot springs to the top of Mt. Kusatsu-Shirane and thus relatively directly affected by its volcanic activity, is plotted farthest from the vertex of Si. The secular changes of water chemistry of Kusatsu-Yubatake and Bandaiko hot spring waters are also plotted along the same line, approaching the vertex of Si as the years go on. While Kagusa hot spring water did not show the one-way trend with time, its data are also along the same line. The direction of this line is similar to the direction of change in chemical composition of rocks altered under strongly acidic environment characterized by relative enrichment of Si (solid line in Fig. 1). Furthermore, the hot springs belonging to the Manza hot spring group also show a tendency similar to that of the Kusatsu hot spring group. These results indicate that the water chemistry of the acidic hot springs around Kusatsu-Shirane volcano is generated by water-rock interaction at the subsurface in the area and changes in parallel with the chemical composition of rocks that changes with the progress of their alteration caused by water-rock interaction.

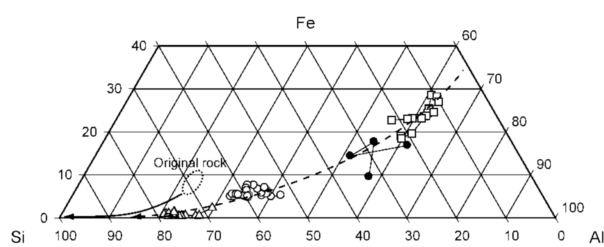

Fig. 1 The Si - Al - Fe ternary plots of the hot spring waters belonging to the Kusatsu hot spring group and the directions of changes in chemical composition of rock altered under strongly acidic environment. open circle, Kusatsu-Yubatake hot spring since 1965; filled circle, Kusatsu-Yubatake hot spring between 1881 and 1941; open triangle, Bandaiko hot spring since 1975; open square, Kagusa hot spring since 1969.