Thermal History Analysis of the Beaufort-Mackenzie Region using Multi-Kinetic Apatite Fission Track Thermochronology

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Introduction

The Geological Survey of Canada is undertaking apatite fission track (FT) thermochronology studies as part of a comprehensive, multi-disciplinary government-industry funded study of petroleum systems for the Beaufort-Mackenzie region of northern Canada. The objective is to provide thermal history constraints for petroleum generation and regional tectonics.

Analysis of Apatite Grains and Results

Apatite grains recovered from Cretaceous and Tertiary core and cuttings samples from onshore and offshore exploration wells give mixed FT age populations that are difficult to interpret and model using conventional FT methods. Elemental data indicate that older FT ages are associated with apatite grains that have elevated abundances of elements (e.g. Fe, Mg, Cl) that make them more track-retentive (i.e. higher annealing temperatures) than fluorapatite ($Ca_{10}(PO_4)_6F_2$), the most common form of apatite. Therefore, new methods of analysis were required to characterize and model this complicated, compositionally-variable suite of samples. Elemental data were used to calculate an rmro parameter (Ketcham *et al*., 1999) for each analyzed apatite grain that permitted grouping of sample FT age and length data into different kinetic populations for modelling FT annealing. Typical ranges for average rmro values (0.73-0.83) indicate that temperatures for total FT annealing for different kinetic populations vary by tens of degrees Celsius. Thus, each kinetic population (typically two or three per sample) behaves as an independent thermochronometer that is sensitive to different parts of the thermal history.

Thermal Modelling and Results

An inverse thermal model (Issler *et al*., 2005) incorporating the multi-kinetic FT annealing scheme of Ketcham *et al*. (1999) was developed and applied to obtain geologically-constrained thermal histories for the FT samples. In addition to matching calculated and observed FT parameters, model thermal histories must be compatible with *a priori* heating rate constraints (from stratigraphic and present temperature data) and measured thermal maturity (e.g. vitrinite reflectance). Simultaneous inversion of different kinetic populations within a FT sample gives time-temperature constraints on both the pre-depositional and post-depositional thermal history of the apatite grains comprising the sample. Therefore, these multi-kinetic FT samples contain valuable information on the heating/cooling history of the Cretaceous-Tertiary sedimentary successions of the Beaufort-Mackenzie region as well as the cooling history of the exhumed source areas from which they were derived. Furthermore, multiple FT samples within a single borehole yield coherent thermal histories, demonstrating the reliability and utility of the analytical and modelling techniques. Compositional variation in apatite is common in sedimentary basins and therefore it is strongly recommended that conventional FT methods (that require a single, uniform population of apatite for proper interpretation) be abandoned in favour of the multi-kinetic approach.

References

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