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INVERSE MODELLING OF APATITE FISSION TRACK DATA

Dale R. Issler* and Sean D. Willett**
*Geological Survey of Canada, 3303-33rd St. NW, Calgary, Alberta, Canada T2L 2A7
**Dept. of Geosciences, Pennsylvania State University, University Park, Pennsylvania, USA 16802

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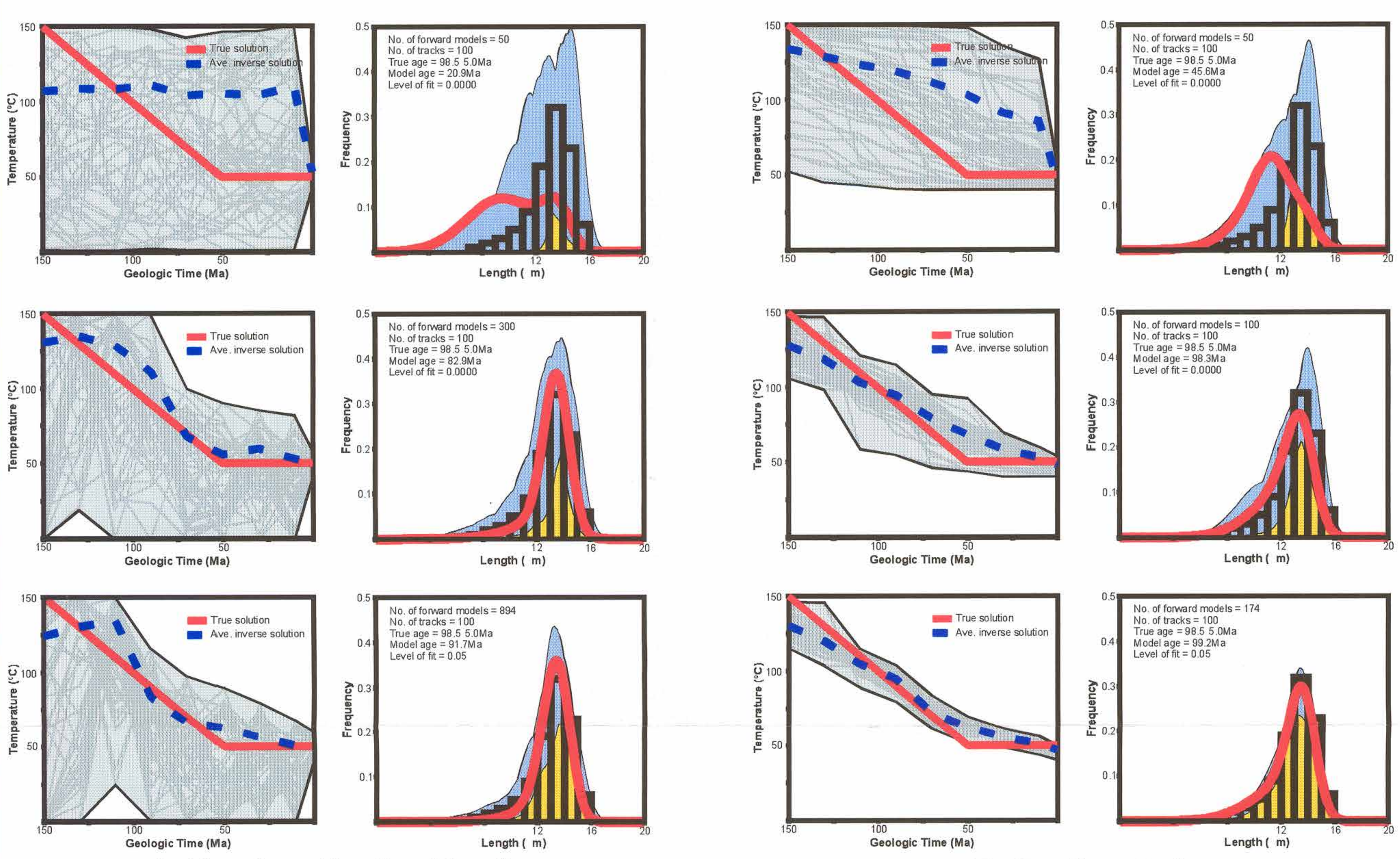
INTRODUCTION

We present a controlled random search inversion method for extracting thermal history information from apatite fission track (AFT) data. This model is a modified version of the inverse model, TINV52, of Willett [1] which was used in a number of AFT studies of the Western Canada Sedimentary Basin [e.g. 2,3]. TINV52 has been modified extensively to become an interactive, user-friendly software package designed to run under the Windows 95 operating system and the executable code and an accompanying instruction manual are available at from the GSC bookstore [4]. This poster outlines some of the major changes to the original inverse model.

The model consists of three 32-bit windowed FORTRAN executable programs: PREAFT32, AFTINV32 and POSTFT32. PREAFT32 is used to set up a model run. At this stage, users can specify the required model times and incorporate temperature and rate constraints based on available geological data. For example, temperature constraints may include the present temperature and limits on temperatures at the time of deposition or during the development of unconformities. Rate constraints can include limits on the direction and/or magnitude of temperature change. A new feature allows users to specify the number of randomly generated heating or cooling events which, for example, allows investigation of the time range over which a maximum heating event may have occurred (panel 4). AFTINV32 performs inverse calculations by generating an initial large set of random thermal histories and by incrementally replacing members of this set with improved solutions until all members represent statistically valid solutions to the AFT data (panel 1). AFTINV32 includes modifications to Willett's [1] technique to objectively suppress strong flucuations in the initial random temperature histories and the final acceptable solution set (panel 3). It also includes a time-step predictor function [5] to ensure accurate and efficient evaluation of the annealing equation (panel 2). POSTFT32 generates model output and plots showing temperature histories and track length distributions for all acceptable thermal solutions and the exponential mean solution.

Panel 1: Controlled Random Search Inversion Technique

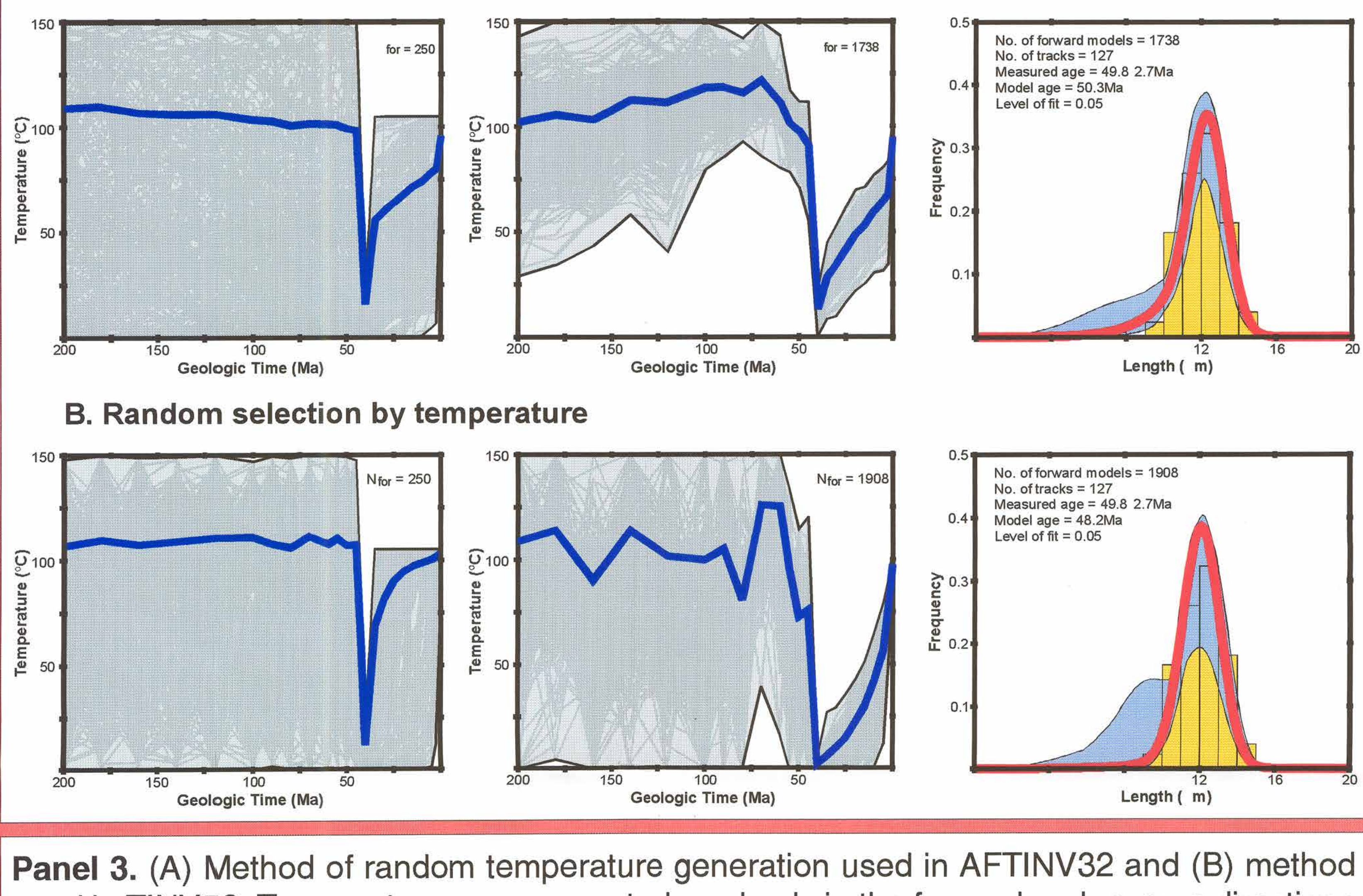


Panel 1. Illustration of inversion method using synthetic AFT data generated from the true temperature solution (red line on temperature plots). In the upper left panels, an initial random set of 50 solutions is created (light grey lines in shaded region). During continued iteration, successive members of the initial set are replaced by improved solutions (middle left panels) until all members of the set are statistically valid (convergence at significance level probability of 5%) (lower left panels). The preferred thermal solution (blue dashes) is represented as an exponential mean of all solutions contained within the acceptable solution space (grey shading). The corresponding calculated track length distribution for the mean solution (red curve in right panels) is shown in comparison with the synthetically generated distribution (histogram). The blue shaded regions indicate the range of track distributions produced by the

Panel 3: Random Temperature History Generation

A. Random selection by rate of temperature change and correction for boundary effects

B. Random selection by temperature



Panel 3. (A) Method of random temperature generation used in AFTINV32 and (B) method used in TINV52. Temperatures are generated randomly in the forward and reverse directions using (A) a random selection for rate of temperature change (tangent function of the projection angle between the new and previous point) and (B) a random selection between minimum and maximum temperature limits. For (A), an additional requirement is that the probability of heating or cooling is equal near a temperature boundary to minimize the effect of the imposed temperature limits. In comparison with A, method B is biased to higher rates of temperature change, with large cyclic flucuations yielding a wider range on parameter space for heating/cooling histories. However, for uni-directional temperature changes, method A tends to yield a wider range on acceptable parameter space.

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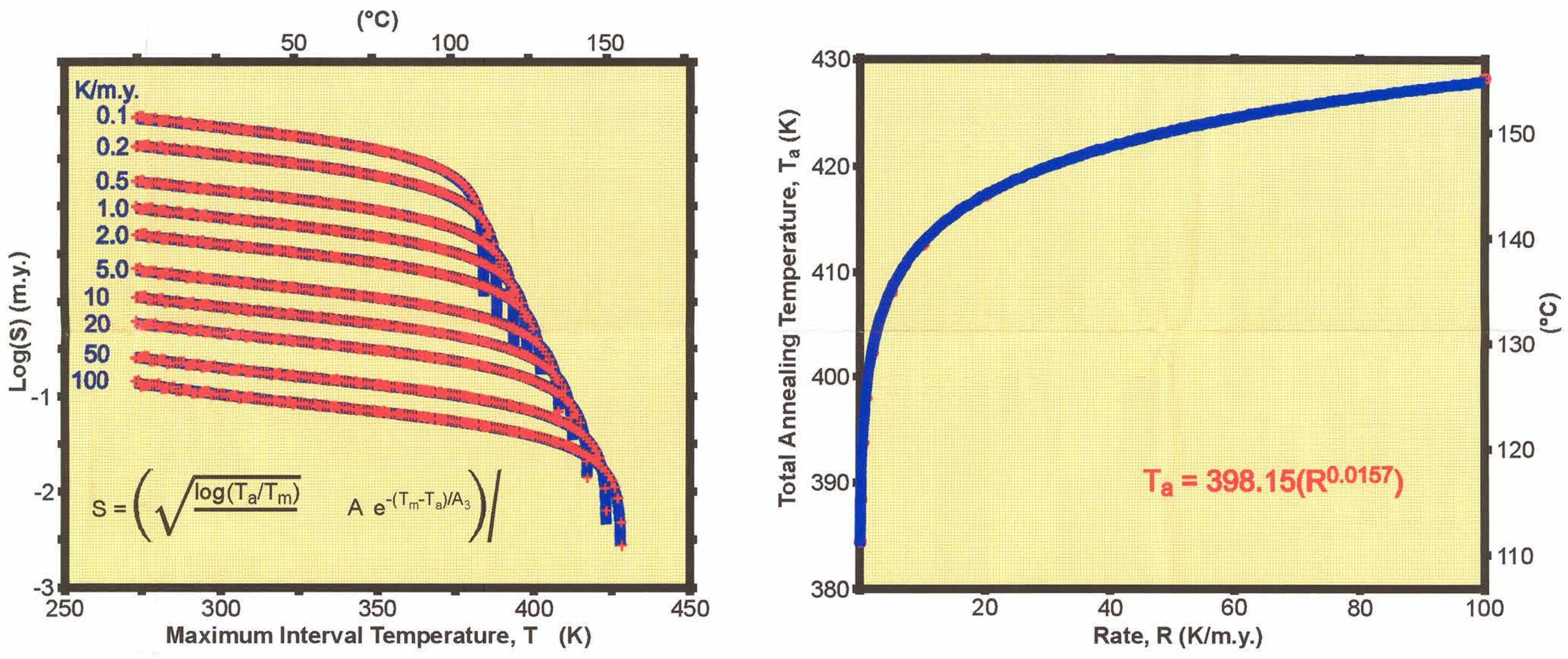
4. Issler, D.R. 1996. An inverse model for extracting thermal histories from apatite fission track data: instructions and software. GSC Open File 2325, 84p.
5. Issler, D.R. 1996. Optimizing time step size for apatite fission track annealing models. Computers & Geosciences, 22/1, 67-74.

Panel 2: Integration Time Step Predictor for Empirical Annealing Equation



Panel 2. Left panel shows isothermal time step size predictor function used for efficient and accurate evaluation of the empirical apatite fission track annealing equation. Step size (S) is a function of heating/cooling rate as well as the maximum interval temperature. Annealing calculations can be specified to an approximate level of accuracy by scaling S values by the factor $(10E)^{1/2}$ where E is the approximate percentage error on calculated track lengths (default is 0.1% accuracy). The right panel shows how the total annealing temperature, T , varies as a function of the rate of temperature change, R. T is defined as the temperature at which

Panel 4. Illustration of different rate options for random temperature history generation. AFT sample is from a Tertiary granite in the internal zone of the southern Canadian Rocky Mountains (Omineca Belt). Wide open temperature limits (0-150 C) were used for all model times except for the present (0-10 C). For three of the models, heating/cooling rates were restricted to a maximum of 20 C/m.y., a reasonable maximum upper limit for burial/erosional processes typical of this tectonic setting. For the fourth model, maximum heating/cooling rates were determined by the initial temperature limits and model times (2 m.y. steps). The cooling only model shows a steady monotonic decrease in temperature with an increase in cooling rate in the last 2 million years. The recent cooling may be an artifact of the annealing model which has poor resolution at lower temperatures. Similar results are obtained for the random heating/cooling model (compare mean solutions (blue)). The last two models allow for a random reheating event. When rate limits are relaxed (lowermost panel), the model produces solutions indicating mild reheating (~85 C) during the Miocene. Although these solutions are nonunique, it is interesting that nearby samples from the southern Rocky Mountain Trench have Miocene ages and hydrothermal

Panel 4: Examples of Rate Options