On Track

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In this Issue:

On Track will remain free, at least for the near future. However, to save costs we generally mail only one copy per lab so please be sure to pass On Track around your lab.

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Editor's Notes

First of all I would like to thank the previous editor of On Track, **Ruth Siddall**, for her help during the transitional period of editorship. Issue 13 of On Track marks the seventh year of the newsletter's existence, reflecting the need and importance of On Track! The constant support and stream of requests from labs and individuals expressing their interest and wish to be added to the mailing list indicate that On Track represents a well-accepted and important forum, bringing new and interesting issues to the attention of the international FT community. On Track has always been a newsletter for the FT community by the FT community. The very existence of On Track is based on all your support and contributions. Somewhat disturbing, however, is the fact that most On Track contributions are written by a very small number of individuals from an even smaller number of research groups and laboratories, although the number fission-track labs, especially in the old world, is growing at a rather amazing rate. I would like to encourage all people and groups to contribute to On Track. I would also like to thank **Ray Donelick** of Donelick Analytical, Inc for his financial contributions which have permitted the continued free distribution of On Track.

In this issue, **Ann Blythe** presents intriguing, new data on compositional effects on zircon fission-track annealing properties. **Paul O'Sullivan** fills us in on the potential influences of long-term surface temperature variations on apatite FT data in Arctic environments. Two contributions in this issue deal with modeling of fission-track data. **David Coyle** tries to convince us that we can do almost everything using Mathematica™, presenting a Mathematica™ notebook for modeling annealing. **Dale Issler** offers an inverse model for determining time-temperature histories.

After **Trevor Dumitru**'s MEI zircon/apatite separation demonstrations at the Gent meeting, we decided to also introduce the method in On Track. As announced by **Stefan Boettcher** in issue 9, On Track is on the web! **Dennis Trombatore** of UT-Austin offered to archive electronic versions of On Track at **http://www.lib.utexas.edu/Libs/GEO**. Also featured in this issue is the new updated, annual fission-track directory, as well as some technical news and of course the short track news.

One copy per lab; please copy and distribute

Preliminary Note on Hf And U Concentrations and Fission-Track Annealing in Zircon

by Ann Blythe

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During the recent International Fission Track conference in Gent, Belgium, a discussion occurred on the need for studies of the effects of zircon chemistry on fission-track annealing in zircon. Specifically, it was suggested that Hf (which substitutes for Zr) should be examined. In this preliminary note, I describe Hf and U concentrations from a sample that appears to have both reset and nonreset zircon fission-track ages. The sample was one of a suite of samples collected by K. Kleinspehn from the Tertiary-age Forlandsundet basin of Spitsbergen. The Forlandsundet basin rocks are considered Paleogene and younger in age, but the exact sedimentary ages of individual samples are poorly constrained. Vitrinite reflectance values of R_o = 2.55-5.07 (representing temperatures of >180°C) were measured near the samples used in this study (Kleinspehn and Teyssier, 1992), suggesting that partial to total annealing of fission tracks in zircon was possible. The time of peak temperatures in the basin is constrained only by apatite fission-track analyses from 32 samples collected throughout Spitsbergen. These samples ranged in age from 27 ± 4 to 55 ± 13 Ma, with a mean age of 37 Ma; track-length models of several of these samples (using the models of Corrigan and Gallagher) were consistent with regional cooling beginning at ~40 Ma (Blythe and Kleinspehn, in prep.).

Zircons from 6 Forlandsundet basin samples were analyzed. Four samples had zircon fission-track single grain ages ranging from 80 to 700 Ma, which, based on the probable age of deposition (Tertiary), appeared to be unreset. A single sample, PKF-688, appeared to have been totally reset, with a pooled age of 42.4 ± 1.8 Ma. The most interesting sample, however, was PKF-49, which appeared to have a population of grains that had been reset at ~42 Ma, and a second population that had not been reset.

In **Figure 1a**, histograms of individual grain ages and probability distributions are shown for samples PKF-49 (reset and unreset grain ages), PKF-65 (one of the four samples with unreset ages, shown for comparison), and PKF-688 (all grains reset). Although the effects of chemical composition on fission-track annealing in apatite are well-known (e.g. Green et al., 1989), no such effects have been documented in zircon.

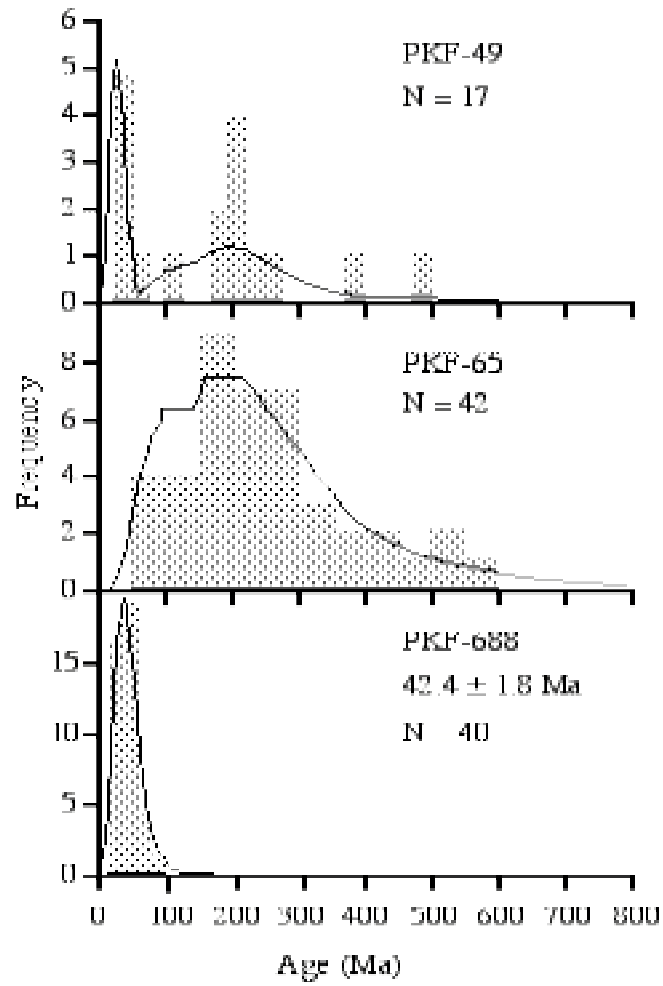

Fig. 1a: Zircon single grain fission track age histograms and probability distributions.

Zircon [$ZrSiO_4$] has a much simpler structure than apatite. The only major variation in chemical composition that occurs is the substitution of hafnium (Hf^{4+}) for Zr^{4+}. The degree of substitution can be up to 6Hf:10Zr (Phillips and Griffen, 1981), and is easily measured with a microprobe. In order to see if variations in Hf correlated to the differences in individual grain ages from PKF-49, Hf and Zr were measured on individual grains with the Cameca Microprobe at the University of California at Santa Barbara (with the assistance of D. Pierce and H.

Dervin). Hf concentrations in individual grains did not vary within analytical error and no correlation between zircon fission-track age and Hf concentration was seen.

However, when I plotted U concentration versus single grain age, a distinct correlation emerged (**Figure 1b**). The grains with young zircon fission-track ages had higher U concentrations than grains with older ages. This correlation was apparent in PKF-49 as well as PKF-65, the sample I had initially interpreted as totally unreset, suggesting that the younger grain ages might be partially reset.

However, it should be pointed out that counting bias is a problem with these data - obviously, it is easier to count tracks in old, low-U zircons than in old, high-U zircons (too many tracks); and it is easier to count tracks in young, high-U zircons than in young, low-U zircons (too few tracks). In the Forlansundet basin samples, tracks in the young, low-U zircons could still be counted, but several of the old zircons could not be counted because the densities of spontaneous tracks were too high.

Therefore, I need to find a method for dealing with the counting bias problem with these old zircons (any suggestions would be appreciated!). I suggest that if these correlations between age and U concentration are still evident after counting bias has been eliminated, that the most likely explanation for the resetting of zircon fission-track ages involves metamictization of high-U zircons.

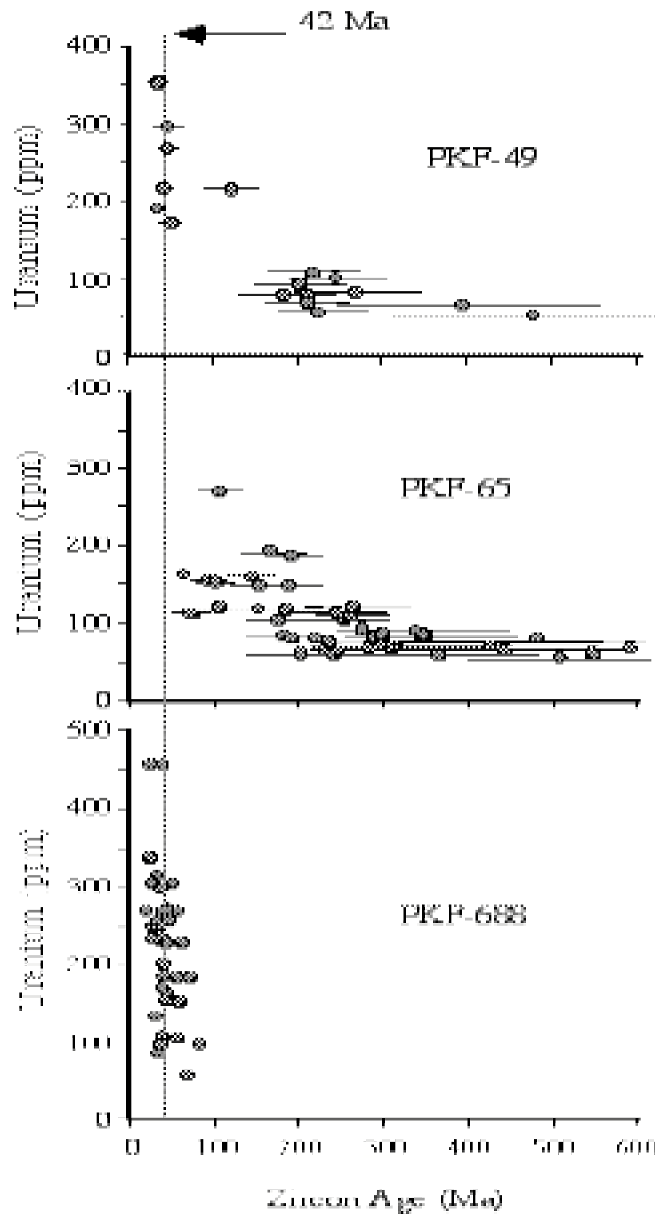

Fig. 1b: Plots of U concentration vs. zircon fission-track age. One sigma error bars on ages are shown.

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Long-Term Change in Mean Annual Surface Temperature and its Effect on Estimating Denudation

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Introduction

The North Slope foreland basin is a late Mesozoic and Cenozoic basin that spans the entire width of northern Alaska (Fig. 1). During the Late Jurassic through Early Paleocene, denudation of the Brooks Range to the south resulted in many kilometers of material being rapidly deposited into the adjoining foreland basin. Subsequently, foreland basin rocks cooled from maximum paleotemperatures in response to km-scale denudation beginning in the Paleocene (O'Sullivan, 1996); prior to a major climatic change from temperate to arctic conditions during the late Cenozoic. Due to the lower mean annual surface temperatures resulting from the change to arctic conditions, the subsurface stratigraphy experienced significant cooling (O'Sullivan and Brown, 1996, we also have a paper ready for the FT Workshop volume but are waiting to hear whether or not they will be accepting submittals anytime soon). Therefore, since the rocks in the foreland basin cooled from maximum paleotemperatures prior to the decrease in mean annual surface temperatures, estimates of total denudation using maximum paleotemperature indicators (e.g. R_O), and present-day surface temperatures, will be overestimated.

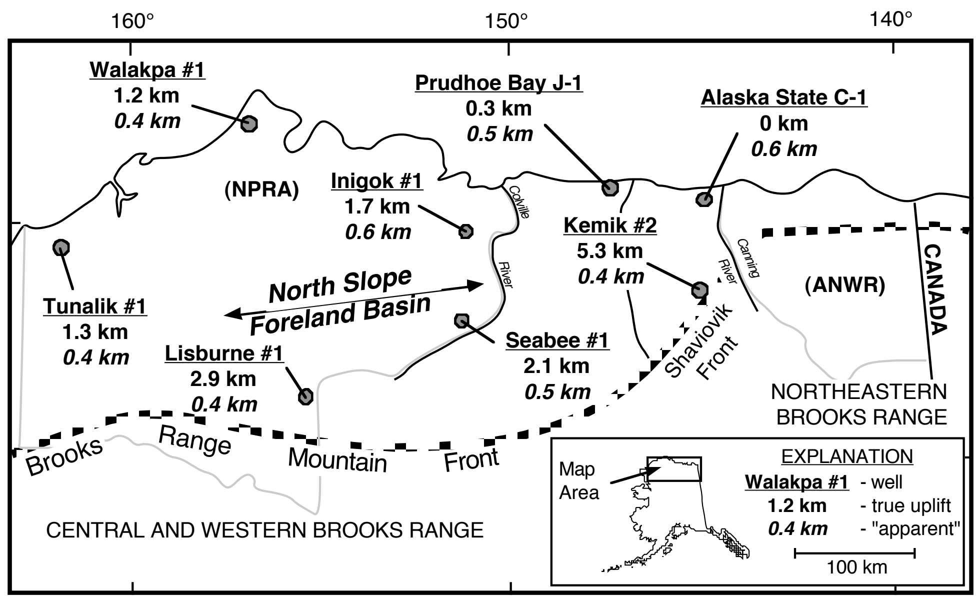

Figure 1: Location of the North Slope foreland basin study area showing major geographic features and wells referred to in the text, and estimated denudation of the North Slope foreland basin study area. See text for explanation.

The case study summarized here illustrates the importance of utilizing both R_O and apatite fission track thermochronology (AFTT) data when evaluating the thermal history of an area, and estimating the amount of denudation that area has experienced. As most trackers know, when assessing the thermal history of rocks, there are many uncertainties (e.g. porosity, compaction, and diagenesis associated with sedimentary basins) which are difficult to assess quantitatively in the relationship between heat flow and thermal gradient. These problems may be substantially reduced by using the method outlined by Bray et al. (1992), based on the integration of apatite fission track and vitrinite reflectance methodology, which yields a direct estimate of both the time at which cooling from maximum paleotemperatures began and the paleogeothermal gradient at that time. Furthermore, when trying to estimate maximum denudation, the time at which cooling from maximum paleotemperatures began and the surface temperature at that time are important factors to know.

One Method for Estimating Maximum Paleogeothermal Gradients and Amount of Uplift and Erosion

After maximum paleotemperatures are determined for AFTT and R_O samples from a vertical sequence, plotting these values relative to depth provides a maximum paleotemperature profile (Bray et al., 1992). From this profile, a paleogeothermal gradient at the time of maximum paleotemperatures can be estimated as well as the amount of section which has been removed since maximum paleotemperatures were reached. In a vertical section that has been hotter in the past, the paleogeothermal gradient can be compared to the present-day geothermal gradient, allowing interpretation of the cause of the high paleotemperatures, and the cause of the subsequent cooling to the present temperatures. Figure 2A shows a simple example where heating and subsequent cooling were caused solely by deep burial followed by denudation with no change in mean annual surface temperature or basal heat flow. In this case, the present gradient would remain the same as the maximum paleogeothermal gradient, but the paleotemperature profile trend would be translated towards higher temperatures. Therefore, the amount of removed section can be estimated by dividing the amount of cooling by the geothermal gradient.

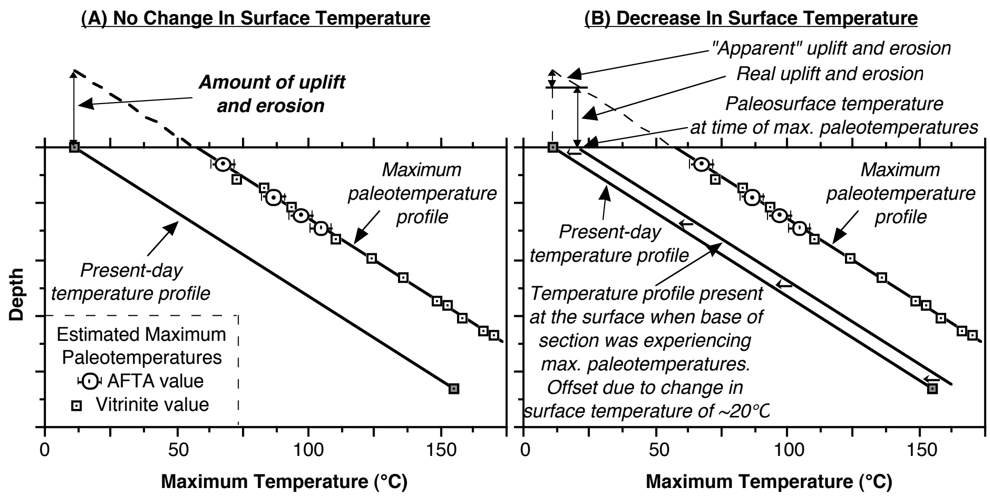

Figure 2: Hypothetical case to illustrate estimation of paleogeothermal gradients and the cause of heating and subsequent cooling from paleotemperature profiles. In each case a paleotemperature profile is shown which is similar to the present-day profile, suggesting that heat flow has not changed since maximum paleotemperatures were reached. However, the maximum profile is offset to higher temperatures indicating that the section has been hotter in the past. Therefore, heating in the past was caused by deep burial prior to cooling by denudation, and the amount of removed section can be estimated by dividing the amount of cooling by the geothermal gradient. (A) shows the simple case where mean annual surface temperatures have not changed since the time at which the section reached maximum paleotemperatures and all cooling has resulted from denudation. (B) shows the case where the mean annual surface temperature has decreased significantly since the time at which the section reached maximum paleotemperatures. In this case a component of "apparent" denudation is introduced.

Figure 2B shows a complicated example in which the mean annual surface temperature has decreased significantly since maximum paleotemperatures were reached (i.e., the North Slope foreland basin). If the surface temperature at the time the section began to cool from maximum temperatures is not known, and thus the present surface temperature is used, the amount of cooling which has occurred since maximum paleotemperatures were reached will be overestimated by a value of "apparent" denudation. The value of "apparent" denudation can be estimated by dividing the amount of cooling (difference between paleo- and present-day mean annual surface temperatures) by the geothermal gradient. The paleo-surface temperature is that which was present at the time when the subsurface section started to cool from maximum temperatures. The case shown in Figure 2B just reiterates a point which we all must keep in mind - that when calculating the amount of denudation in regions which have experienced significant changes in climate, it is important to know the time at which the climate changed, the time when cooling from maximum paleotemperatures began, and the surface temperature at that time.

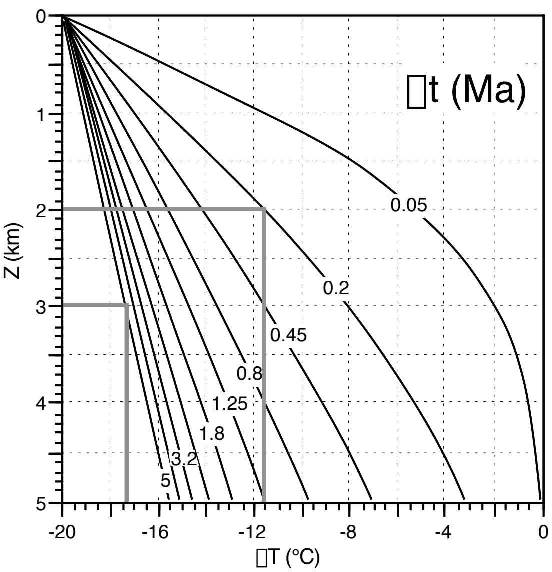

Figure 3: Plot showing the change in temperature (DT) at depths (Z) less than 5 km through time (Dt) between 0 and 5 Ma, after a decrease in the mean annual surface temperature of ~20°C. Calculations assume a geothermal gradient of ~30°C/km and a thickness of the slab of ~30 km. See text for details.

Middle To Late Cenozoic Climatic Change and Associated Subsurface Response

As mentioned, the Cenozoic thermal history of the North Slope foreland basin is complicated because the region has experienced a significant decrease in mean annual surface temperatures, from temperate conditions in the mid-Cenozoic (~+5°C in the late Maastrichtian to Eocene) to present-day arctic conditions (~-12°C along the northern coastline). The timing of this change in climate is poorly constrained primarily due to a lack of an adequate data base, however, Clark (1990) proposed the transition of the Arctic Ocean from ice-free conditions during the early Cenozoic, to late Cenozoic arctic conditions occurred during the late Cenozoic and by late Miocene, conditions, essentially the same as exist today, were present.

In response to the drop in mean annual surface temperature accompanying the change in climate, the subsurface isotherms in time would have been repositioned downward, resulting in cooling of the stratigraphic section by a means unrelated to erosion (O'Sullivan and Brown, 1996).

In their study to determine whether a decrease in the mean annual surface temperature of the order of ~15-20°C could result in a noticeable change in temperatures in the subsurface, O'Sullivan and Brown formulated a simple thermal model of the lithosphere that could be described in terms of the mathematical equations describing the transfer of heat. The results of their calculations are presented graphically in Figure 3 which shows that a decrease in temperature at the surface of ~20°C results in a rapid (in geologic time) decrease in shallow-level (<5 km) subsurface temperatures. For example, after only 0.2 Ma, temperatures at ~2 km depth will have decreased between ~11-12°C, and after 5 Ma, temperatures at ~3 km depth will have decreased between ~17-18°C (Fig. 3).

North Slope Foreland Basin Thermal History

Previous knowledge of the North Slope thermal history was based primarily on present-day thermal profiles, measurements of organic maturation (mainly R_o, TAI, and CAI), and geothermal conditions calculated from these data. The present-day North Slope thermal regime is characterized by variable geothermal gradients; with higher geothermal gradients generally found in wells located close to the present-day coastline, and lower gradients in wells located in the foothills north of the Brooks Range. The organic maturation of rocks at the surface generally decreases northward across the North Slope; a reflection of denudation in the Brooks Range orogenic belt and subsidence and sedimentation in the adjacent foreland basin. The estimated total amount of Cretaceous and Tertiary denudation across the North Slope foreland basin, based on the position of the 0.6% and 2.0% R_o isograds, range between ~3-5 km within the foothills to ~500 m in the Inigok #1 well, to ~1 km in the region of Pt. Barrow (Howell et al., 1992).

As part of a study undertaken to determine the Cenozoic thermal history study of the North Slope foreland basin (ye' old POS PhD thesis), AFTT samples were collected from eight wells and outcrop localities across the basin. Detailed descriptions of the results and interpretations of the data were presented in O'Sullivan (1996). Results of modeling of AFTT data from 6 of 8 wells, located in the central and western

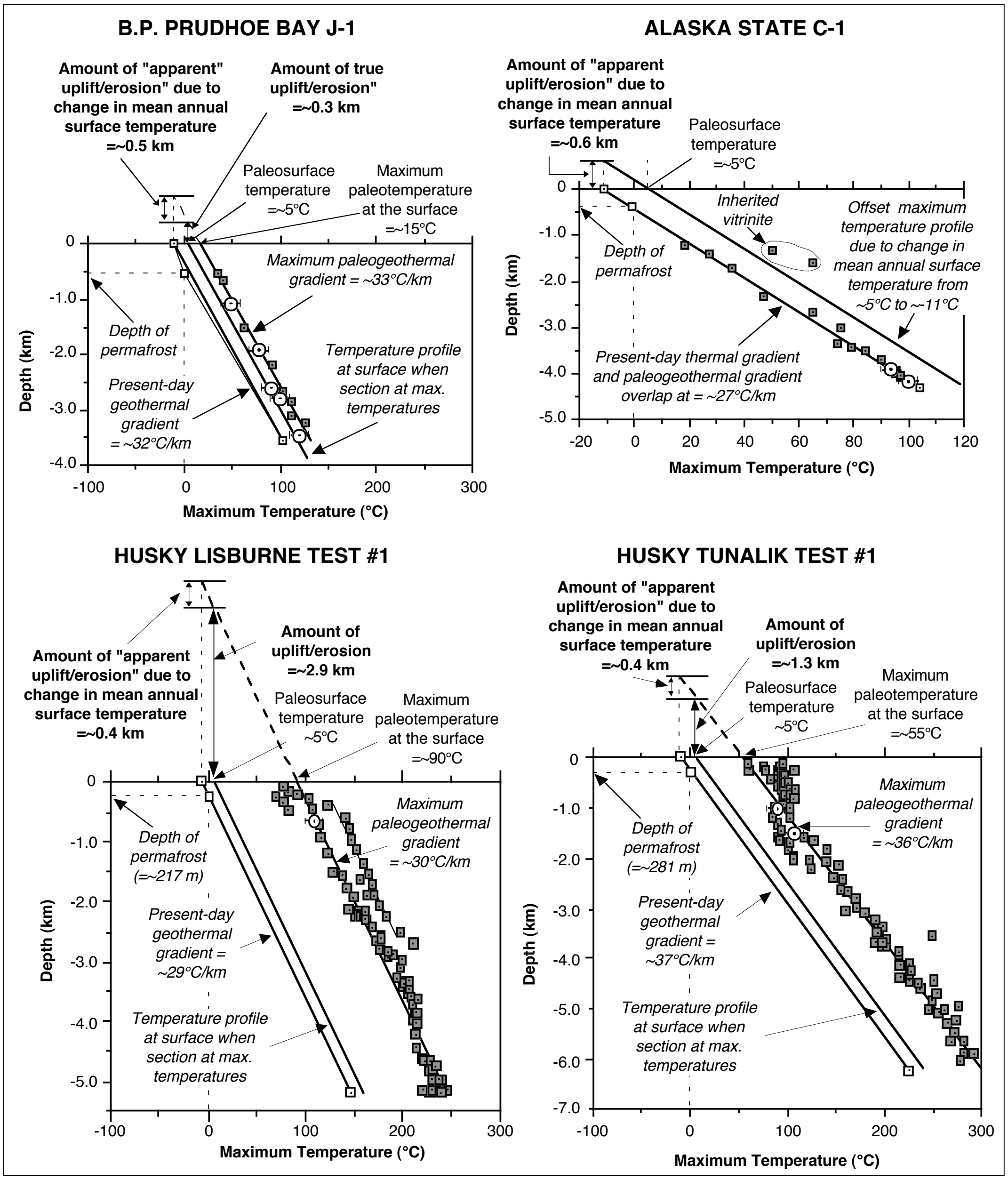

Figure 4: Estimated maximum paleotemperature profiles for the Lisburne Test #1, Tunalik Test #1, Prudhoe Bay J-1, and the Alaska State C-1 wells, derived from vitrinite reflectance and AFTT plotted against sample depth. The offset between maximum temperature and present temperature profiles in both the Lisburne and Tunalik wells are the result of both denudation and "apparent" denudation. Cooling recorded in the remaining two wells has been primarily in response to the Cenozoic decrease in mean annual surface change.

North Slope foreland basin (Fig. 1), suggest that the samples experienced maximum paleotemperatures, due to burial, during the Late Cretaceous to mid-Paleocene. The data also suggest that during the Tertiary, the basin subsequently experienced two episodes of rapid cooling due to denudation; during the mid-Paleocene at ~60±4 Ma, and during the late Oligocene at ~25±3 Ma. Data from two other wells, located along the present-day northern coastline between Prudhoe Bay and the Canning River (Prudhoe Bay J-1 and Alaska State C-1), also suggest rapid cooling occurred at some time <10-15 Ma. However, in contrast to the other six wells, the preserved stratigraphy within the two wells suggests that little or no section was removed during that time. Therefore, it is proposed that cooling recorded in these two wells was primarily the result of the decrease in mean annual surface temperature during the late Cenozoic.

In order to come to these conclusions, and to determine the maximum paleogeothermal gradient and amount of section removed from the section preserved in each well, maximum paleotemperatures calculated from the R_o and AFTT data were plotted against present depth (for example Fig. 4). As explained earlier, the slope of the fitted linear relationship between maximum paleotemperature and present depth provides a direct estimate of the maximum paleogeothermal gradient (maximum paleotemperature profile) prior to cooling. The "least-squares" best-fit estimates of the maximum paleogeothermal gradient for each well, derived using the maximum paleotemperature profiles, suggest the maximum paleogeothermal gradients for each well were very similar to the present-day geothermal gradients. These data indicate that the heat flow has changed little in the basin since maximum paleotemperatures were reached prior to Paleocene cooling, however in most cases, the maximum paleotemperature profile is offset towards higher temperatures as a result of previous exposure to elevated temperatures.

Since basin heat flow values have not changed much since maximum paleotemperatures were reached, but the data suggests the rocks in many of the wells experienced higher temperatures in the past, this indicates a great deal of section has been removed as a result of denudation. Therefore, the amount of removed section can be estimated by dividing the degree of cooling by the geothermal gradient. The degree of cooling is calculated by determining the maximum paleotemperature value at the present surface and subtracting the mean annual surface temperature at the time cooling from maximum paleotemperatures began. As determined from the AFTT data, cooling from maximum paleotemperatures occurred in the Paleocene. Because there has been a noticeable decrease in the mean annual surface temperature since denudation started, not all cooling experienced by the rocks from maximum paleotemperatures has been the result of denudation.

For each of the wells the calculated values of denudation and "apparent" denudation, respectively, equal (Fig. 1): ~5.3 km and ~0.4 km (Kemik #1 well); ~2.1 km and ~0.5 km (Seabee #1 well); ~1.7 km and ~0.6 km (Inigok #1 well); ~1.2 km and ~0.4 km (Walakpa #1 well); ~2.9 km and ~0.4 km (Lisburne #1 well); ~1.3 km and ~0.4 km (Tunalik #1 well); and ~0.3 km and ~0.5 km (Prudhoe Bay J-1). If the mean annual surface temperature at the time cooling started was not known, calculations of the amount of denudation would be over-estimated by an amount equal to the "apparent" denudation. In the case of the Alaska State C-1 well, no denudation has occurred, however, ~0.6 km of "apparent" denudation must have occurred in response to the decrease in the mean annual surface temperature from ~5°C to ~-11°C during the late Tertiary.

Implications

As demonstrated by many folks long before I became interested in FT (Chuck Naeser, Gunter Wagner, Paul Green, Andrew Gleadow to name a few who come to mind quickly) apatite fission track data provides a powerful method of thermal history assessment and determining amounts of denudation. In sections that have experienced higher temperatures in the past, these data allow estimation of the time at which cooling from maximum paleotemperatures began, while combined with R_o give independent estimates of maximum paleotemperatures and provide an estimate of the paleogeothermal gradient at the time of maximum paleotemperature (e.g.. Bray et al., 1992). Control on the paleogeothermal gradient allows interpretation of the cause of the heating and subsequent cooling to present temperatures.

In this North Slope foreland basin study, the combination of R_o and AFTT data have helped establish: 1) that maximum paleotemperatures were attained prior to cooling which began in the Paleocene at ~60±4 Ma, 2) that paleogeothermal gradients when cooling began were close to the present-day values, and 3) that Cenozoic surfical cooling resulted in a significant amount of "apparent" denudation. This suggests that heating throughout the basin was largely due to deeper burial, and that cooling was due to both removal of section by denudation and by a drop in the mean annual surface temperature of ~10-20°C, the effects of which have gone unnoticed across the foreland basin. It is obvious from the values in Figure 1 that denudation is the dominant cause for cooling within the basin, however, it is important to note that the entire North Slope foreland basin has also experienced ~0.5 km of "apparent" denudation. This suggests that estimates of denudation, which did not consider middle to late Cenozoic climatic cooling, or the surface temperature at the time when cooling from maximum paleotemperatures began, may be over-estimated by ~0.5 km.

Finally, the data and interpretations from the North Slope foreland basin illustrate the importance of understanding several factors when evaluating the thermal history and the amount of denudation. These factors include: 1) knowing the mean annual surface temperature at the time maximum paleotemperatures were reached, 2) knowing the geothermal gradient at the time maximum paleotemperatures were reached, and 3) knowing the time at which cooling from maximum paleotemperatures occurred. This study also illustrates how important it is to recognize the affect long-term changes in mean annual surface temperatures have on subsurface cooling and must be considered when estimating denudation.

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Short Tracks: News

Ed Sobel has finished his postdoctoral work with argonist Nick Arnaud at the University of Clermont-Ferrand. He is now at the University of Potsdam setting up a new fission-track lab. Good luck.

Rasoul Sorkhabi will be on leave from Arizona State University, and will be a visiting scientist at the Department of Earth and Planetary Sciences, Graduate School of Science, Hokkaido University, Sapporo 060 Japan; FAX 81-11-736-3290. Rasoul got his Ph.D. from Kyoto University, Japan, in 1991. He will be at Hokkaido University from October 96 to July 97, and will continue his research on fission-track and Ar-Ar thermochronology of the Himalayan orogen.

Chuck Naeser mentioned that he no longer has any Fish Canyon Apatite available for distribution. He still has Durango apatite from the U. of Texas collection, and Fish Canyon Zircon. He is not planning to do a recollection of the Fish Canyon Tuff for general distribution and the FT community needs to consider what to do about age standards.

Micheal Steinmann and **Dominik Hungenbuhler** from ETH Zurich , working on their dissertations on Andean intra-arc basins in Ecuador at **Diane Seward**'s lab, organized a workshop on basin analysis and fission-track dating for local geoscientists at the University of Quito, Ecuador. The workshop was sponsored by the Swiss agency for development and cooperation. A second workshop is planned for June 1997. More info in On Track 14.

Gulio Viola just started a PhD project at ETH Zurich, working with **Neil Mancktelow** and **Diane Seward** on the kinematics, age, and amount of displacement of the Periadriatic Fault System, SW of the Tauern Window in the central eastern Alps.

Ann Blythe finished her postdoctoral work at UC Santa Barbara. She is now at USC in Los Angeles where she has set up a new fission-track laboratory.

This news section is far from complete and more or less only includes people I know or that sent me some information of there current whereabouts. Any information is greatly appreciated. If you're moving, please drop me a short line, so I can track you down in the future. Merry Christmas and a Happy New Year full of new tracks to everybody.

AFTINV32: An Inverse Model for Thermal History Determination Using Apatite Fission Track Data

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Introduction

AFTINV32 is an inverse model for determining time-temperature histories from apatite fission track data. Although it shares some common features with other inverse models (Corrigan, 1991; Lutz and Omar, 1991; Gallagher, 1995; Ketcham *et al.*, *in prep.*), there are some notable differences in how thermal models are set up and evaluated. The purpose of this article is to introduce AFTINV32 and discuss how it differs from some previous models rather than to provide an exhaustive comparison of the advantages and disadvantages of the various modeling techniques.

Basic Model

AFTINV32 has had a rather protracted history of development. The original model, TINV52, was developed by Sean Willett at Dalhousie University during the late 1980's to early 1990's. The model uses a constrained random search algorithm (see Figure 1) to refine the parameter search space. The model proceeds by generating a set of random forward model thermal solutions which are used to calculate apatite fission track age and length parameters for comparison with observed data. Predicted cumulative track length distributions are assessed with respect to observed lengths using the Kolmogorov-Smirnov statistic and a pass/fail criterion is established at the 0.05 significance level. A further requirement is that predicted fission track ages must be within two standard deviations of the measured age. The initial set of random thermal solutions is updated iteratively, with better-fitting solutions progressively replacing the poorest-fitting members of the set. The model converges when all members of the retained solution set pass the statistical test.

The model has been described and used in a number of studies (e.g. Issler *et al*., 1990; Willett and Issler, 1992; Ravenhurst *et al*., 1994) and a more comprehensive account can be found in a manuscript by Willett (to be published in the American Journal of Science).

Modified Version

TINV52 has been modified extensively to become an interactive, user-friendly software package designed to run under the Windows 95 operating system (I know that this is contrary to the Macintosh Universe inhabited by a large segment of fission trackers). The modified inverse model, AFTINV32, differs from TINV52 in how random thermal histories are generated, how the fission track annealing calculations are performed (Issler, 1996), and how temperature and rate constraints are dealt with (see Issler, *in press*, for further details). The model consists of four 32-bit windowed FORTRAN executable programs: TSORT32 (sorts track length data); PREAFT32 (interactive model initialization); AFTINV32 (inverse model); and POSTFT32 (preparing model output and plots). The software has been designed to allow for easy incorporation of geological constraints into the initial specification of time-temperature and rate bounds. Examples of temperature constraints may include the present temperature and limits on temperatures at the time of deposition or during the development.

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 for investigation of the time range over which a maximum heating event may have occurred.

Differences With Respect to Other Models

An attractive feature of this model is the ease with which geological constraints can be incorporated when specifying the initial parameter search space. The model offers considerable flexibility in specifying temperature and rate bounds and different conditions can be applied to different segments of the thermal history. Unlike some of the other inverse models, rate constraints can be decoupled explicitly from temperature constraints. First, users must specify a time grid with corresponding upper and lower temperature limits for each point. Then maximum heating and/or

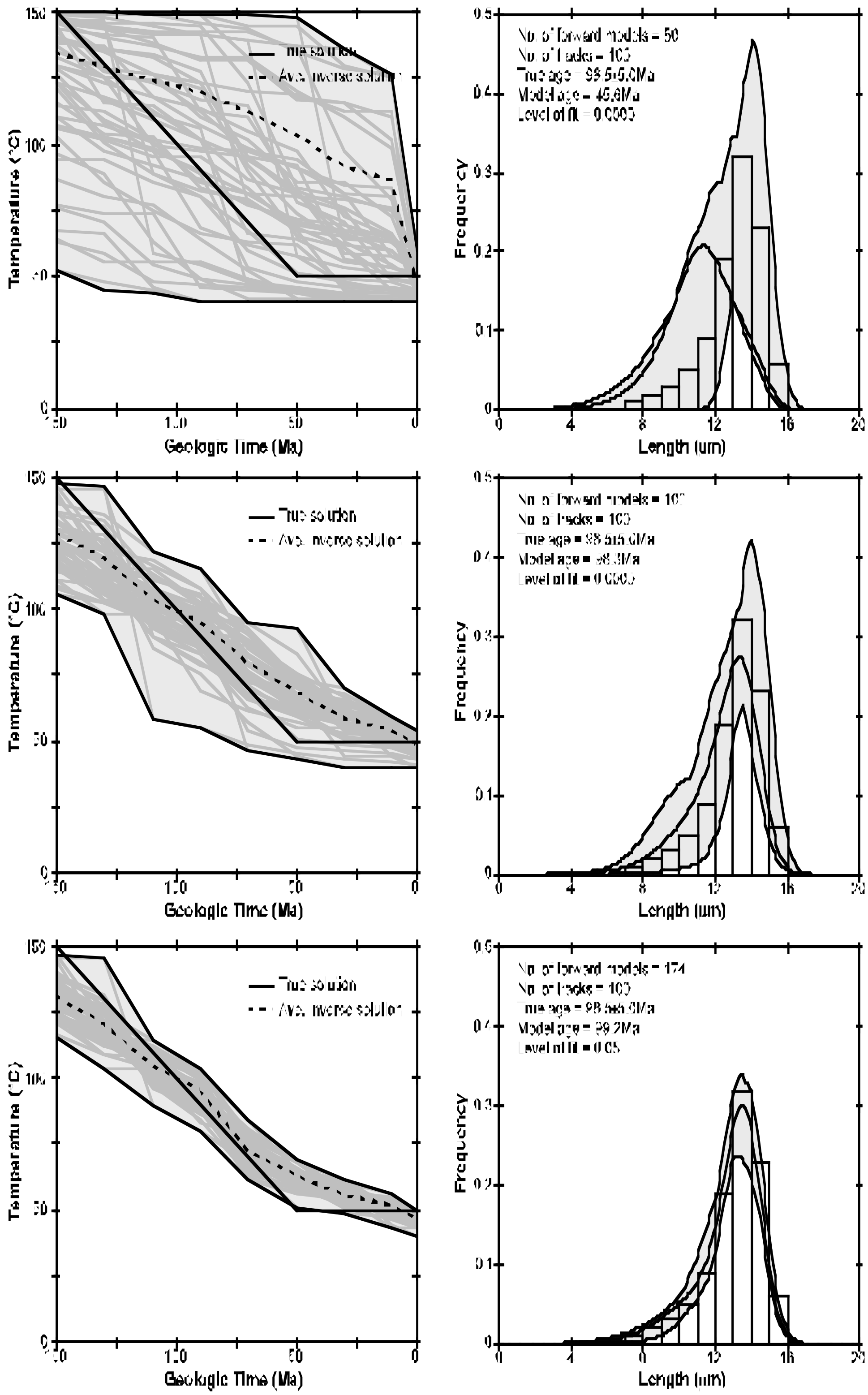

Figure 1: Illustration of constrained random search inversion method using synthetic apatite fission-track data generated from the true temperature solution (heavy black line on temperature time plots) for random cooling only thermal histories. In the upper left panel, an initial random set of 50 solutions is created (light gray lines in shaded regions). During continued iteration, successive members of the initial set are replaced by improved solutions (middle left panel) until all members of the set are statistically valid (convergence at significance level probability of 5%)

(lower left panel). The preferred thermal solution (dashes) is represented as an exponential mean of the solutions contained with the acceptable solution (heavy black curve in right panels) is shown in comparison with the synthetically generated distribution (histogram). The shaded regions of the length distribution plots indicate the range of the track distributions produced by the random temperature set.

(editor's note: wonder if these figures would look better drawn on a Macintosh...)

cooling rates can be calculated either directly using the time-temperature limits or users can customize their choices for the maximum allowable rates. For example, there may be little control on the acceptable temperature range (and thus a wide range on temperature) for a particular thermal history but users may be able to restrict the magnitude and/or direction of temperature change using other criteria. This approach differs from some other methods (e.g. Lutz and Omar, 1991; Gallagher, 1995) where constraints are defined in terms of the minimum number of points required to fit the data (Occam's Razor) and where time-temperature ranges are supplied for individual points. In this formulation, rates are restricted by and depend on the minimum number of points used. Therefore, the range on acceptable parameter space should be narrower than in models where this restriction is not applied. Although use of the minimum number of points is a valid and useful modeling technique, AFTINV32 provides an alternative, complementary approach.

In addition to limiting the magnitude and direction of temperature change, users can have the model search for heating or cooling events over specified time ranges if there are good geological reasons for doing this. An example might be a foreland basin dominated by an early subsidence phase and late exhumation phase. The timing of maximum temperature may not be well known and the model can be used to generate a series of random thermal histories with a single stage of heating and cooling. These models could provide a range for the time of maximum heating. The usefulness of this approach would depend on how close the sample was to temperatures at which total annealing occurs. This example is similar to the pulse heating type of history used by Corrigan (1991) but thermal histories need not be smooth as required by the Chebyshev polynomial approximation of thermal histories in Corrigan's model. Care should be taken when choosing this option. The model can always find a reheating event when instructed to do so but this "event" may not be required by the data, due to the nonuniqueness problem.

AFTINV32 uses the empirical isothermal annealing equation of Crowley *et al*. (1991) with coefficients for Sr fluorapatite, fluorapatite and Durango apatite (Crowley *et al*., 1991) and for the Durango model of Laslett *et al*. (1987). This equation is solved efficiently and accurately using an equation which predicts the integration step size as a function of rate of temperature change and maximum interval temperature for each linear heating segment of a given thermal history (Issler, 1996). This avoids having to choose a uniformly small step size for the entire model history in order to maintain sufficient accuracy at high temperatures and high rates of temperature change. Coefficients for the time step predictor equation have been optimized for each of the compositionally-dependent annealing models.

All of the inverse models use an iterative direct search scheme for locating statistically-acceptable thermal solutions. Ketcham *et al*. (*in prep*.) employ random Monte Carlo simulation in which a large number of independent, random thermal histories are generated. Solutions that fit the data are used to define the parameter space. AFTINV32 also uses random Monte Carlo simulation but the approach is closer to that of Gallagher (1995). The constrained random search algorithm is very similar to the genetic algorithm used by Gallagher (1995) in that the model uses information from the initial random selection to improve the fit of subsequent models. However, unlike the model of Gallagher (1995), AFTINV32 does not try to find the optimum solution. This is in recognition of the fact that the apatite fission track data are not optimal but are an imperfect sample of the "true" population of tracks. Instead, a pass/fail criteria is used to build up a family of acceptable solutions and a weighted average is chosen as being representative of the thermal history.

How to Obtain the Model

The computer software and an accompanying user's manual are being published as a Geological Survey of Canada Open File that will be available from our Calgary bookstore (same address as above) in either November or December 1996 (Issler, *in press*). I am told that the price should be approximately $50 (Canadian funds - so far we are not a profit-driven organization but pressures are mounting). For those interested in obtaining the software and document, further information can be obtained by contacting the Calgary bookstore at: (403) 292-7030 (phone); (403) 299-3542 (Fax); gsc_calgary@gsc.NRCan.gc.ca (Internet). I plan on making future modifications to the program to keep on top of advances in fission track research and if bugs in the program are discovered, I'll fix them. The current model uses the empirical annealing equation of Crowley *et al*. (1991) with coefficients for 4 different apatite compositions and options for inserting other coefficients. Other annealing models will be incorporated in future versions.

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Modeling Annealing With Mathematica

by David A. Coyle

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(editor's note: This is an abbreviated version of Dave's article. The complete version can be found on the web, where you can also see MathAnneal in action: **http://goanna.mpi-hd.mpg.de/~dcoyle/ Mannealer.ma**)

Introduction

After the amazing displays of technical wizardry at Gent, I promised Danny that I would show how one can make those cool movies using Mathematica. Well, the fact that this article is not about making movies should not be taken as meaning that it's not possible: it's just that the output from freely-available Mathematica contouring routines was less than impressive, and I was really not interested in hacking the C code to make it pretty (and let's face it: the whole point to the exercise was to have something pretty). But those contouring routines ran using a little-used capability of Mathematica called MathLink, and that got me thinking...

An unimpressive contour plot of randomly-spaced data points to get a movie, you just generate a series of these, select them, and press command-y. That's not so hard, is it? Coloring them in can be done using Adobe Illustrator, for example.

If you know me at all, you know that I've been doing my track work with Mathematica for about six years now. So you may have wondered why I have never implemented the Laslett et al annealing algorithms in Mathematica (OK, so you didn't wonder. Just indulge my ego a little, would you?). The reason is simple: Mathematica is interpreted, and the annealing algorithms like to repeatedly iterate through (potentially) large arrays of numbers. Fine, Mathematica would do it, no problem. But it'd be a dog in terms of performance. So I left that problem, and later wrote it up in Objective-C.

So, I have working C-code for annealing, and I have Mathematica. How can I use them together? The answer is MathLink: it lets you access compiled routines from within Mathematica, and also access Mathematica functions from your own programs. Want to do a numerical integration, but are just too lazy to copy all that code out of Numerical Recipes? No problem, MathLink will do it for you. MathLink lets you use Mathematica's fancy plotting capabilities from within your own applications (see, e.g.., UHMath and the UHMathView from the University of Houston). But for us, MathLink lets us use faster compiled annealing routines from within Mathematica's flexible and interactive notebook interface. So, how do you do it?

MathLink makes interprocess communication magical (which is to say, it takes all the fun out of it). If you're going to access your C-code from within Mathematica, all you need to do is provide a template for each function that you'll be calling, and add a single line to your main() function that gets MathLink up and running (see Listing 1). Then process the code with a little program called mprep, compile, link and enjoy. If you've already got the code from another project, ML-ifying it is a trivial task. This project took me about an hour of actual work (coffee breaks not included), and this was the very first time I'd ever used MathLink. In fact, I've spent more time writing this article, than I did writing the MathLink program!

Listing 1: A MathLink Objective-C source file with Template

```
#import <WebObjects/WebObjects.h>
#import "Annealer.h"
#import "mathlink.h"

:Begin:
:Function:      annealTracks
:Pattern:       Annealtracks[points_List]
:Arguments:     { points }
:ArgumentTypes: { RealList }
:ReturnType:    Manual
:End:

int main (int argc, char* argv[])
{return MLMain(argc, argv);}

void annealTracks(double *points, int alen) {
    /*" alen is the length of the list    "*/
    Annealer     *myAnnealer = [[Annealer alloc] init];
    // rest omitted
    ...
```

Once your program compiles without errors or warnings, then you can test it from Mathematica. Accessing the functions is easy: you just use Mathematica's Install[] directive, thus:

myLink = Install["/LocalScientist/bin/MathAnneal"];

This returns a Link object, which in this example is assigned to the variable myLink.

So what's the point?

Well, the point is that people are reasonably sure of the validity of the annealing model they use (until PFG releases the multi-compositional model, that is...) and so it's quite natural to make that an immutable compiled function. Methods of generating and evaluating thermal histories, on the other hand, vary greatly. There's genetic algorithms, Monte Carlo, Simulated Annealing (yes, I know it's confusing), the promising "Great Deluge" algorithm, just to name a few. And that's not to mention the fact that just comparing your observed to modeled data is riddled with uncertainties. Geoff Laslett once told me that there are no robust ways of comparing histograms (well, something along those lines..."binned data" I think he said). That says it all, eh?

In Mathematica, writing functions to do customized path generation is really simple (see example). The same is true for comparing observed to modeled data. In practice, what you'd probably do is write new generate-anneal-refine routines for each new sample, sample suite, or sample category (good, bad, indifferent), adapting previous routines to the unique problems and geological environments of your projects. You'll never have an excuse for that uncomfortable feeling that you get when you use present-day programs ("Just what do these MonteTrax parameters really mean?"). Plus there are all kinds of packages available from Wolfram research itself, to help you do just these things. Browse around in http://www.mathsource.com/

Here's an example of simple function to create a monotonically-cooling history, with random point selection, and an arbitrary number of segments. Note, this is the verbose version...

```
Clear[BuildPaths];
BuildPaths[maxt_Real, presT_Real, startT_Real,
        num_Integer, segs_Integer] :=
Module[{a, t, bl, op},
    op = {};
```

```
bl = {};
 Do[ bl = {{maxt, Random[Real, startT]}, {0.0, presT}};
 (* This example actually sets the starting temp as *)
(* some random number between zero and startT     *)
    If[segs > 1,
         (*We need to build up bl by inserting nodes*)
         a = Sort[Table[Random[Real, maxt], {segs-1}], Greater];  (* times *)
         t = Sort[Table[Random[Real, 140.0], {segs-1}], Greater]; (* temps *)
         bl = Partition[Flatten[Insert[bl, Transpose[{a,t}], -2]], 2];
    ];
    AppendTo[op, bl]
  , {num} ];
  op ]
```

But the main point for me, is that now I've finally got all my data generation and evaluation software together in one place. I determine my ages and plot my radial plots using my FTD package, I do 2-component analyses using my 2CM package. I fool around with "minimum" ages using my Minimage package. And I read in and process my confined length data using my LengthHandler package (which at present only deals with TrevorScan files, but that can be changed. Call for a quote.). And the cool thing about it all, is that it doesn't require any particular operating system. Mac, Windoze, UNIX, VMS: Mathematica doesn't care (though I certainly do...) .

Not quite true: your Annealer MathLink program won't run everywhere! Well, sorry to disappoint you there, but it can. The MathAnneal program uses the Gnu Objective-C++ compiler (gcc), which runs just about anywhere (except the Mac, but that'll change when Linux runs on the PowerMac). If you don't have Next/OpenStep (from Sun [comes with NEO], or NeXT itself), you can install the Free Software Foundation's GnuStep, which implements every one of the (very few!) Common and Foundation classes that I've used in creating MathAnneal. So if you're running W95, WinNT, DEC OSF/1, Solaris, Linux, or some others I've forgotten, then probably you can also use my sources, with only a minimum of changes (the makefile, #import directives, and so on...). By the time you read this, I'll probably have it running on WindosNT, since NeXT is kindly giving me a copy of OpenStep/NT for free.

Mathematica itself is ubiquitous in academic departments: I'd be really surprised if you don't already have a license for your uni/department/lab.

Summary

So, in total, the MathLink solution to modelling fission-track data is quite attractive. You get custom search algorithms, a nearly-interactive interface (check out the Mathematica function that lets you click or drag in a Graphic view, and convert the point(s) into a List of {x, y} coordinates), full source code for your inspection, robust methods, and a clean Annealer engine that is reasonably efficient. Another point I didn't mention is that the annealing engine can be easily swapped for another, if/when better algorithms are made publicly available (PFG, are you listening?). It's also a handy way to compare annealing algorithms, or to debug that little module of code that you may want to build into a larger program (well, why would you, now).

I have to admit that at first even I was skeptical (doing this only as an alternative to the movie project), but now I've even sold myself on it. I think that I'll be doing a lot more modelling this way, from now on. I hope you will too.

Here is an example of the modeling results generated using Mathematica (ed.):

Epilogue

Well, I hope you've enjoyed this extremely brief introduction into the possibilities offered by Mathematica and MathLink. My wish is that, rather than expecting others to do it all for you, you'll now be motivated into finding your own, individual, solutions to your unique modeling problems.

A Better Way to Separate Apatite from Zircon Using Constriction Tubes

by Trevor Dumitru and Danny Stockli
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Most FT laboratories currently separate apatite from zircon in separatory funnels using methylene iodide (MEI, density 3.32). We have found it better to undertake these separations using constriction tubes inserted inside glass test tubes. We simulated this in Gent using water, successfully separating plastic bits from quartz grains in about 15 seconds. Everyone, I'm sure, was duly impressed.

We have a profusely illustrated write-up available with all the details that we handed out in Gent. Anyone who didn't get one can write or email for a copy. A Microsoft Word for Macintosh version is available via email, so please specify if you can handle attached Macintosh email files.

To summarize the procedure, we usually work with batches of about twenty samples following this general procedure:

1--Fill twenty standard 16 mm diameter test tubes with ≈4 ml of MEI from a buret.

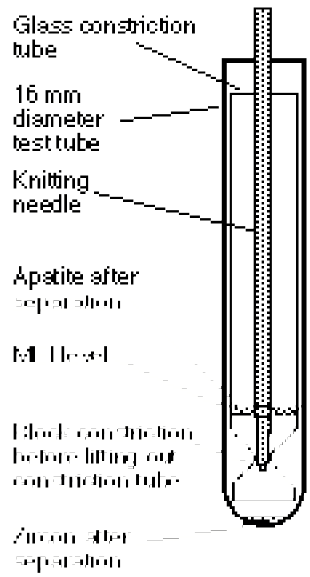
2--Insert glass constriction tubes into each test tube. Our local glassblowing shop makes these for us for US$4 each.

3--Pour the nonmagnetic apatite + zircon splits into the centers of the constriction tubes. Cap the test tubes.

4--Tap, jiggle, and knock the tubes to stir the grains a bit. Repeat several times with short breaks in between to allow settling. The key point is that if you agitate very gently the first time, then progressively more vigorously, virtually all zircon adhering to the tube walls will be washed free and sink. Unlike separatory funnels, there is no need to use a stirring rod or rinse down the walls with MEI from those retched little squeeze bottles.

5--Anchor the test tubes one at a time in a ringstand test tube clamp that will rotate, remove the cap, then insert a rod or needle to block the constriction. We have found that Teflon coated knitting needles work well.

6--Use forceps to carefully lift out the constriction tube and the MEI and apatite it contains. Drain the constriction tube into filter paper to recover the apatite, catching the MEI in a flask. Shift the filter funnel to a wash flask and rinse with acetone from a squeeze bottle.



7--Tip the test tube into a second filter paper to recover the remaining MEI and the zircon. We do this by smoothly rotating the test tube clamp until the test tube is tipped 10° past horizontal. After the tube has drained of MEI, we used a special acetone squeeze bottle with its tip bent 10° upward to squirt acetone up into the bottom of the tube and wash out the remaining MEI and zircon into the filter (over a wash flask).

This procedure is about twice as fast as using separatory funnels and uses so little MEI per sample that MEI loss into wash is reduced to roughly 0.5 ml per sample. However the equipment should be selected with care. Key pitfalls include: (1) the constriction tube must fit *loosely* within the test tube to avoid squirting MEI when the constriction tube is inserted or removed; (2) a *rotatable* test tube clamp is essential to hold the test tube while it is being tipped to drain the MEI and zircon; (3) the height and tip angle of the acetone squeeze bottle must be matched to the test tube clamp height and angle so that you can cleanly squirt acetone up into the bottom of the test tube to rinse out the MEI and zircon; (4) the sample must be smaller than about 0.1 cm^3 (250 mg) to get a very clean separation. We split larger samples in multiple tubes.

Disclaimer: MEI and acetone are hazardous; consult other sources for proper safety precautions. Practice this procedure with water before undertaking it with MEI. You really should read our detailed handout before attempting this procedure. Use at your own risk.

New improved grinding plates from Bico

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About a year ago we were having problems getting a good grind out of our Bico disc grinder ("Bico Pulverizer Type UA"), so we decided to investigate and see what could be done to improve the situation. The grinding plates were wearing out fast, they tended to jam with rock fragments that would not grind down, and the output of the grinder had a wider range of grain sizes than we wanted.

We came up with two significant improvements. First, the plates on our Bico jaw crusher ("Braun Chipmunk") proved on inspection to be worn down by a few millimeters. We replaced them and it helped a lot, producing a much finer crush to then feed into the grinder. I had looked at the crusher plates before and didn't think the wear would make any difference, but it did. We generally crush each sample twice, one pass with the plates at maximum separation followed by one at minimum separation. This has made our grinder much happier.

Second, we called Bico and found they had a new type of grinding plate for their disc grinder, the "Lead Dog" plate. We tried some of these and they are a genuine improvement, lasting roughly three times as long. For our model grinder the plates are part numbers LD-03 (Stationary Semi Steel Plate, 8 inch diameter) and LD-04 (Revolving Semi Steel Plate, 8 inch diameter). A set is about $60 in the U.S.

Bico Inc.
3116 Valhalla Drive
Burbank California 91505 USA
Phone 1-818-842-7170
Fax 1-818-842-7976

Group order of PFA Teflon planned

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Several fission track labs, including Kyoto Fission Track Company, Kyoto University, and ETH-Zurich, have been using PFA Teflon for mounting zircons and have found it superior to the older FEP Teflon. Dupont, the maker, advertises that PFA is suitable for applications at temperatures higher than 250°C. Danhara et al. discussed the merits and mounting procedures for PFA in the November 92 issue of On Track, finding it was eroded considerably less by the zircon etchant. This and the higher melting temperature reduce the numbers of zircons that fall out during etching.

However, it has been hard for individual labs to buy PFA because suppliers generally have minimum order sizes of about 5 or 10 square meters (enough for 20,000 to 40,000 zircon mounts) at a cost of about $1000. We are therefore trying to assemble a group order from several labs.

We are going to order PFA Teflon sheet, 12 inches wide, 0.5080 mm thick. The approximate price including shipping to the individual labs will be $150 per square meter. The minimum order we need to assemble is 8.36 square meters, or about $1250 (including estimated shipping costs to the individual labs). The supplier is also willing to fill smaller orders, but will add a $200 service charge to the cost in that case.

If your lab would like to participate, please send the order form below to me by 31 December 1996. The key terms are as follows:

1--Individual labs that sign up by 31 December 1996 will receive their Teflon at dealer's cost plus their share of the shipping fees. For simplicity, shipping fees will be split equally, thus U.S. labs will subsidize shipping to other labs by a small amount.

2--Payment must be made by check or electronic payment in U.S. dollars drawn on a U.S. bank, check payable to Trevor Dumitru rather than Stanford University. Shipment will be made to the individual labs via U.S. Postal Service air mail. Usual customs duties and delays may apply outside the U.S. I am happy to write receipts, etc., but hope that buyers will help minimize the amount of paperwork that I need to do. If any lab cancels out or fails to pay, it will come out of my pocket, and I will pillar you in the next issue of On Track.

3--We cannot guarantee the Teflon will work in your lab. Sorry, no refunds.

4--Please consider ordering all you want now. We do not expect to repeat the order in the foreseeable future. Estimated delivery date is March 1997.

PFA Teflon Order Form

Name, lab, and mailing address of buyer:

Phone, fax, and email addresses:

Amount you wish to buy, in square meters, minimum order is 0.5 square meters:

Cost of your order at $150 per square meter. Please note that you may be charged up to 10% more, but will probably actually be charged slightly less, depending on final cost.:

If we do not receive enough interest to total $1250, we will need each lab to contribute equally toward the $200 service fee for small orders. Please check the maximum amount you are willing to pay extra toward your share of this $200 fee if it proves necessary. If your contribution is smaller than needed, your order will be canceled. If it is larger than needed, you will pay only the amount needed.:

___$100 (2 labs participating) ___$50 (4 labs participating) ___$25 (8 labs participating)
___$67 (3 labs participating) ___$40 (5 labs participating) ___$20 (10 labs participating)

This is a firm agreement to participate in this group order. You agree to pay the amounts due in a timely manner. Do not pay now, but payment in advance may be needed (we will contact you).

Mail, fax or email to: Dumitru, Dept. of Geol. & Env. Sciences, Stanford Univ., Stanford California 94305-2115 USA; Fax 1-415-725-6155; email trevor@pangea.stanford.edu. **Deadline December 31, 1996**
(information may be sent by email without the form)

Recent Fission-Track Papers

Please send items for future listings in On Track to the editor, Danny Stockli. The reference or a photo copy of the first page will suffice but a copy of the entire paper is appreciated. We especially want non-fission-track papers that may be of special interest to the fission-track community. Papers in press are welcome, please include an estimate of the expected month of publication.

Balestrieri, M. L.; Abbate, E.; Bigazzi, G. (1996) Insights on the thermal evolution of the Ligurian Apennines (Italy) through fission-track analysis. Journal of the Geological Society of London ; Vol. 153, Part 3, p. 419-425

Blythe, Ann E.; Bird, John M.; Omar, Gomaa I. (1996) Deformation history of the central Brooks Range, Alaska; results from fission-track and 40Ar/39Ar analyses. Tectonics ; Vol. 15, No. 2, p. 440-455

Carter, Andrew; Bristow, Charles; Hurford, Anthony (1995) Constraints on the thermal history and provenance of the Khorat Group in Thailand using fission track analysis.
Journal of Geology, Series B ; Vol. 1995, No. 5-6, p. 341-353

Carter, A.; Yelland, A.; Bristow, C.; Hurford, A. J. (1995) Thermal histories of Permian and Triassic basins in Britain derived from fission track analysis. Geological Society Special Publications ; Vol. 91, p. 41-56

Chen, Y.; Zentilli, M. A.; Clark, A. H.; Farrar, E.; Grist, A. M.; Willis-Richards, J. (1996) Geochronological evidence for post-Variscan cooling and uplift of the Carnmenellis Granite, SW England. Journal of the Geological Society of London ; Vol. 153, Part 2, p. 191-195

Coyle, David A; Wagner, Guenther A. (1995) Fission tracks; a report on post-Variscan tectonics and compensation in the KTB region. Die Geowissenschaften (Weinheim, Zeitschrift) ; Vol. 13, No. 4, p. 142-146

Crowhurst, P. V.; Hill, K. C.; Foster, D. A.; Bennett, A. P. (1996) Thermochronological and geochemical constraints on the tectonic evolution of northern Papua New Guinea. J. Geological Society Special Publications; Vol. 106, p. 525-537

Currie, Lisel D.; Grist, A. M.; O'Sullivan, P. B. (1996) New apatite fission track results from Vancouver Island, the southern Coast Mountains, and the St. Elias Mountains; implications and questions for the Tertiary and younger tectonic history of the western Canadian Cordillera. Lithoprobe Report ; Vol. 50, p. 163

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Call for Contributions to the May 1997 On Track issue 14

Dear Fellow Fission Tracker:

The next issue will be printed in May, 1997 and **we are looking for contributions.** We welcome contributions of virtually any kind, including descriptions of new lab techniques, reviews of useful products, news and gossip, raving editorials about what all the other labs are doing wrong (or right), corrections of errors that appeared in the previous issue, meeting announcements, job openings, cartoons, and descriptions of what you are doing in your research.

On Track always includes a list of **Recent Fission-Track Papers**. If you know of a paper that was published recently, or that is in press and should be published in the near future, please send it in. The **Short Tracks: News** section allows all of us to keep up with fission "trekking" around the globe. On Track also includes an **International Fission-Track Directory** in each November issue, with errata and amendments in the May issue. If you are about to move, have moved, or know of someone who has moved, please inform me so the directory can be updated.

If you would like to contribute, send the final text and figures before the **DEADLINE, 15 APRIL, 1997**. If it is a lengthy article, let me know the title and length as soon as possible. Please send a paper copy of your contribution and a 3.5 inch **Macintosh™ compatible disc** with the text saved in Microsoft Word. If you can't send a Macintosh compatible disc, send a 3.5 inch IBM compatible disc in Word, or WordPerfect. Contributions can also be sent electronically. Send all contributions for the next issue of On Track to:

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This directory is published solely for the information of fission-track researchers. It is neither a comprehensive directory including all fission-track researchers nor an official document endorsing the scientific stand of individuals by the fission-track community. We provide here an update to the initial directory prepared by Rasoul Sorkhabi with the hope that we have accounted for the changes in addresses that have occurred since the last release of the directory. ***If you have changed your address, know someone else who has or think that someone should be on this list, please let me know (danny@pangea.stanford.edu)***!

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"OFF TRACK™" ... :)

by an anonymous tracker from down-under
(ed. chicken!)

We all know that Geotrack Int. Pty. Ltd has "Trademarked" "AFTA" and that they search out and destroy anyone who uses the term (there must be a lot of Chinese authors who had better watch out). For fun, a tracker recently searched the World Wide Web for evidence that "AFTA" was being used. What she found was:

AFTA™ (meaning "apatite fission track analysis" by Geotrack Int. Pty. Ltd) does not come up anywhere on a home page. However, other home pages using "AFTA" include:

Australian Federation of Travel Agents Ltd.
(http://www.afta.com.au/)
Australian Freestyle Taekwondo Academy
(http://hutch.com.au/%7Ethomasr/afta.htm)
Arts For The Aging, Inc.
(http://www.offer-ent.com/afta/)

Do they need to worry also?

(ed. Off Track™ "humor" expressed in On Track is that of anonymous authors and does not necessarily reflect that of the editor of On Track. BTW this new section was born and the term "Off Track™" was coined and of course "trademarked" by Rebecca Harman et al. at a bar in Gent Belgium...... :)