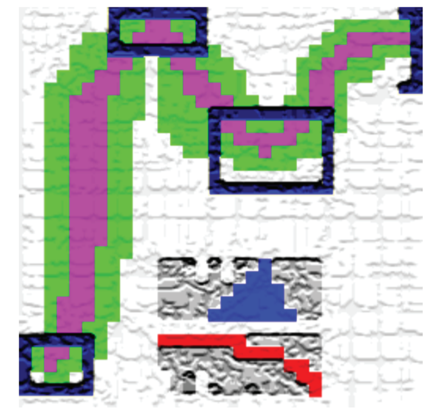
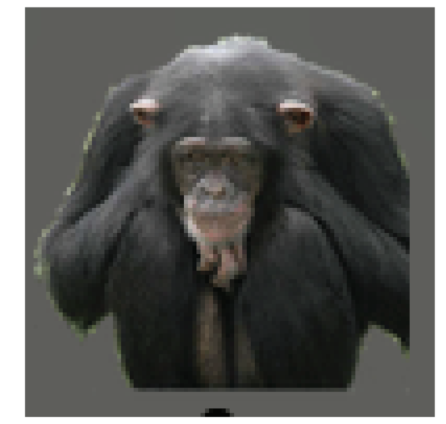
Navigating the modelling puzzle: Using forward and inverse models to make clear decisions when exploring and interpreting cooling ages in both HeFTy and QTQt.

Thermo2020 Santa Fe, NM





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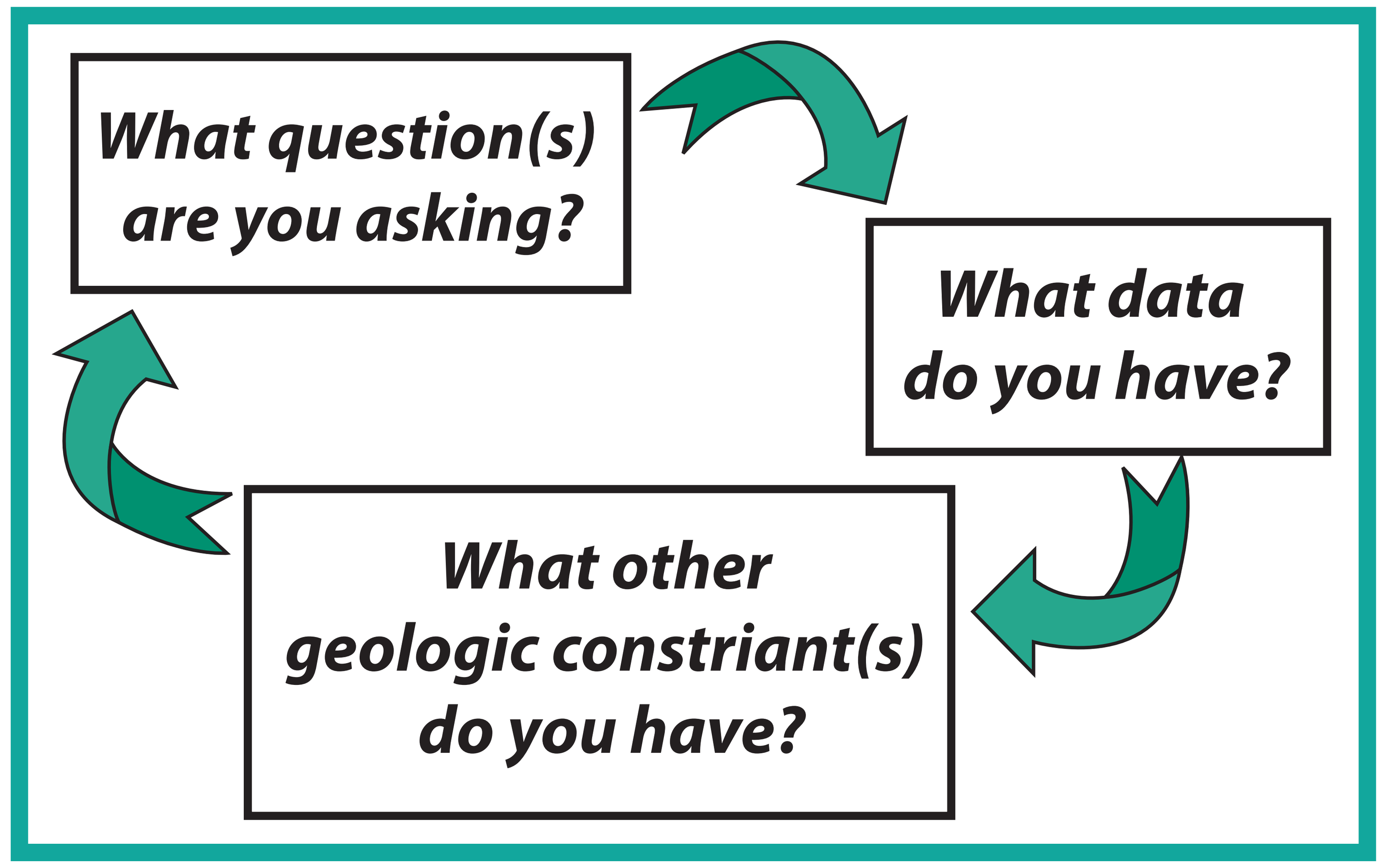
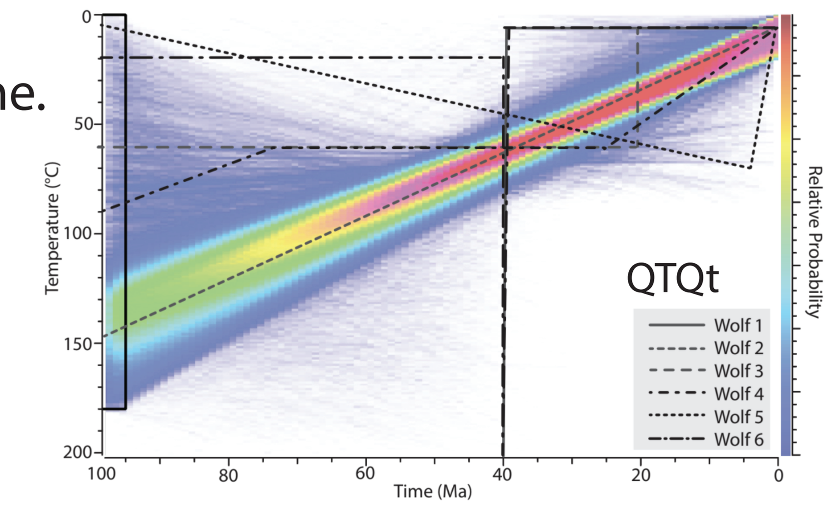


Motivation

We present a suite of simple forward and inverse models that we recommend everyone should perform before embarking on t-T modeling in HeFTy and/or QTQt for the first time. We suggest using a series of sensitivity tests to hone your understanding of each program and determine what decision pathways can be taken and how they will effect model outputs.

Figure 1: Inversion of synthetic data derived from a single 40 Ma grain with a 60um radius and an [eU] of 60 ppm. 'Wolf' histories overlain with possible geologic scenario and predicted cooling ages. HeFTy outputs (left corner) & QTQt outputs (below)



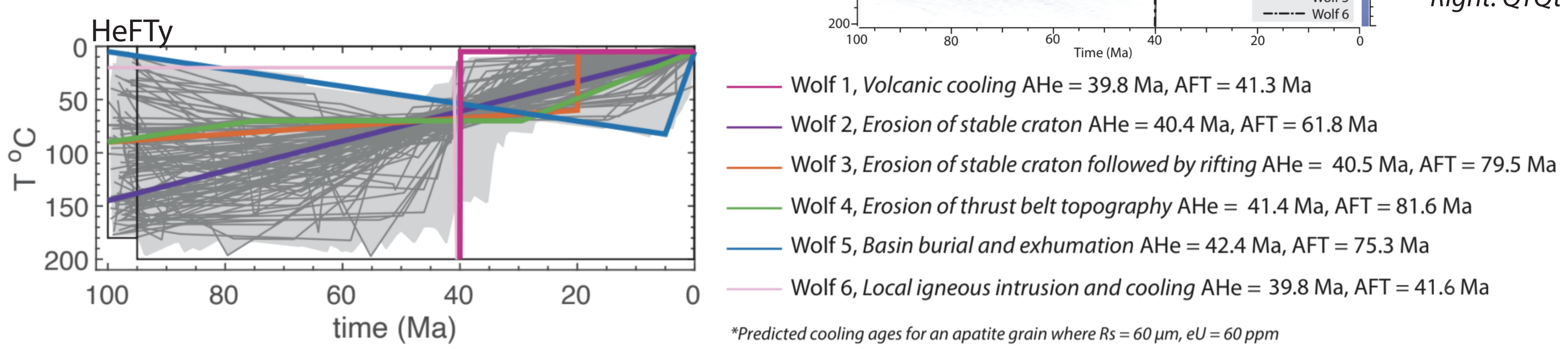
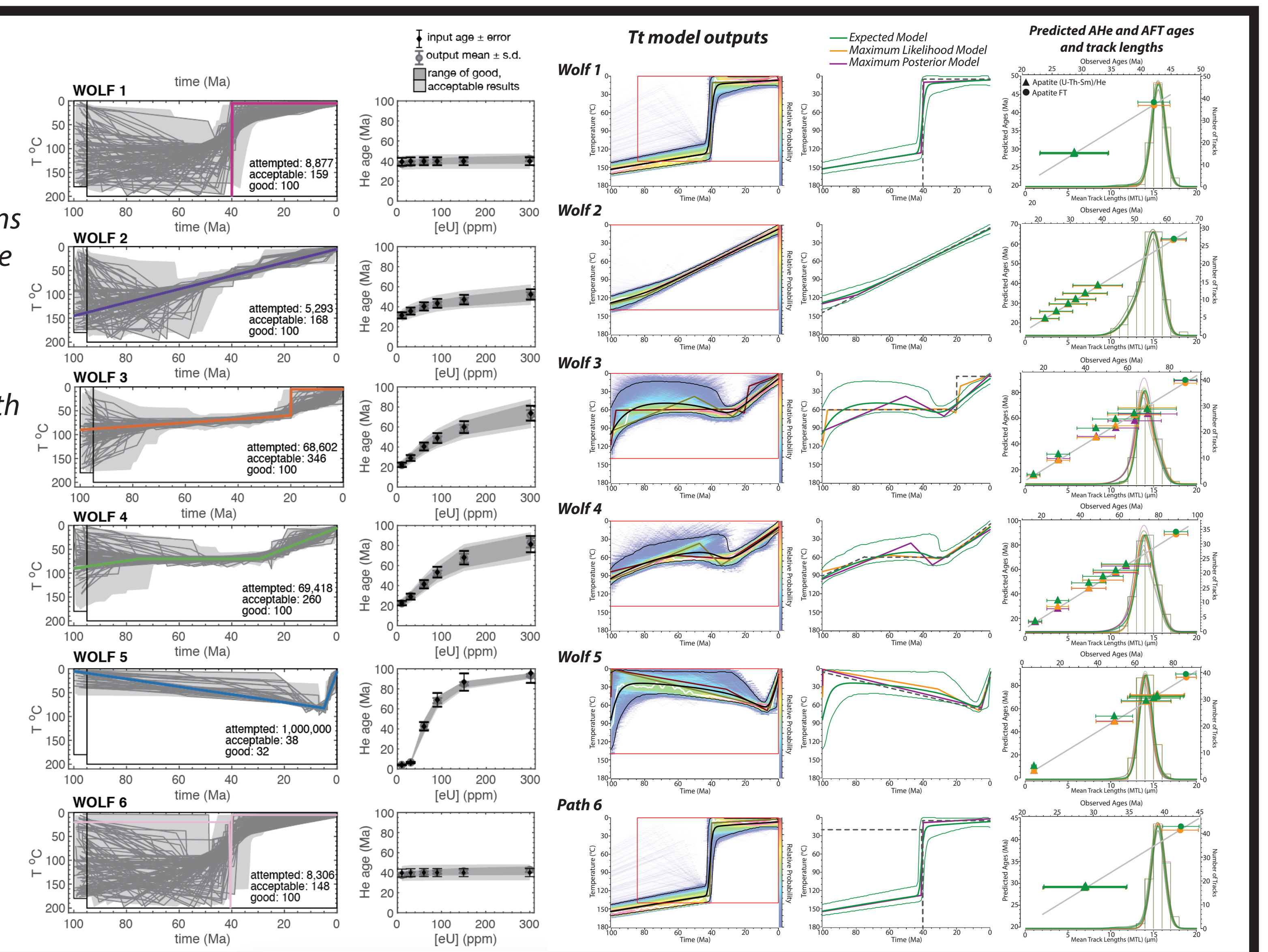


Figure 2: Inversions of synthetic data derived from forward models of 'Wolf' thermal histories. 6 AHe grains with varying eU and grainsize and AFT data with 20 counts and 100 lengths. Outputs show much better recovery of original input path when compared to possible paths from a single grain (Fig 1). Left: HeFTy outputs Right: QTQt outputs



QTQt (Gallagher, 2012)

We show decision effects in QTQt by changing various model inputs and parameters including: (i) Data inputs, (ii) Initial Constraints, (iii) Prior Ranges, and (iv) Data Uncertainties

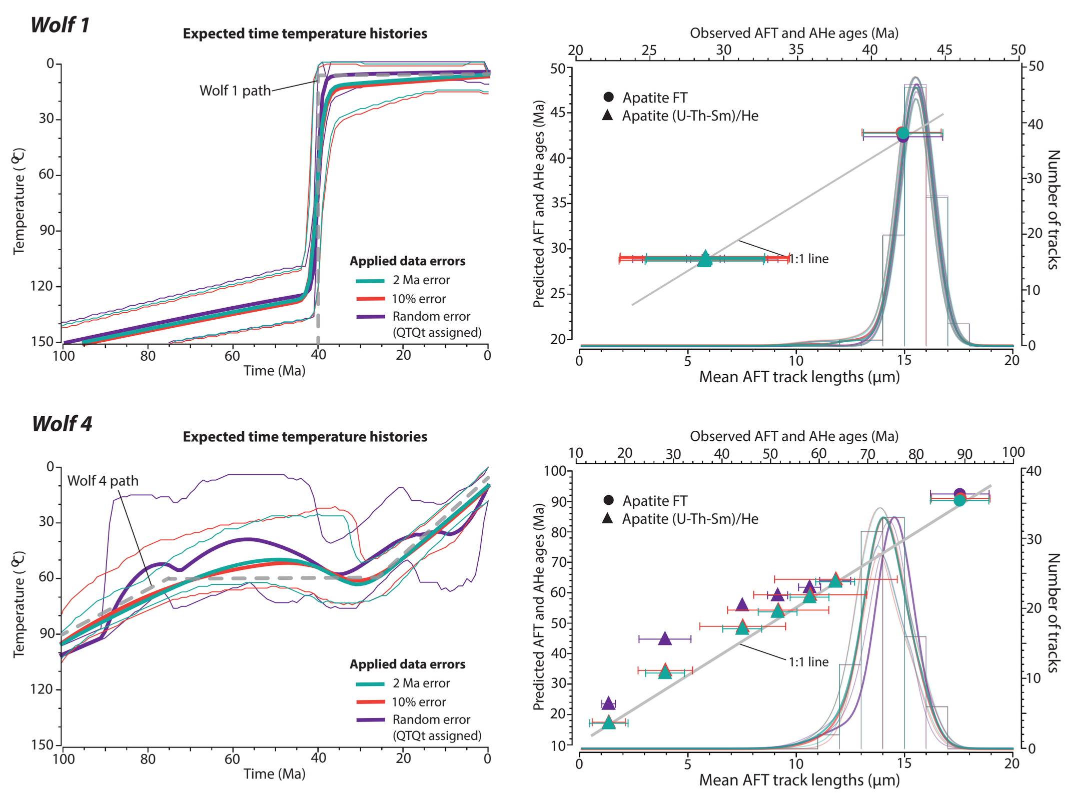


Figure 3: Example testing the effect of changing data uncertainties on output models and data predictions for both a 'simple' and 'complex' thermal history, Wolf 1 (top) & Wolf 4 (bottom) respectively.

HeFTy (Ketcham, 2005)

We see related decision effects in HeFTy running similar tests changing different model inputs and parameters: (i) Design of constraint boxes, (ii) Data Inputs, and (iii) Data Errors

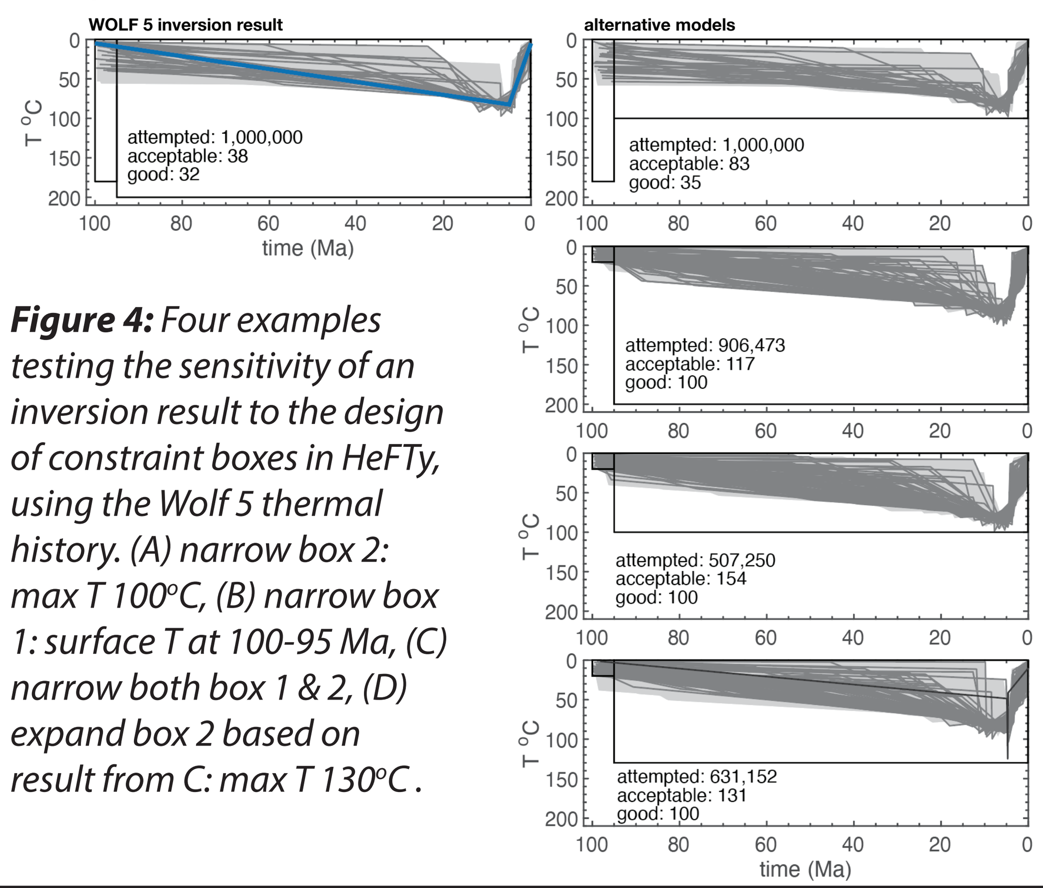
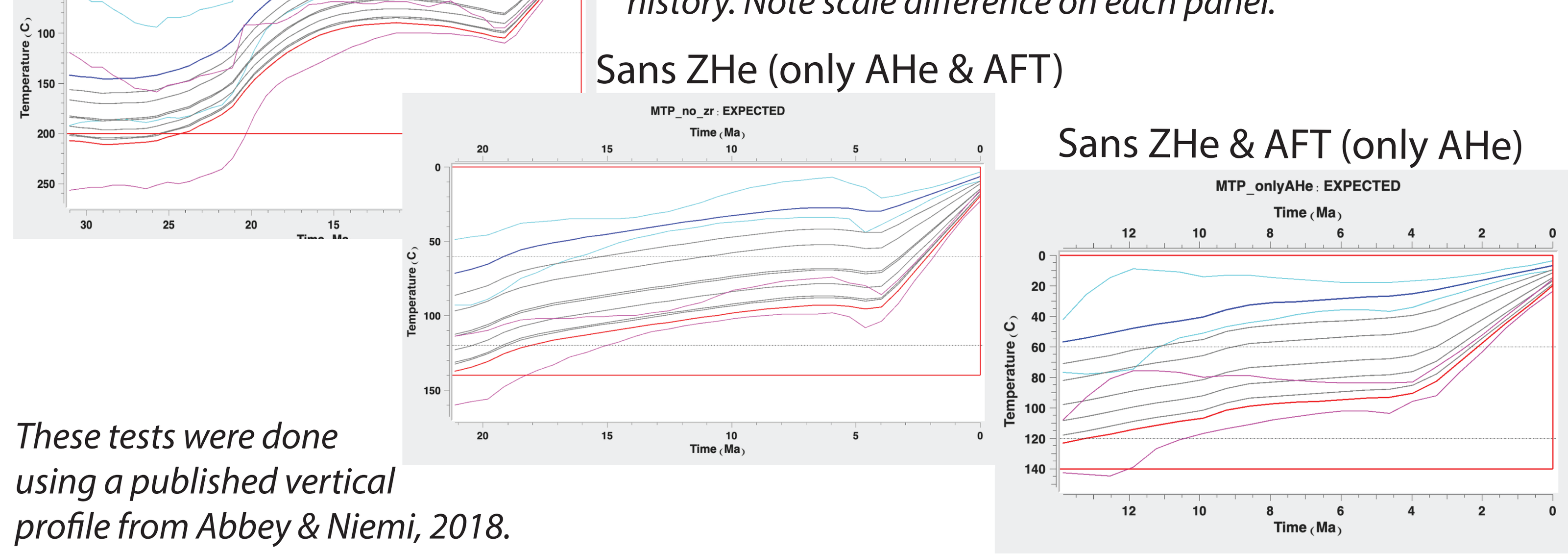


Figure 4: Four examples testing the sensitivity of an inversion result to the design of constraint boxes in HeFTy, using the Wolf 5 thermal history. (A) narrow box 2: max T 100°C, (B) narrow box 1: surface T at 100-95 Ma, (C) narrow both box 1 & 2, (D) expand box 2 based on result from C: max T 130°C .

Reproducing perfectly 'known' thermal histories from generated synthetic data is great for sensitivity testing... What about making decisions with 'real' data and unknown geologic histories?

We tested various decisions and model output effects using published datasets highlighting the utility of QTQtwhen samples are collected in (1) a vertical profile, (2) when multiple thermochronometers are used, and (3) when there is complex or dispersed data and no obvious trends with age in either grain size or [eU].

Figure 5: Example testing the effect of including different thermochronometers. With the addition of AFT and ZHe we see increased structure as well as information about the higher temperature and thus, in this case, older part of the thermal history. Note scale difference on each panel.



These tests were done using a published vertical profile from Abbey & Niemi, 2018.

Additionally, we tested various decisions and model output effects using published datasets highlighting the utility of HeFTy when (1) there are notable age-eU trends, and (2) multiple thermochronometers are used.

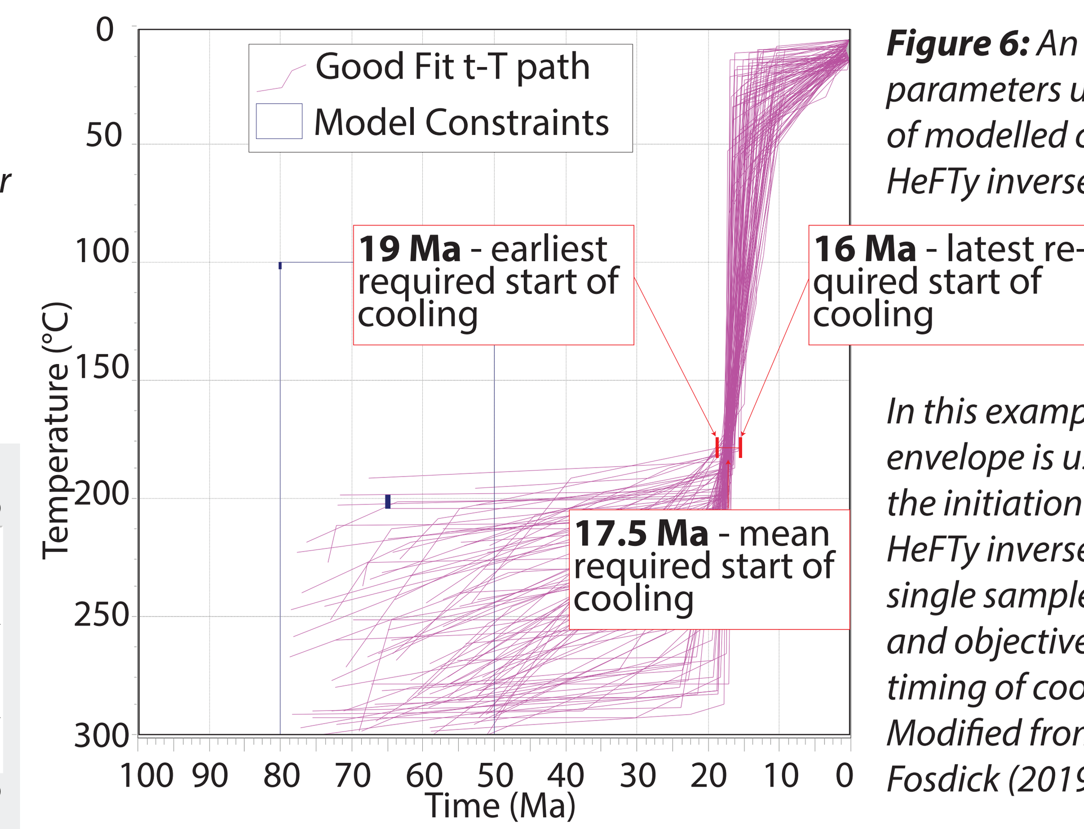


Figure 6: An example illustrating the parameters used to quantify the timing of modelled cooling initiation using HeFTy inverse model results.

In this example, the good fit path envelope is used to objectively extract the initiation of cooling. HeFTy inverse model results from a single sample showing good fit paths and objectives used to quantify the timing of cooling initiation. Modified from Stevens Goddard & Fosdick (2019).

What's Next?

We are in the process of writing this project up as a manuscript with additional education tutorials for everyone to try out these tests for themselves to develop individual intuition on when and how to use both HeFTy and QTQt for modeling thermochronometric data. ***Ask for a copy of a tutorial draft and be the first to try it out and send us feedback!***

References

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