From sink to source: extracting onshore erosion signals preserved in offshore thermochronometric data.

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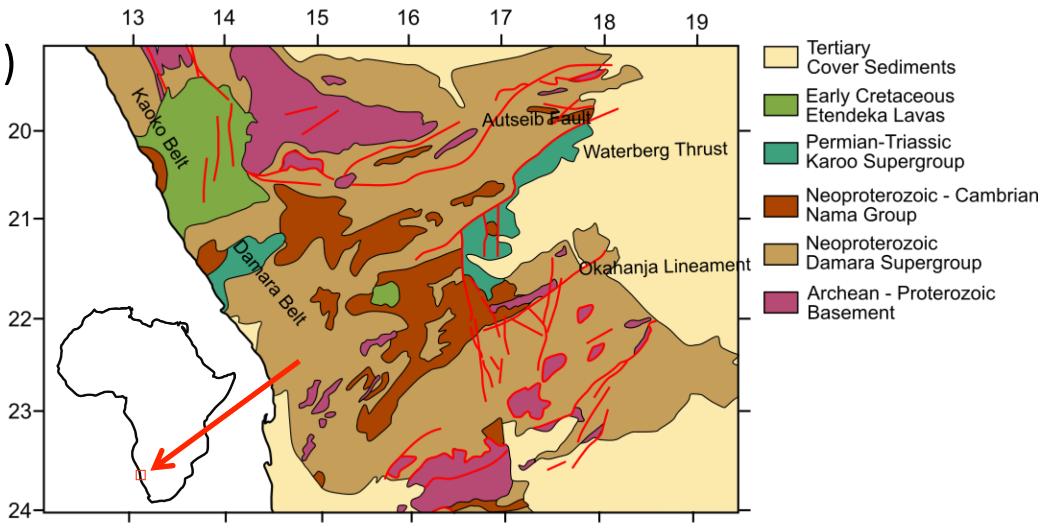
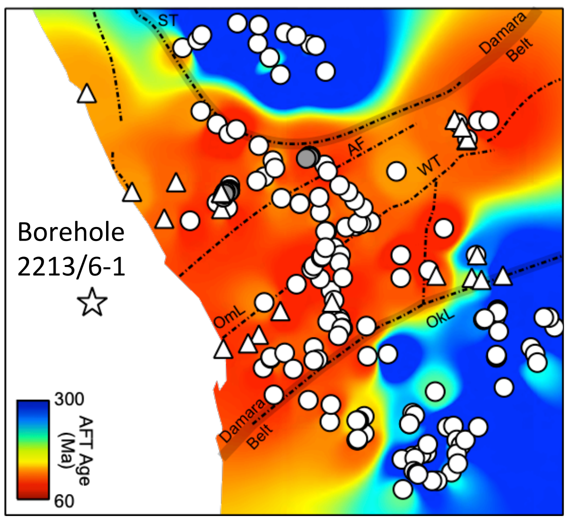
(i) Namibia : Passive margin – rifting/break-up around 130 Ma.

(i)



(ii)



(ii) Extensive onshore AFT database :

Ages from 60 to > 350 Ma.

Younger ages - closer to rift margin

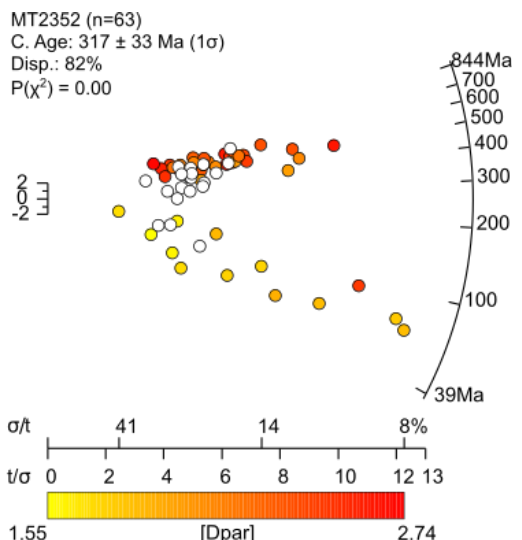
- structural reactivation (late Cretaceous)

New AFT data from offshore borehole (13 samples)

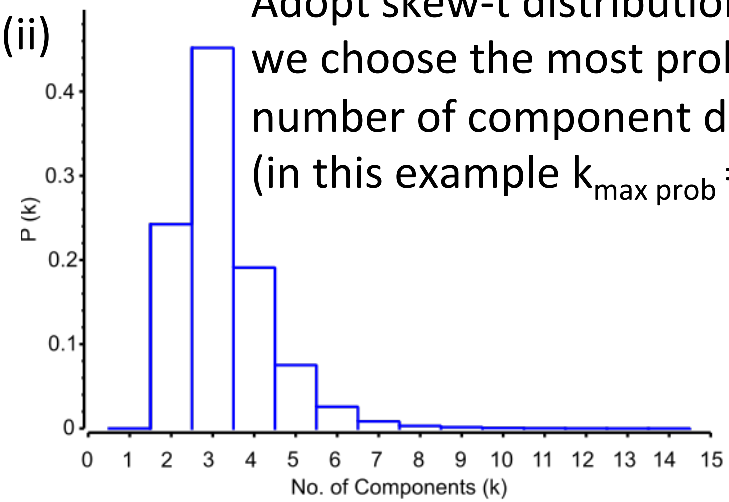
- No sample has been totally reset since deposition (preserve some provenance info. ?)
- Large age dispersion implies multiple inherited age components

(i) AFT ages have large dispersion, often older than strat. age (Cret-E.Tert) so
(ii) we use Bayesian Mixture Modelling to extract age component distributions
(iii) to produce sub-samples for modelling

(i)

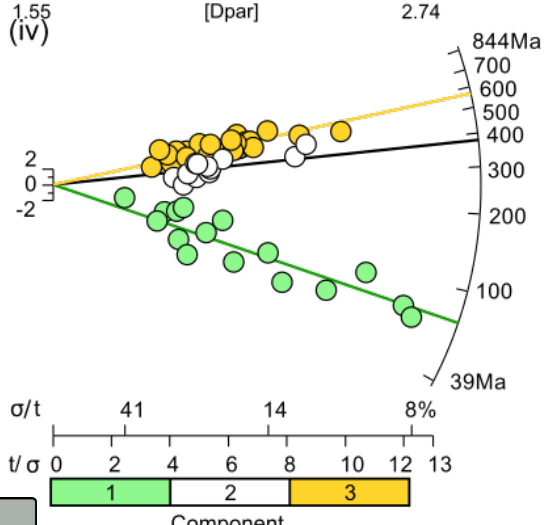


(ii)



Adopt skew-t distributions, and we choose the most probable number of component distributions (in this example $k_{max\ prob}$ = 3)

(iii)



Given the most probable number of age component distributions, the proportion and parameters of each distribution, we can classify all age (and length) data according to their most probable age component distribution to produce a set of 21 subsamples (from the 13 original samples) for inverse thermal history modelling

Inverse thermal history modelling with QTQt

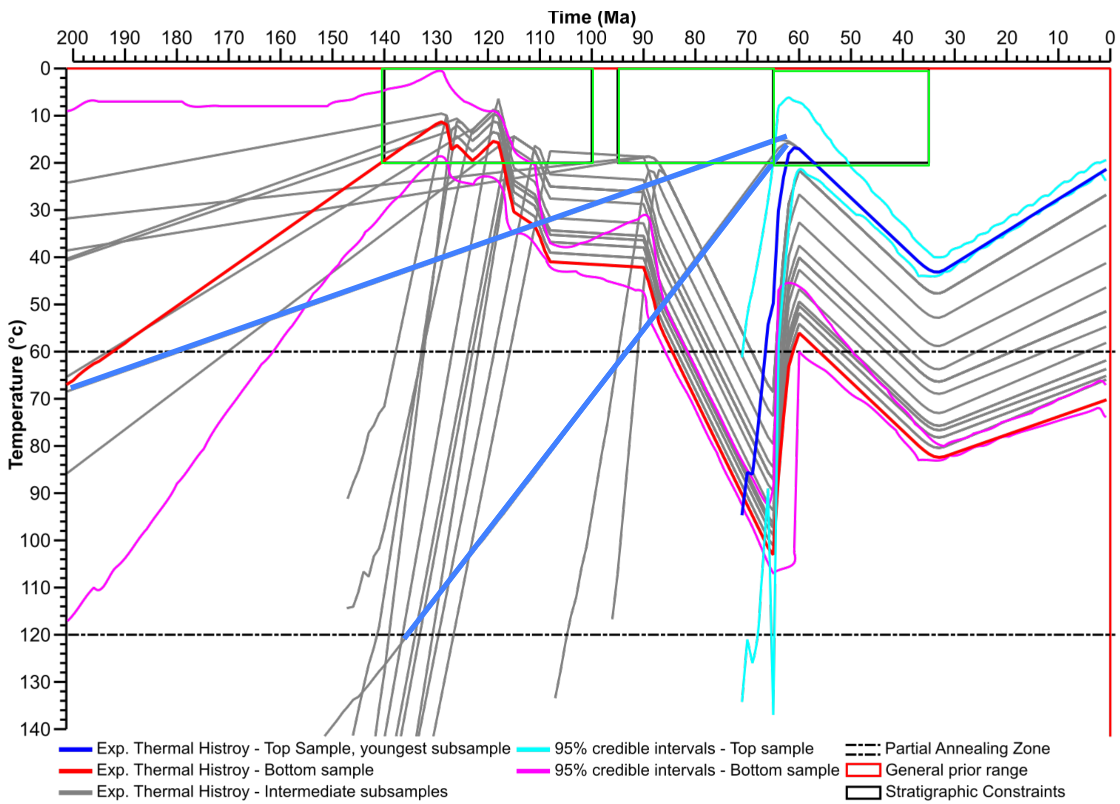
For a given sample, the sub-samples have

(a) a common (same) post-depositional thermal history

(b) independent pre-depositional thermal histories (defined by one time-temp point)

(c) use loose stratigraphic age constraints (green boxes).

No sample reaches a temperature high enough to anneal inherited, or pre-depositional, tracks. It is not possible to fit these data without a pre-dep. thermal history component.

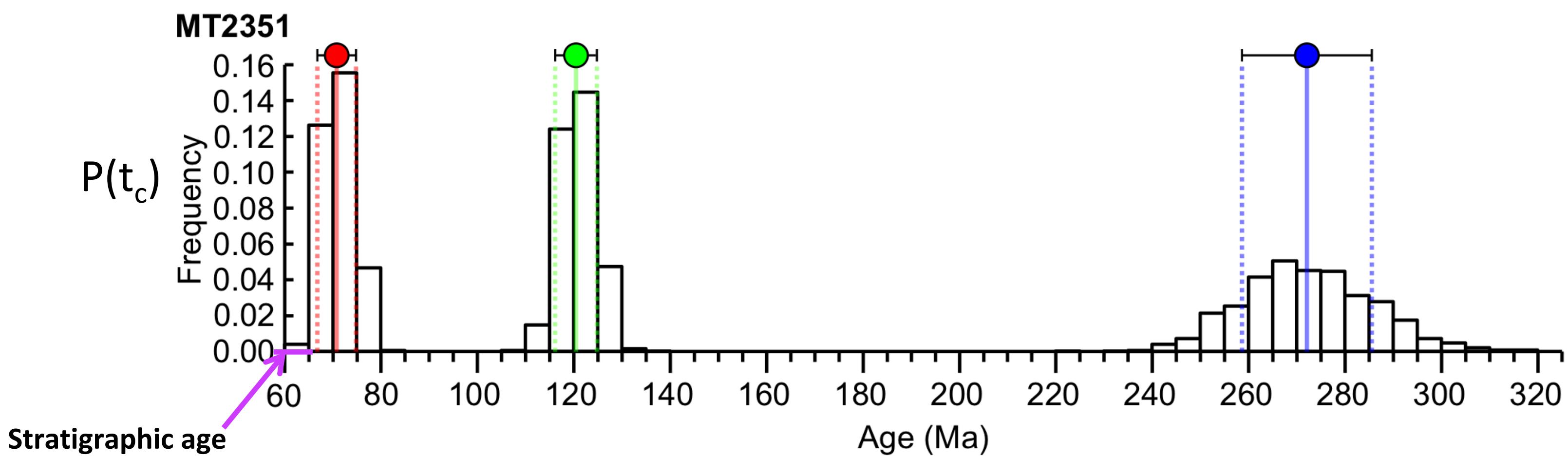


The dark blue lines show the independent pre-depositional and the common post-depositional thermal history for the shallowest sample M2351 (which has 3 sub-samples).

Inverse thermal history modelling with QTQt

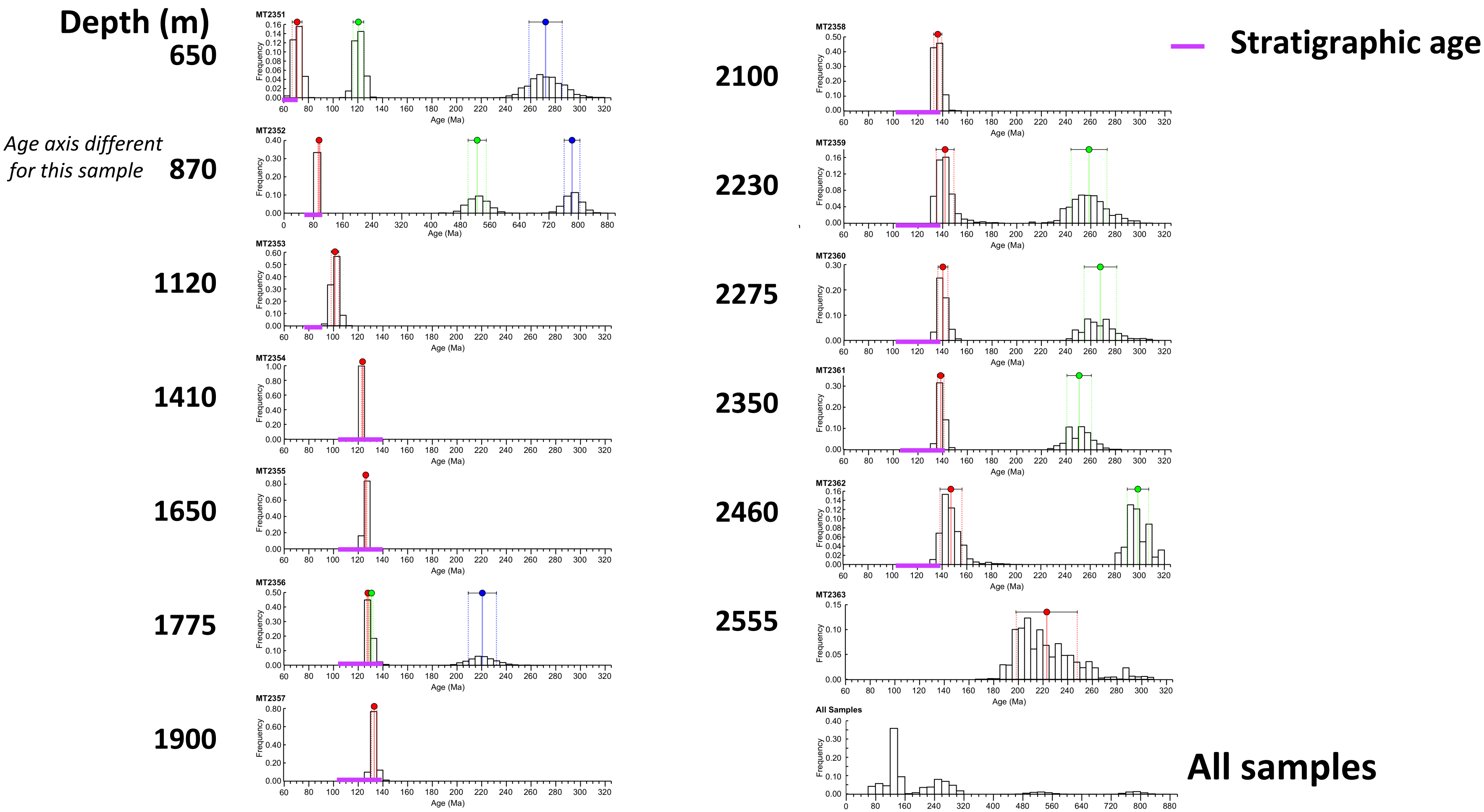
For every accepted thermal history model, we can predict the time of total annealing such that any fission tracks formed prior to that time would be preserved today. This indicates how far the thermal history may potentially be resolved back in time.

We refer to this time as the ***closure time (tc)***, and using all the accepted thermal histories, we construct a probability distribution of the closure time for each sub-sample



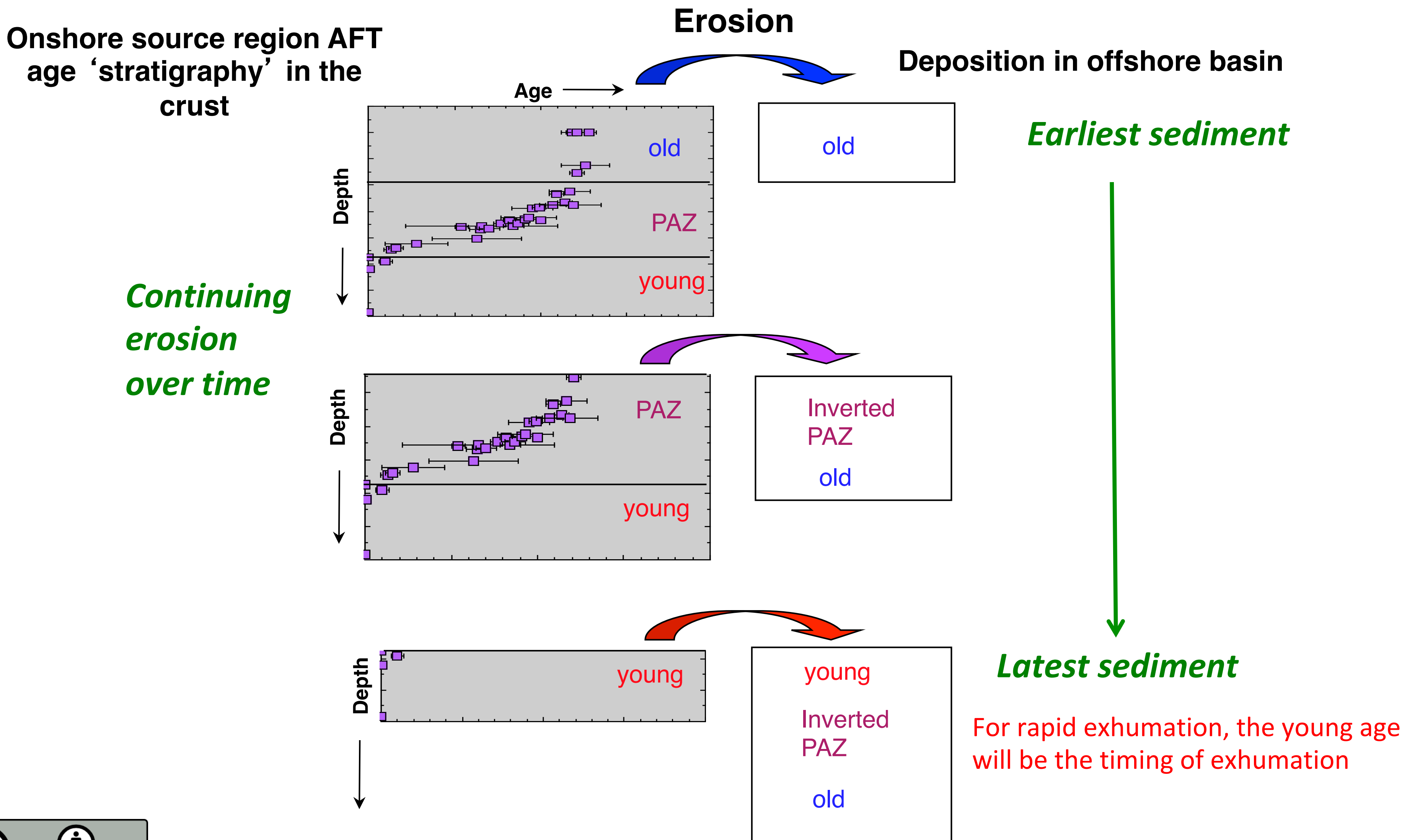
Closure time distributions for the 3 age components for sample M2351 (early Tertiary strat age). These may indicate rapid cooling events related to post-rift reactivation (70 Ma), and rifting/break-up (130 Ma) or an older source region (the oldest group around 270 Ma).

Closure times downhole trends (same age axis, except for 870m)

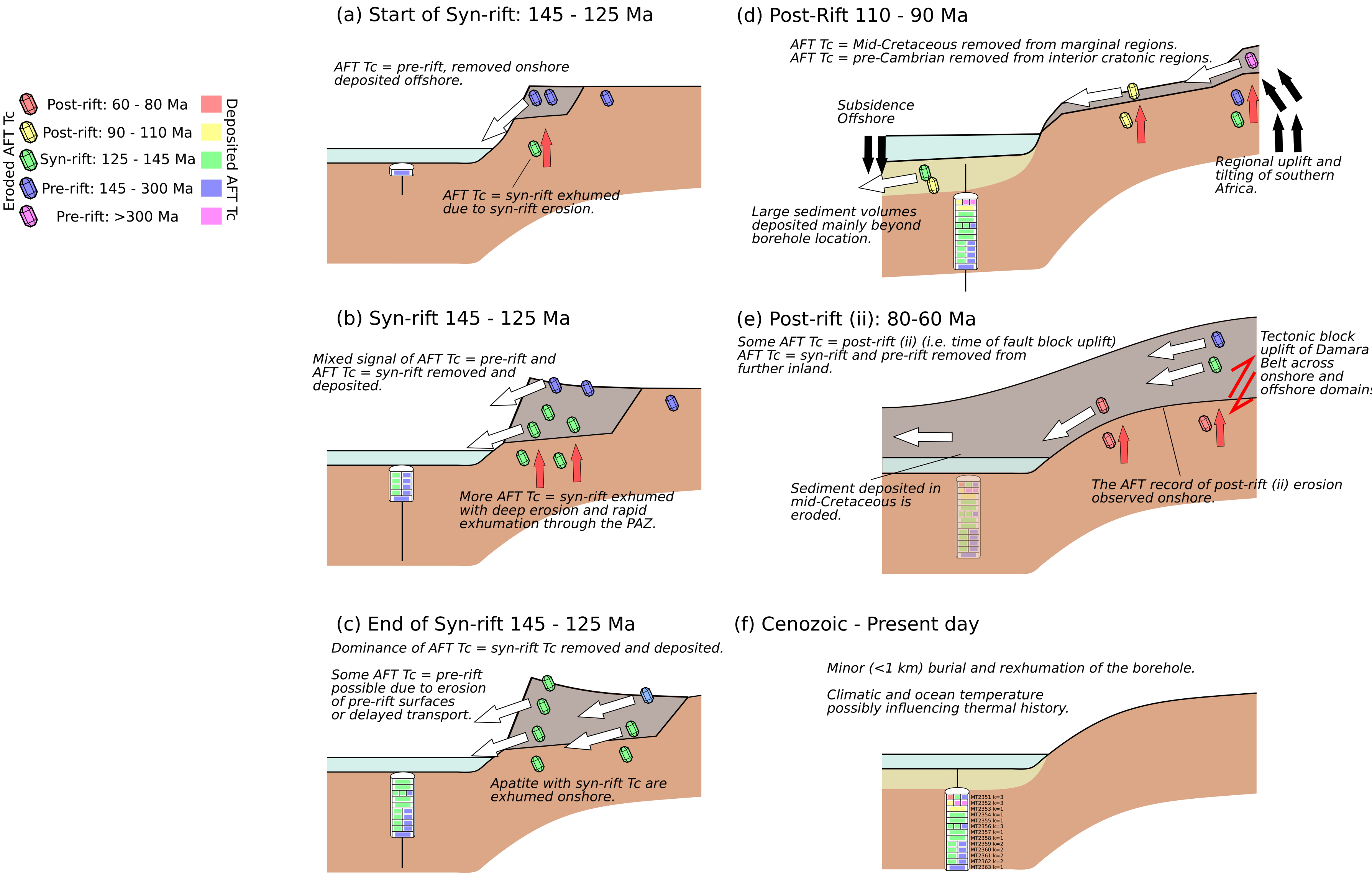


The inferred closure times show regular trends down the borehole, indicating progressive exhumation across the partial annealing zone from the time of rifting:break-up (in red, except top 3 samples), and also contributions from older source regions (colder than the PAZ, generally blue and green)

Exhumation of the partial annealing zone (PAZ) leads to an inverted PAZ detrital signal in the basin, which can be preserved if the sediments do not get too hot….which they did not.

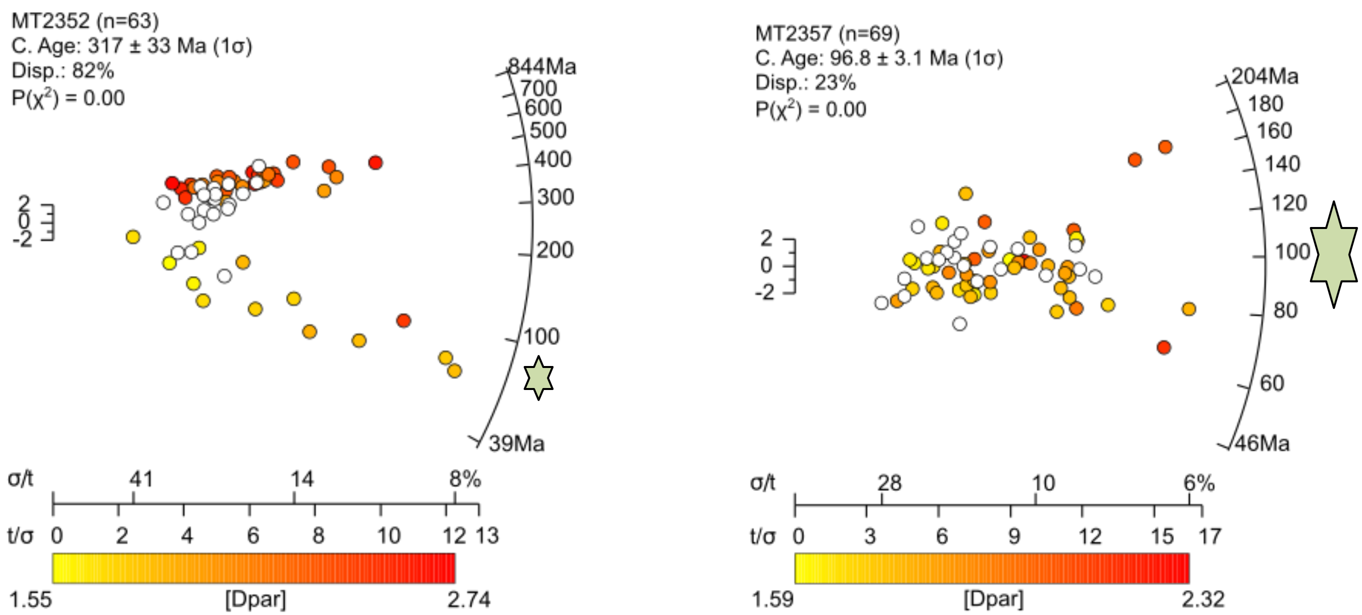


Summary


Eroded AFT Tc
Post-rift: 60 - 80 Ma
Post-rift: 90 - 110 Ma
Syn-rift: 125 - 145 Ma
Pre-rift: 145 - 300 Ma
Pre-rift: >300 Ma
Deposited AFT Tc
(a) Start of Syn-rift: 145 - 125 Ma
AFT Tc = pre-rift, removed onshore deposited offshore.
AFT Tc = syn-rift exhumed due to syn-rift erosion.
(b) Syn-rift 145 - 125 Ma
Mixed signal of AFT Tc = pre-rift and AFT Tc = syn-rift removed and deposited.
More AFT Tc = syn-rift exhumed with deep erosion and rapid exhumation through the PAZ.
(c) End of Syn-rift 145 - 125 Ma
Dominance of AFT Tc = syn-rift Tc removed and deposited.
Some AFT Tc = pre-rift possible due to erosion of pre-rift surfaces or delayed transport.
Apatite with syn-rift Tc are exhumed onshore.
(d) Post-Rift 110 - 90 Ma
AFT Tc = Mid-Cretaceous removed from marginal regions.
AFT Tc = pre-Cambrian removed from interior cratonic regions.
Subsidence Offshore
Large sediment volumes deposited mainly beyond borehole location.
Regional uplift and tilting of southern Africa.
(e) Post-rift (ii): 80-60 Ma
Some AFT Tc = post-rift (ii) (i.e. time of fault block uplift)
AFT Tc = syn-rift and pre-rift removed from further inland.
Tectonic block uplift of Damara Belt across onshore and offshore domains
Sediment deposited in mid-Cretaceous is eroded.
The AFT record of post-rift (ii) erosion observed onshore.
(f) Cenozoic - Present day
Minor (<1 km) burial and rexhumation of the borehole.
Climatic and ocean temperature possibly influencing thermal history.
MT2351 k=3
MT2352 k=3
MT2353 k=1
MT2354 k=1
MT2355 k=1
MT2356 k=3
MT2357 k=1
MT2358 k=1
MT2359 k=2
MT2360 k=2
MT2361 k=2
MT2362 k=2
MT2363 k=1

Extra stuff…

Radial plots for 2 of the 13 borehole samples (typical of the data) − large dispersion, AFT ages often older than strat. age (Cret-E.Tert)

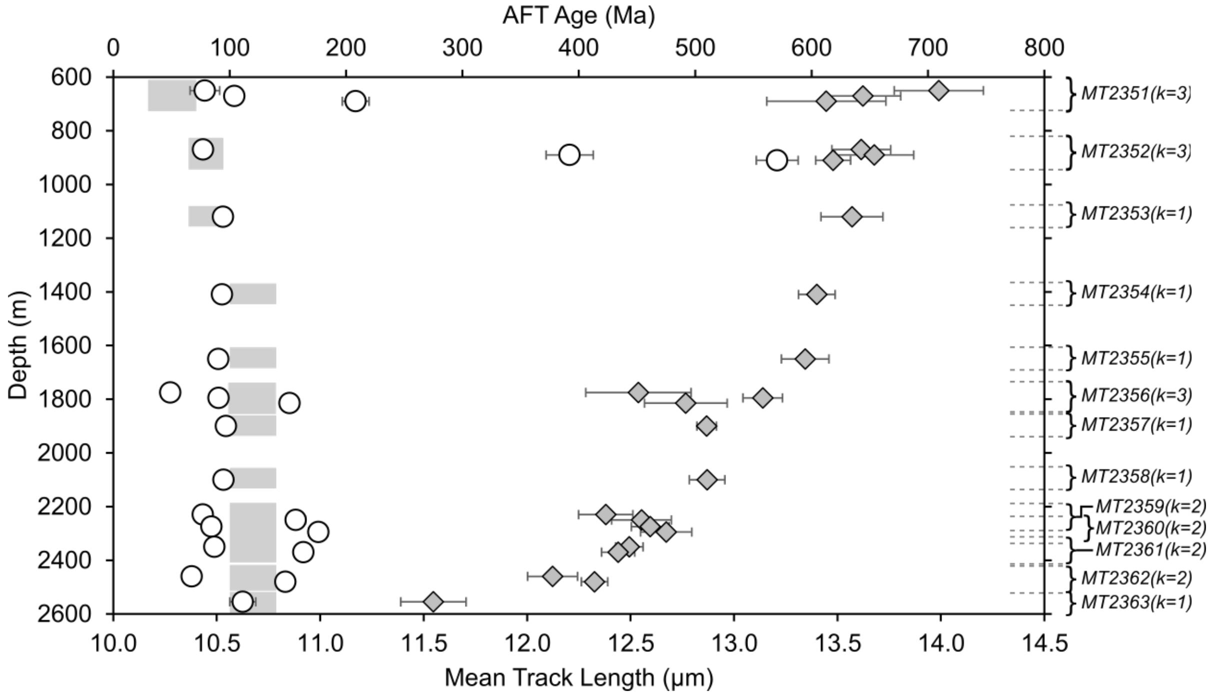


Open circles − EDM method (no compositional data)

Coloured circles − LA-ICPMS method (with Dpar) + ages for all track length data

approx. stratigraphic age

Between 1 and 3 age components for the 13 borehole samples



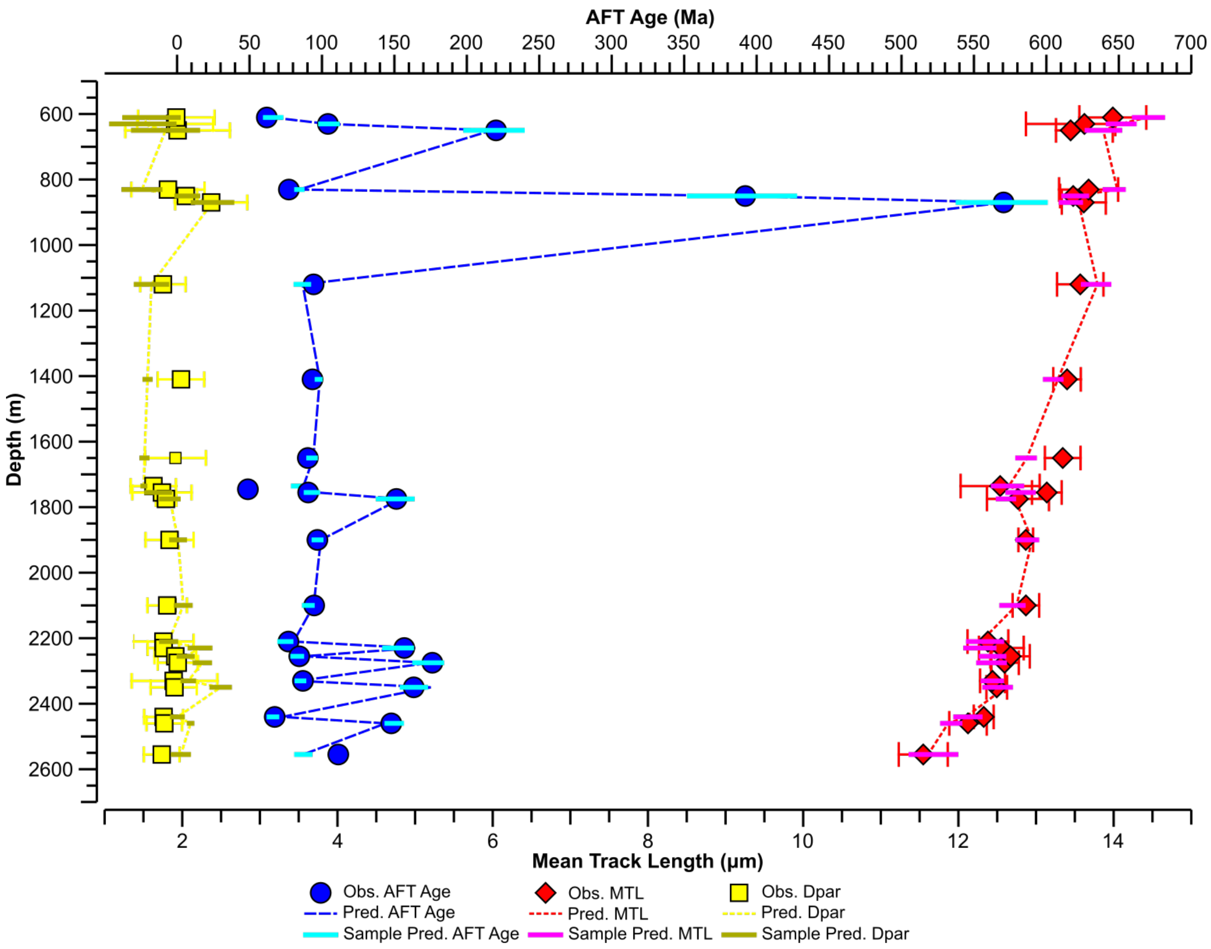
○ Central ages for sub-samples

◇ Mean track lengths for sub-samples

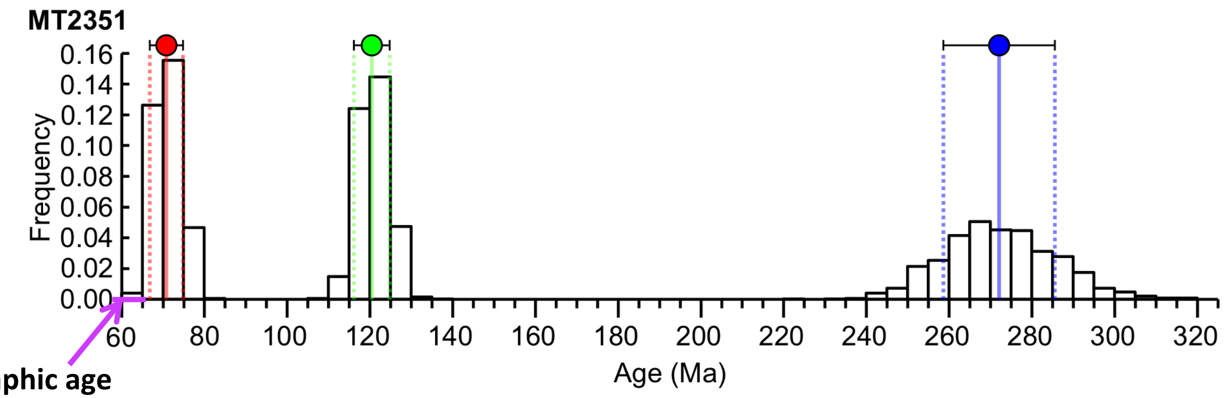
Stratigraphic age range (poorly constrained)

Inverse thermal history modelling with QTQt – the fit to the data

It would not be possible to fit these data without explictly allowing for the pre-depositional thermal history



Spread in inferred tc (Sample MT2351)



Spread in sampled pre-depositional time-temperature points (not the same as tc, but used in the calculation of tc). These imply we constrain an average cooling rate to the depositional age with the approach we implement.