Simple Simulation of Geochronology of Uplift/Erosion

Bill Menke, September 10, 2019

My purpose here is to get a feeling for the pattern produced by a simple uplift event, in the case where the uplift rate increases for a brief interval and then returns to normal.

In this model, erosion always keeps up with uplift, so that the Earth's surface is always at depth $z = 0$. The temperature T is assumed to increase linearly with depth:

$$T(z) = gz \quad \text{with} \quad g = 20\ °C/km$$

This profile does not change with time; the model makes no provision for heat advection. Time t increases from 0 in the distant past to time $t_{max} = 1000$ m.y. today. The uplift rate is assumed to be steady with U=1/30 km/m.y., except for a time interval of length $\Delta t = 1$ m.y. at time t_e, when it increases to $A \times U$, where A is a multiplicative amplitude.

Each parcel of rock is assumed to contain two clocks, A and B, which reset to zero when the temperature exceeds critical temperatures $T_A = 80\ °C$ and $T_B = 120\ °C$, respectively.

Results of the simulation, for a suite of (t_e, A) values, are shown in Figures 1 and 2. In these figures, the event time is parameterized by the time of the event *before* the present, $t_{max} - t_e$.

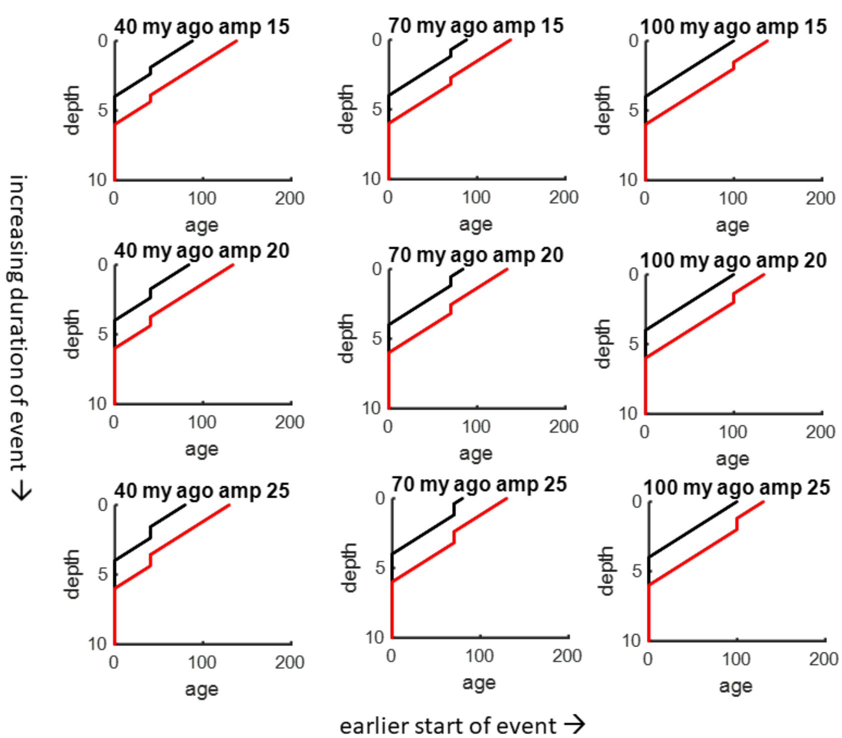
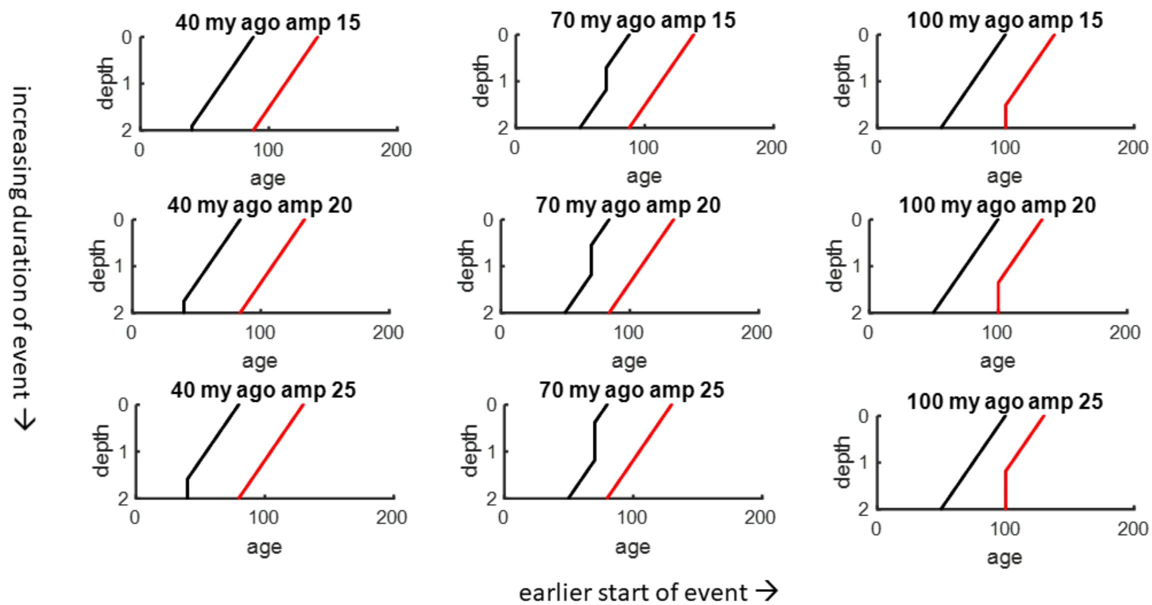


Fig. 1. Results of the simulation, with clocks A (black) and B (red).

Fig. 2. Results of the simulation, with clocks A (black) and B (red). Only the top 2 km is shown.



The period of rapid uplift creates a nearly-constant age intervals of the same duration for Clocks A and B. The duration of the interval increases with the amplitude *A* of the uplift event. The interval for Clock A is shallower in the Earth (since its critical temperature is lower and temperature increases with depth). The depth of the interval is shallower when time of the event is further back in the past, since more uplift/erosion has had time to occur. Consequently, the interval for Clock A is eroded away first.

This model can be compared to data from Amidon et al. (2016) (Figure 3).

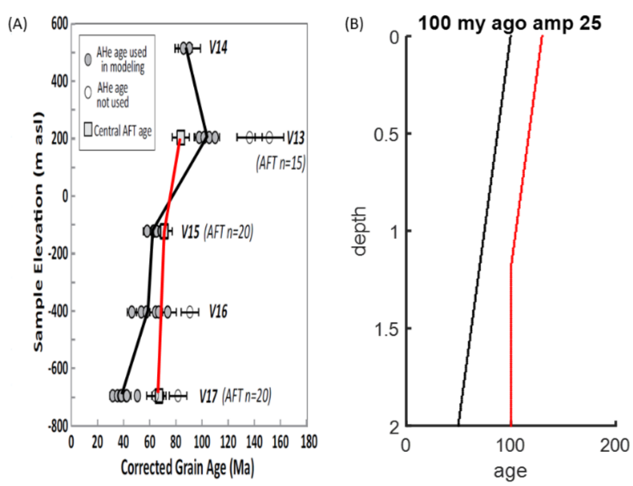


Fig. 3. (A) Data from Amidon et al. (2016) (their Figure 2). (B) Results of the simple model, with clocks A (black) and B (red).

No attempt has been made to fit Amidon et al.'s (2016) data closely. However, the general shape of the curves shows some similarity, which indicates to me that Amidon et al.'s (2016) data might be able to constrain the timing of a rapid uplift event (as those authors claim).

Note however that the simple model cannot account for the curves from Clocks A and B crossing. In the simple model, Clocks A can never be greater than Clocks B.

A more sophisticated model might account for: (A) a clock losing time at temperatures that are just a little below the critical temperature; (B) a non-steady state thermal profile that satisfies the advection-diffusion equation; and (C) a more complicated time-dependence of the uplift rate.

Reference

Amidon, WH, M Roden-Tice, AJ Anderson, RE McKeon and DL Shuster, Late Cretaceous unroofing of the White Mountains, New Hampshire, An episode of passive margin rejuvenation?, Geology 44, 415-418, 2016.