The (mis)conception of an average Quaternary equilibrium line altitude

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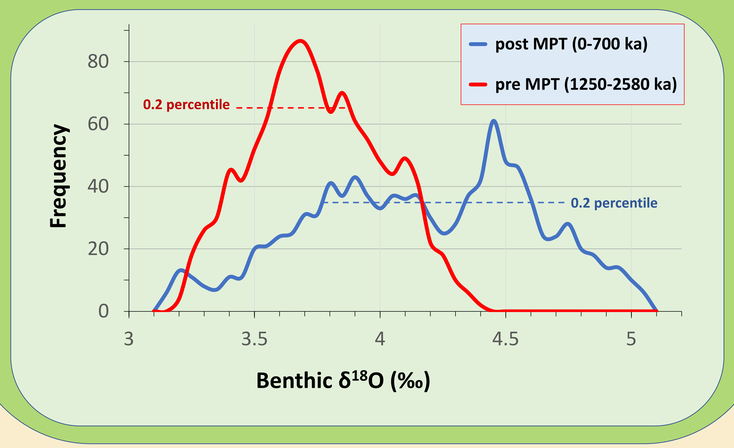
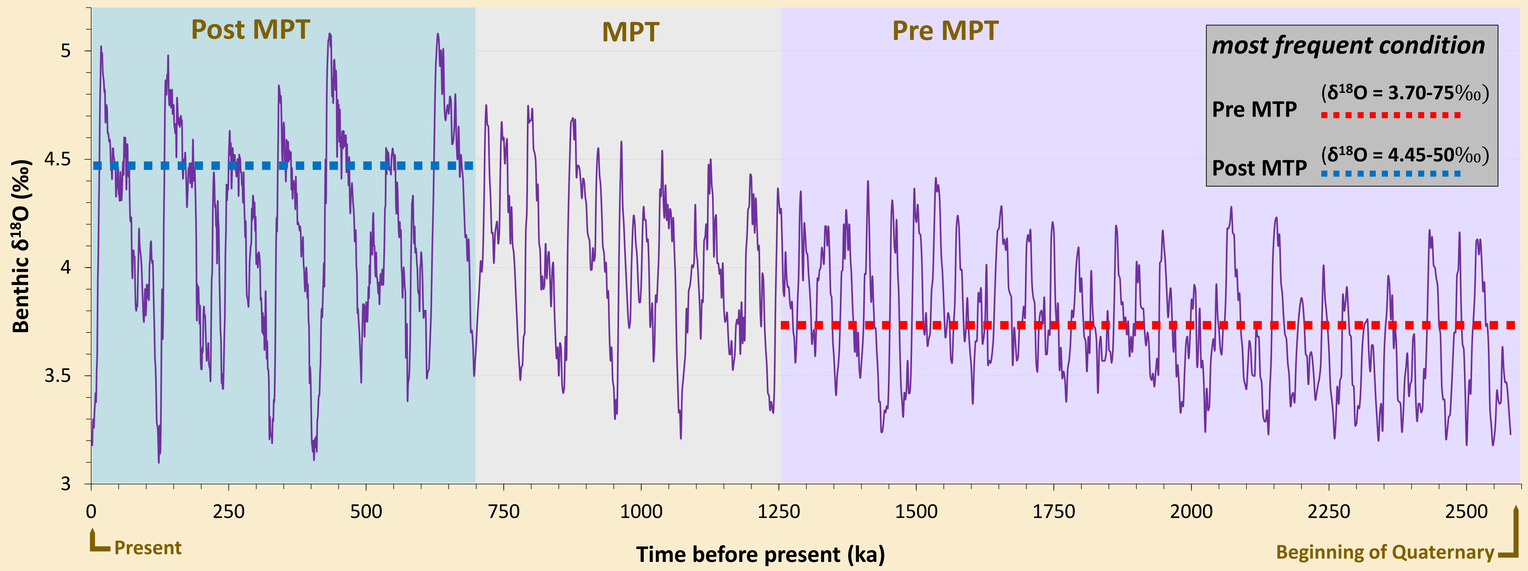
INTRODUCTION - To counter the excessive attention to Quaternary "extremes" (glacial maxima and interglacials), the concept of average Quaternary conditions was defined in 1989[1]. It was argued that a number of glacial landscapes around the world reflect erosion under average conditions[1,2]. The concept has continued to gain popularity over the following 30 years. For example, many studies have suggested that cirques are the geomorphological expression of average Quaternary conditions. Other studies have used the correlation between peak altitude and average Quaternary equilibrium line altitude (ELA), roughly defined as the midpoint between the LGM and the present ELAs (and often coinciding with cirque floor elevation), to support the glacial buzzsaw hypothesis[3,4,5,6].
Thirty years later, with much improved climate proxy data for the Quaternary[7], it is perhaps time to reconsider this concept, and ask some key questions.

Q1: One or multiple averages?
Amplitude and frequency of Quaternary climate oscillations changed at the Middle Pleistocene Transition (MPT, 700-1250 ka). Instead of one average value ($\delta^{18}O$ = 3.97‰) across the whole Quaternary, we should consider at least 2 averages: pre MPT (2580-1250 ka, when average $\delta^{18}O$ = 3.73‰) and post MPT (700-0 ka, average $\delta^{18}O$ = 4.36‰).

Q2: Average or most frequent conditions?
Quaternary climate oscillations have variable amplitudes even within the two periods defined above and within each cycle. A better statistical approach is to look at the $\delta^{18}O$ value that occurred most frequently. These are: **$\delta^{18}O$ = 3.70-3.75‰** for the pre MPT, and **$\delta^{18}O$ = 4.45-4.50‰** for the post MPT (calculated with bin sizes of 0.05 ‰).

Q3: How frequent were these conditions?
The climatic condition represented by the $\delta^{18}O$ = 3.70-3.75‰ (**pre MPT** frequency peak) occurred **86 times** throughout the Quaternary, while 20% of the analysed climatic conditions (i.e. 0.2 percentile) occurred at least 65 times.
The climatic condition represented by the $\delta^{18}O$ = 4.45-4.50‰ (**post MPT** frequency peak) occurred **61 times** throughout the Quaternary, while 20% of the analysed climatic conditions (i.e. 0.2 percentile) occurred at least 37 times.





Q4: Do the pre and post MPT frequency peaks have a geomorphological expression?
Most likely not. If we look at the 0.2 percentile (Q3), there is actually a whole range of climate conditions, which occurred a relatively high number of times throughout multiple glaciations.
Also, the geomorphological expression of any specific climatic condition differs notably even within a single region. For example, in an alpine environment, within individual valleys, cirque glaciers often co-exist with valley glaciers, controlled by, for example, elevation and aspect.


Aletsch Glacier, Switzerland. Photo courtesy of Bernhard Edmaier www.bernhard-edmaier.de

Q5: When did these values last occur?
The climatic condition represented by the $\delta^{18}O$ = 3.70-3.75‰ (**pre MPT** frequency peak) occurred last **11.31-11.47 ka** (during the warming period between the end of the Younger Dryas cooling and the Holocene).
The climatic condition represented by the $\delta^{18}O$ = 4.45-4.50‰ (**post MPT** frequency peak) occurred last **14.81-15.04 ka** (during the Oldest Dryas).


Iceberg Lake, USA. Mapio.net

Q6: Is the midpoint between last glacial maximum ELA and present-day ELA a proxy for Quaternary average ELA?

A Quaternary ELA could possibly be extracted from the peak frequency values in Q2, but the same issues mentioned in Q5 will apply: is it valid and meaningful to look at two values only? Also, the most frequent (or average) condition across a multi-cycle period (the Quaternary) will unlikely coincide with the most frequent (or average) condition experienced within a single (the last) glacial cycle.
With all this in mind, the use of cirque floor elevation as a proxy for average/most frequent Quaternary ELA conditions is problematic.

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