Calibrating the Chronology of Late Pleistocene Modern Human Dispersals, Climate Change and Archaeology with Geochemical Isochrons

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Introduction and Summary

Chronometric dating of Late Pleistocene modern human dispersals from Africa, environmental changes, archaeological sites and technological transitions can be refined by intercontinental correlations with precisely dated stalagmites, marine isotope stages (MIS), ice cores and the Toba volcanic eruption isochron (Fig. 1).

- In **Israel**, correlation of Soreq Cave stalagmite with faunal isotopes at Qafzeh shows Level 21 burials date to 119-128 ka (MIS-5E) rather than 92 ka (MIS-5B).
- Lake **Malawi** core age-depth models revised using Toba volcanic ash (74 ka) shows megadroughts date to ~115-165 rather than 75-135 ka. A 2 kyr cold/arid event follows Toba in L. Malawi and **Greenland** ice cores.
- Toba ash in Pinnacle Point 5/6, **South Africa**, coincides with low sea level, reduced site use, and the first MSA backed blade industry, and a new form of technological organization.

Soreq Cave and Qafzeh Burials

Soreq and Pequin Cave stalagmites have high $\delta^{13}C$ and low $\delta^{18}O$ values only during MIS-5E (119-128 ka), showing C_4 grass cover and summer rainfall (Fig. 2). Qafzeh Cave Level 21 goat teeth (Figs. 3-4) also show high $\delta^{13}C$ and low $\delta^{18}O$ values only in Level 21 (Hallin et al. 2012), reflecting C_4 grass cover and summer rainfall. Modern humans thus occupied the Levant during warm, humid MIS-5E. *Africans expanded to the Levant during the era of least ecological resistance.*

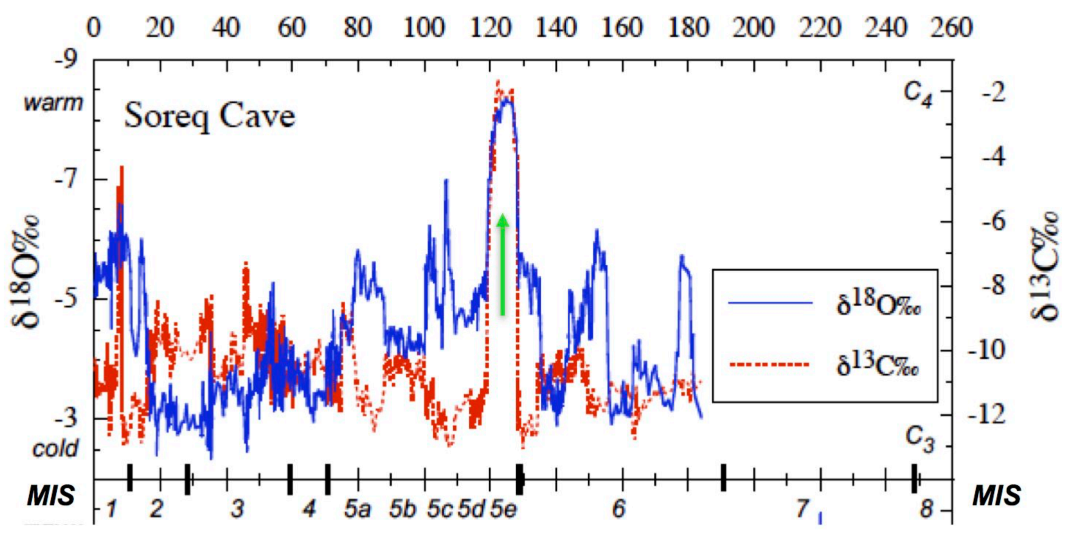

Figure 2. Soreq Cave stalagmite carbon and oxygen isotopes. MIS-5E (green arrow) had a climate regime with summer rainfall and high C_4 plant biomass, like tropical African savannas (Bar-Matthews et al. *GCA* 2003). Data from IGBP PAGES/World Data Center for Paleoclimatology Data Contribution Series #2003-061

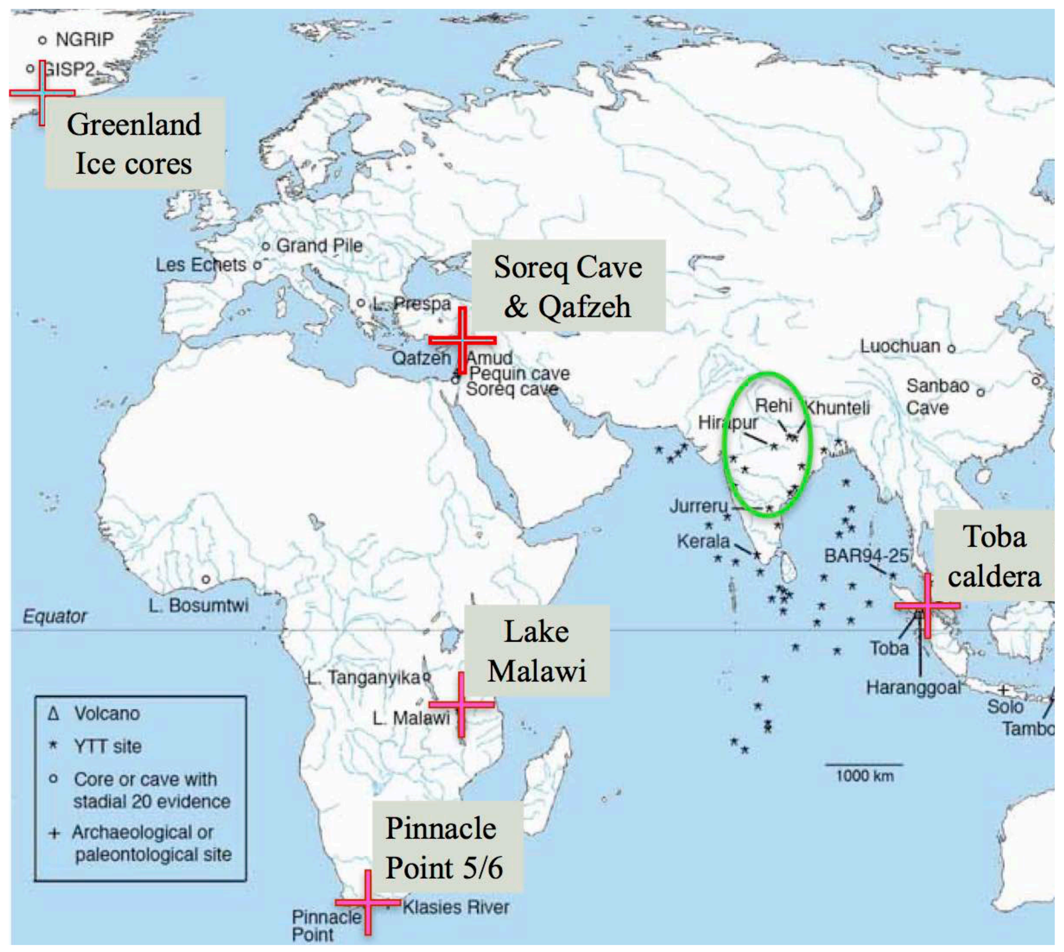

Figure 1. Localities correlated by MIS-5E or Toba ash isochrons. Green oval shows Indian paleosols with carbon isotope evidence of deforestation following the Toba super-eruption (Williams et al. *Palaeo. 3*, 2009).

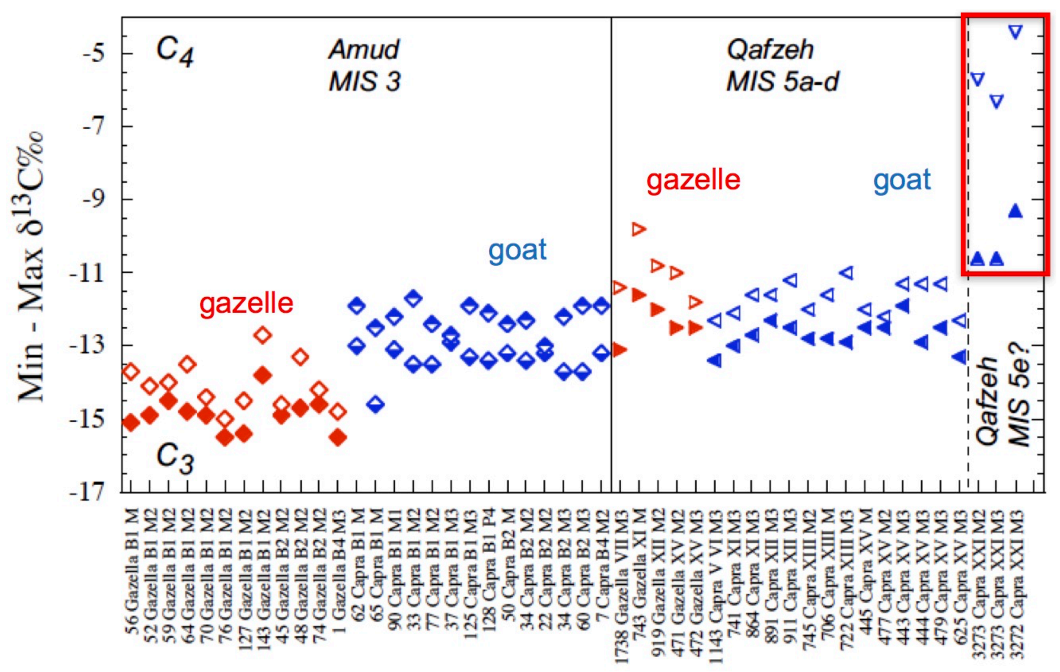

Fig. 3. Amud and Qafzeh goat & gazelle enamel carbon isotopes. Goat teeth from level 21 show feeding on C_4 plants, as in tropical savannas. Data from Hallin et al. *J. Hum Evol* 2012, Table 1.

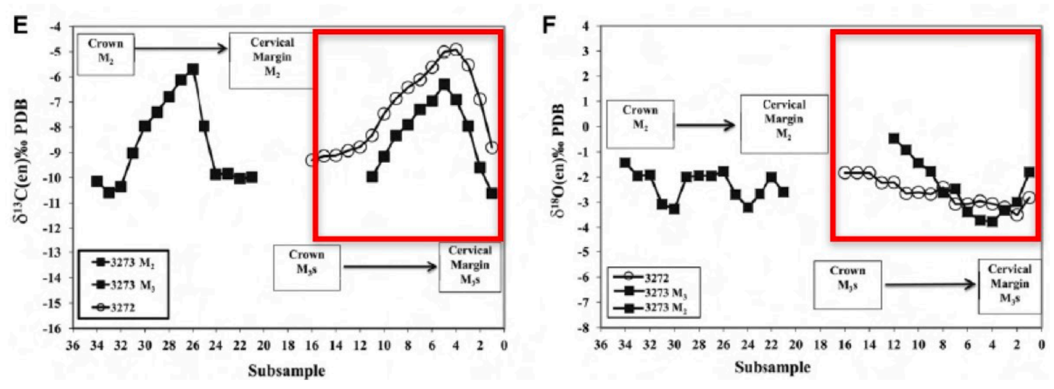

Fig. 4. Qafzeh Level 21 carbon and oxygen isotopes of serially sampled goat teeth from level 21 that show feeding on C_4 plants (high $\delta^{13}C$) in a climate with summer rainfall (low $\delta^{18}O$), indicating a tropical savanna environment. From Hallin et al. 2012, Fig. 5E-F.

Toba Super-Eruption

The Toba supereruption, dated 73,880±320 BP, was the largest volcanic eruption of the Quaternary (Storey et al. *PNAS* 2012), ejecting ~3800 km^3 Dense Rock Equivalent of volcanic ash into the atmosphere, over an area of ~40 million km^2 (Costa et al. *FES* 2014). The largest spike of volcanic sulfate in Greenland ice cores, spanning six years after the onset of Stadial 20, is attributed to Toba (Zielinski et al. *GRL* 1996). The coldest temperatures of the 123 kyr core span ~1800 years following this event, during Greenland Ice event stadial 20 (GI-20s, Fig. 5).

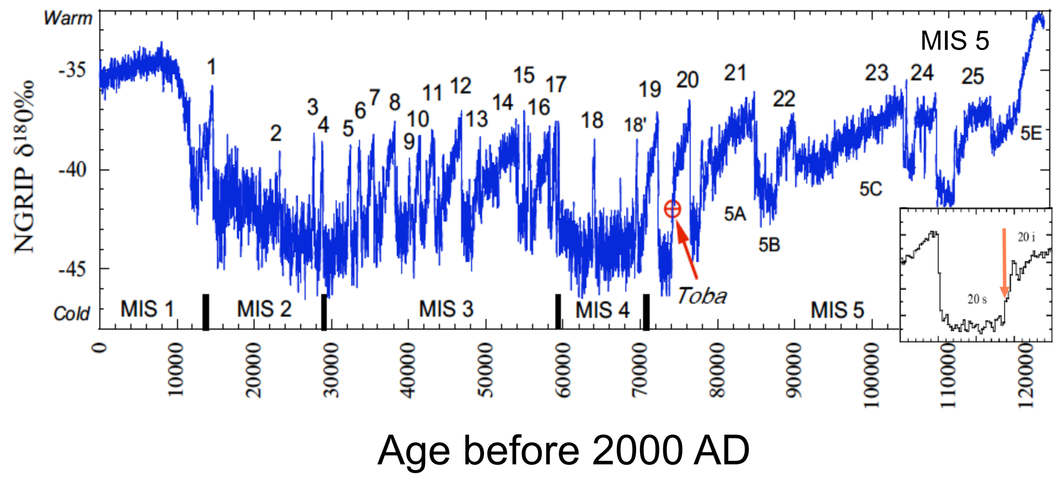

Figure 5. North Greenland ice core oxygen isotope values from 0-123 ka (NGRIP Members, *Nature* 2004). Inset figure shows consistently cold climate (low $\delta^{18}O$) during GI-20s in GISP core. Data from www.iceandclimate.nbi.ku.dk/data/.

Toba Ash in L Malawi Cores

Toba ash occurs in 2 cores in 2-cm-thick layers, 28.10 and 26.78 m below lake floor (MBLF), respectively (Lane et al. *PNAS* 2013). These levels were previously dated to ~62.5 ka. Revising the age-depth model with this isochron shows a 12 kyr error at this level and a ~35 kyr error at 40 MBLF in Core 1C (Fig. 6). Megadroughts first dated to 90-115 ka (Cohen et al. *PNAS* 2007) likely date to MIS-6, ≥130 ka.

Toba ash is diffused over ~55 years of sedimentation (2 cm, ~27 yr/cm). If ash input spanned six years, then time-averaging limits chronological resolution to detecting severe environmental events lasting ~25-55 years.

Biogeochemical markers in Malawi cores show a ~2000-year interval after Toba with low lake levels and temperatures colder that the Last Glacial Maximum (Woltering et al. *3P* 2011; Stone et al. *3P* 2011). For example, the lowest leaf wax hydrogen isotope ratios from 74-0 ka are directly above the ash (Fig. 7), consistent with extreme cold during GI-20s.

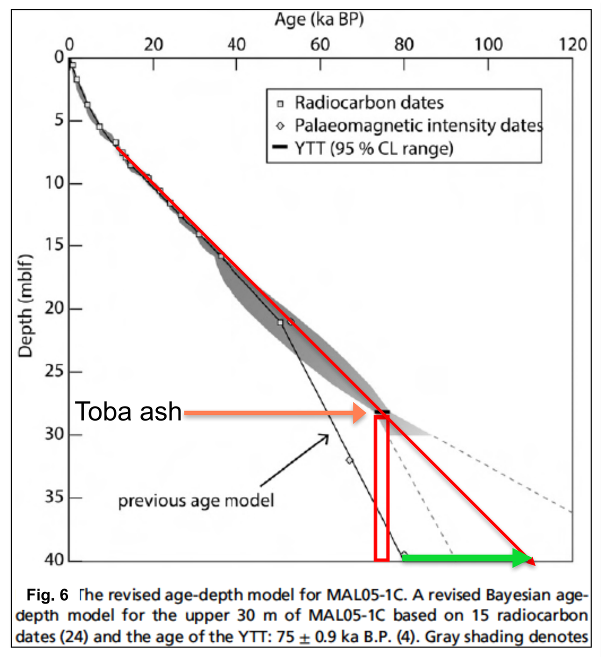

Fig. 6. Malawi MAL05-1C core age-depth model revised to fit Toba ash. Linear age-depth model changes age at 40 m MBLF from ~81 to ~115 ka (green arrow). Modified from Lane et. al. *PNAS* 2013, Fig 4.

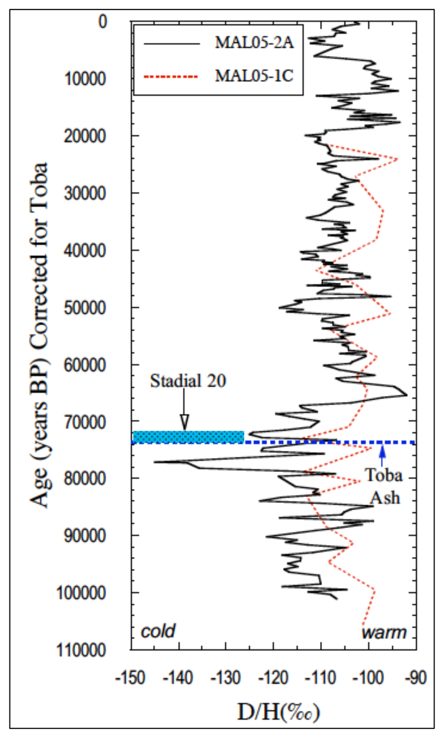

Fig. 7. Malawi core leaf wax hydrogen isotope ratios Data from Konecky et al. *Earth Planet. Sci. Lett.* 2011.

Toba Ash at Pinnacle Point 5/6

Toba ash occurs within the ALBS aeolian sands, during a time of low sea levels (Smith et al. 2018). Stone artifact densities are extremely low for ~30 cm overlying this isochron (Fig. 8). This apparent **failure to "thrive"** after Toba may reflect severe environmental degradation during GI-20s. Occupation resumes with the earliest known MSA backed blade artifacts on fine-grained raw materials.

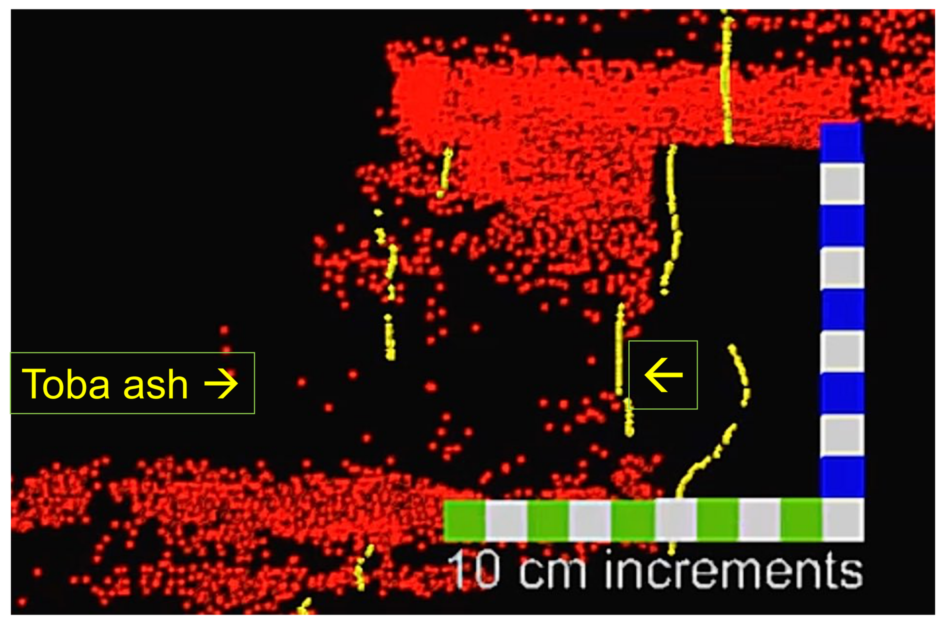

Fig. 8. Piece plots of stone artifacts in Pinnacle Point 5-6 (Smith et al. 2018, *Nature* 555, supplemental video 4). Toba ash first appears at the base of the aeolian Conrad Sands, during a period with few stone artifacts. Position of ash based on Smith et al. 2018, fig. 2, and extended data figs. 2c and 4.

Conclusions

- Modern humans likely occupied Qafzeh 119-128 ka, when the Levant was a tropical savanna. They are far older than ≤70 ka molecular dates of modern human dispersals.
- Malawi cores and Pinnacle Point levels with Toba ash appear to show GI-20s severe environmental degradation.
- This 2 kyr era of cold climate may have contributed to human population bottlenecks.

Notes

In response to comments and corrections suggested by Curtis Marean, two revisions have been made to the printed version of the poster presented at the Paleoanthropology Society meetings poster session on April 10 2018:

1. In figure 8, The position of the first Toba ash shards has been adjusted upward by ~15 cm. Few artifacts or bones occur in the overlying 30 cm of ALBS (Smith et al. 2018, figure 2), as shown in their supplemental videos 3 and 4.
2. The lithic industry found 30 cm above this occupation hiatus was described in this poster as the earliest representative of the Howiesons Poort (HP) lithic industry. Brown et al. 2012 describe this as "…an enduring advanced technology spanning 11,000 years." The Pinnacle Point Industry shares numerous features with the HP, including backed blade segments and notches. and The main justifications for excluding this assemblage from the HP seems to be that "SADBS segments are shorter and thinner than HP segments with no overlap in confidence intervals for width (p. 592);" and that notches are rare in the SADBS (p. 591). The authors note that this assemblage differs from the Klasies River HP, but is not significantly different from the HP at Montagu Cave (SI p. 9). Based on data provided by Brown et al. 2012, the SADBS assemblage could be considered the earliest phase of an enduring HP industry that, like other named lithic industries, has synchronic and diachronic variability.

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