GEOCHRONOLOGY

Age of Mexican ash with alleged 'footprints'

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A report of human footprints preserved in 40,000-year-old volcanic ash near Puebla, Mexico (http://www.royalsoc.ac.uk/exhibit.asp?id=3616&tip=1), was the subject of a press conference that stirred international media attention[1]. If the claims (www.mexicanfootprints.co.uk) of Gonzalez *et al.* are valid, prevailing theories about the timing of human migration into the Americas would need significant revision. Here we show by $^{40}Ar/^{39}Ar$ dating and corroborating palaeomagnetic data that the basaltic tuff on which the purported footprints are found is 1.30 ± 0.03 million years old. We conclude that either hominid migration into the Americas occurred very much earlier than previously believed, or that the features in question were not made by humans on recently erupted ash.

We report the results of $^{40}Ar/^{39}Ar$ dating and palaeomagnetic analysis of volcanic rock (tephra) from the surface carrying the indentations interpreted by Gonzalez *et al.* as footprints. The tephra is a moderately indurated olivine basalt lapilli tuff, in which the lapilli are cemented by a matrix composed of fine-grained claylike minerals that seem to be formed by marginal alteration of the lapilli. At the sampled locality in Toloquilla quarry (18° 55.402' N, 98° 009.375' W), this tuff occurs near the top of a stratigraphic succession of at least several metres of similar, rhythmically bedded tuff layers, 1–10 cm thick, which are exposed in small quarrying trenches and pits.

Nine samples (six comprising a single 2–4-mm lapillus, three comprising 3–11 such lapilli) were analysed by incremental laser-heating $^{40}Ar/^{39}Ar$ analysis. Isotopic data are available at www.bgc.org/renne/data/XalneneArData.xls. All the aliquots yielded mutually indistinguishable plateau ages ranging from 1.26 ± 0.10 to 1.47 ± 0.30 Myr (Fig. 1). A weighted mean of the nine plateau ages is 1.30 ± 0.03 (2σ) Myr.

The palaeomagnetic analysis (Fig. 2) reveals two components of essentially opposite polarity, a reverse component held by magnetite within the lapilli and an antipodal normal component held by goethite within the claylike matrix. The sample is azimuthally unoriented but the stratigraphic top and bottom are known. The reverse polarity component held by the tuff is thermoremanent, which strongly suggests that the tuff pre-dates the Brunhes/Matuyama geomagnetic polarity transition at about 790 kyr (ref. 2). A reverse polarity is consistent with magnetization acquired during chron C1r.2r, between 1.07 and 1.77 Myr (ref. 3), as indicated by the $^{40}Ar/^{39}Ar$ data. Because only the *in situ* top of the sample is known, the declination is arbitrary but the inclination (−32.1°) is meaningful and compares favourably with that (−33.4°) expected from a reversed geocentric axial dipole at this latitude.

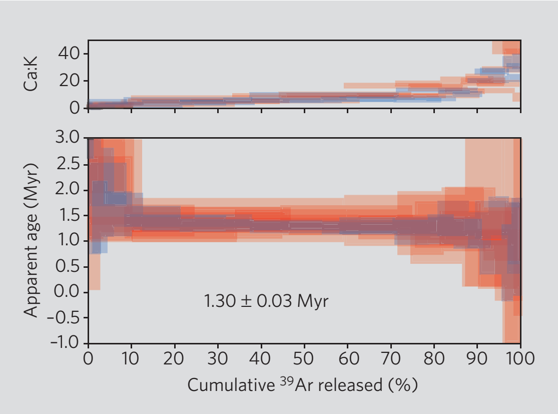

Figure 1 | Analysis of Xalnene ash samples from central Mexico. Top, calcium:potassium spectra show effects of degassing calcic minerals (clinopyroxene and plagioclase cores) at increasing temperature. Bottom, age spectra for nine samples, degassed in 5–13 steps with a carbon dioxide laser, are superimposed and shown with the weighted mean of nine plateau ages determined in each of the individual experiments. Ages are reported relative to the 1.194-Myr Alder Creek sanidine standard[6]. Single lapilli samples are shown in red, multi-lapilli samples in blue.

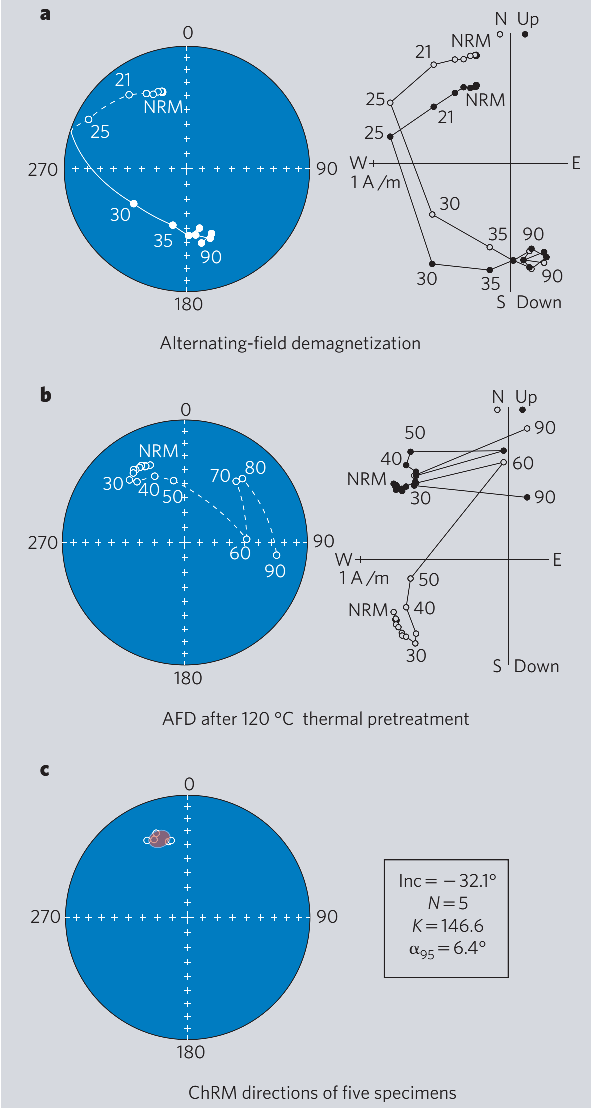

Figure 2 | Equal area and orthogonal demagnetization diagrams for a specimen of volume 16 cm³. a, Only alternating-field demagnetization (AFD) used; and **b,** AFD used after a 30-min demagnetization step at 120 °C. The heating step removes a secondary component due to goethite (Néel temperature, 120 °C; ref. 7). NRM, natural remanent magnetization. **c,** Reversed components from five such samples were determined using least-squares methods[8] and combined as a fisherian characteristic direction (ChRM) with the confidence ellipse shown. *K*, concentration parameter; α_{95}, 95% confidence interval.

The clustering of directions from the multi-lapilli specimens indicates that the lapilli were emplaced hot, above the blocking temperature of their constituent titanomagnetite grains, and have not been disturbed since emplacement. If the lapilli in the sample were derived by erosion of pre-existing older tephra, their age could substantially pre-date deposition. This possibility can be ruled out by the homogeneous textural, compositional and geochronological characteristics of the lapilli, paucity of extraneous volcanic clasts, absence of mechanical abrasion features, lack of soil development or sedimentary horizons within the Xalnene tuff sequence, and palaeomagnetic evidence for hot emplacement.

If the markings on the exposed surface of the tuff are human footprints recorded soon after its eruption, the obvious implication is that they are 1.3 million years old. This would be truly extraordinary as such antiquity pre-dates even the most speculative credible inferences about the first known appearance of *Homo sapiens* in the western hemisphere by more than a million years. Indeed, the Xalnene tuff pre-dates the first known appearance of *H. sapiens* (in Africa[4,5]) by more than a million years. If the markings are hominid footprints, they would be most likely to have been made by a hominid that existed before *H. sapiens*, and we consider such a possibility to be extremely remote. We conclude that the identification of any of these features as syn-depositional hominid footprints is erroneous.

Paul R. Renne*†, Joshua M. Feinberg†, Michael R. Waters‡, Joaquin Arroyo-Cabrales§, Patricia Ochoa-Castillo||, Mario Perez-Campa¶, Kim B. Knight†
*Berkeley Geochronology Center, Berkeley, California 94709, USA
e-mail:prenne@bgc.org
†Department of Earth and Planetary Science, University of California, Berkeley, California 94720, USA
‡Departments of Anthropology and Geography, and Center for the Study of the First Americans, Texas A&M University, College Station, Texas 77843-4352, USA
§Laboratório de Arqueozoología, Subdirección de Laboratórios y Apoyo Académico, Instituto Nacionál de Antropología e Historia, CP 06060, México
||Subdirección de Arqueología, Museo Nacional de Antropología, Reforma y Gandhi s/n, CP 11560, México
¶Proyecto Cuicuilco, Instituto Nacionál de Antropología e Historia, CP 06700, México

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