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Oldest human footprints dated by Ar/Ar

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ABSTRACT

Fossilized human trackways are extremely rare in the geologic record. These bear indirect but invaluable testimony of human/hominid locomotion in open air settings and can provide critical information on biomechanical changes relating to bipedalism evolution throughout the primitive human lineage. Among these, the "Devil's footsteps" represent one of the best preserved human footprints suite recovered so far in a Pleistocene volcanic ash of the Roccamonfina volcano (southern Italy). Until recently, the age of these footprints remained speculative and indirectly correlated with a loosely dated caldera-forming eruption that produced the Brown Leucitic Tuff. Despite extensive hydrothermal alteration of the pyroclastic deposit and variable contamination with excess ^{40}Ar, detailed and selective $^{40}Ar/^{39}Ar$ laser probe analysis of single leucite crystals recovered from the ash deposit shows that the pyroclastic layer and the footprints are 345±6 kyr old (1σ), confirming for the first time that these are the oldest human trackways ever dated, and that they were presumably left by the modern human predecessor, *Homo heidelbergensis*, close to Climatic Termination IV.

1. Introduction

Records of past human or hominid activity relating to locomotion are extremely rare in nature. These are occasionally found as footprints made in soft sediments that require unusual circumstances to be preserved from erosion or weathering agents. Whereas a number of human and hominid footprints have been reported from naturally protected cave habitats (Ambert et al., 2000; Onac et al., 2005), these are generally not preserved in subaerial conditions. These include, most notably, the hominid footprints discovered in the 3.5 Ma old Laetoli ash bed in Tanzania (Leakey and Hay, 1979), the controversial purported "footprints" found in the Xalnene ash in Mexico (Renne et al., 2005; Gonzalez et al., 2006), the Pleistocene human footprints discovered at Langebaan, South Africa (Roberts and Berger, 1997), the so-called "Devil's footsteps" recently described on the slopes of the Quaternary Roccamonfina volcano, southern Italy (Mietto et al., 2003), and the Pleistocene human footprints from Willandra Lakes, Australia (Webb et al., 2006).

Such trackways fossilized in indurated paleosoils, sediments or ash beds bear indirect but invaluable testimony of site occupation and human/hominid locomotion in open air settings. Their study can provide critical information on the evolution of functional anatomy relating to bipedalism (height, weight, and gait), and locomotor adaption to skeletal gracilization combined with endurance walking and running characteristic of modern humans (Day and Wickens, 1980; Berge et al., 2006). Occasionally, these tracks can tell us how their makers behaved in their habitat (Webb et al., 2006) or when faced with unusual circumstances, like volcanic eruptions (Mietto et al., 2003), with far-reaching implications in terms of hominid ecology and/or decision-making (cognitive) processes that are not implicit in osteological studies. When the preservation of such footprints occurs in datable ash beds, this provides the still more exceptional opportunity of placing them in the chronology of human evolution, occasionally even challenging their interpretation as true footprints (Renne et al., 2005).

2. The Devil's footsteps

The Devil's footsteps are found in a Pleistocene volcanic ash of the Roccamonfina volcano. Roccamonfina is a stratovolcano located north of the Campanian plain (Fig. 1) that is mainly composed of leucite-bearing, High-K Series (HKS) lavas and tephra (Peccerillo, 2005). The volcano formed in two main, petrographically distinct stages: the 550–375 ka leucite-bearing (HKS) Stage I that built the main volcanic cone, followed by the 317–96 ka leucite-free low-K series (LKS) Stage II during which parasitic vents mostly formed. An intervening phase of mixed HKS–LKS volcanism occurred between 376–323 ka BP (Giannetti and De Casa, 2000; Giannetti, 2001). A major ignimbrite-forming eruption (the Brown Leucitic Tuff eruption) occurred during this period as a result of the collapse of the central and northern calderas (Luhr and Giannetti, 1987). The pyroclastic activity resumed later on with a sequence of trachytic ash flows and surges that

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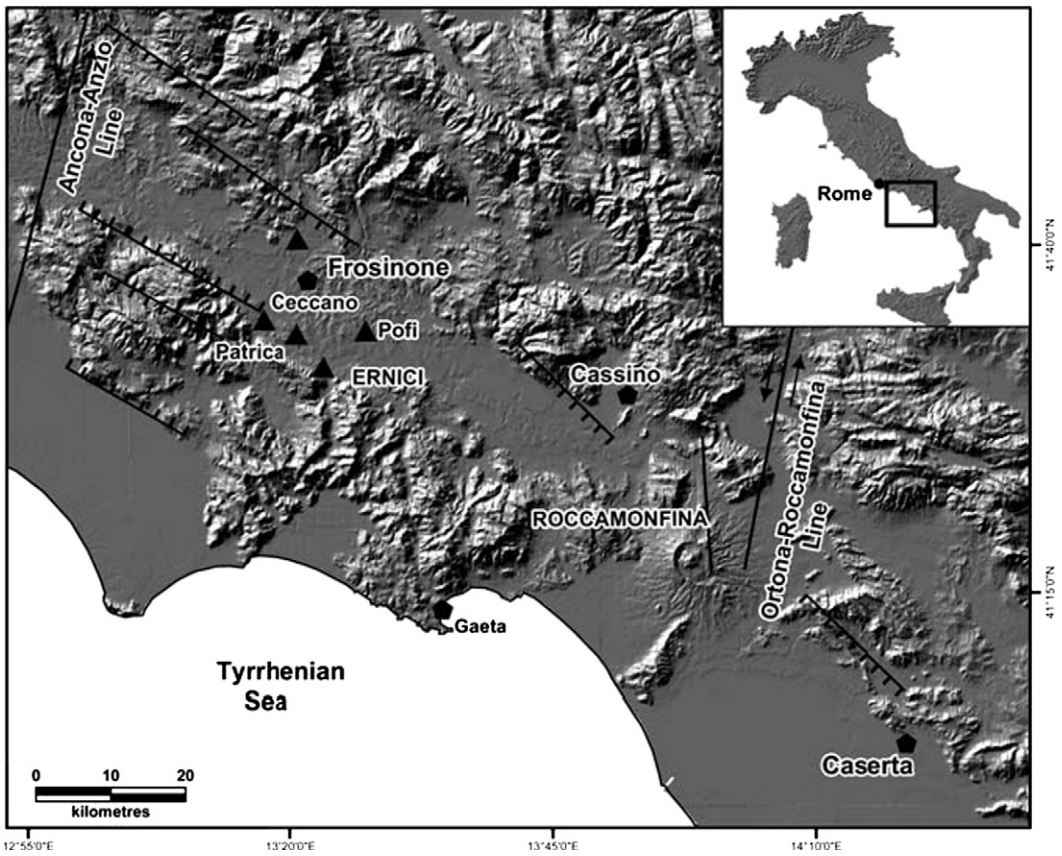

Fig. 1. Shaded-topography rendering map of the northern Campanian plain showing the location of the Roccamonfina stratovolcano in Southern Italy (from Peccerillo, 2005).

culminated with the eruption of the White Trachytic Tuff (WTT) during the 317–230 ka interval (Giannetti and Luhr, 1983). The postcollapse caldera activity then ended with the formation of terminal intracaldera lava domes at about 100 ka that were later blanketed by the Campanian Ignimbrite (~40 ka).

The Devil's footsteps were recently brought to the attention of the scientific community by Mietto et al. (2003) who described one of the most detailed and best preserved footprint tracks ever found in a pyroclastic layer mantling a steep-sided slope of Roccamonfina and ascribed to the Middle Pleistocene Brown Leucitic Tuff. The footprints consist of at least three distinct trackways totalling up to 56 footprints. These are narrow with an average pace of 60 cm and a stride of 120 cm. Based on the mean footprint length (20 cm) and width (10 cm), the track makers were probably no more than 1.35 m tall (Mietto et al., 2003). Detailed analysis of the trackways stride and pattern indicates that the track makers had a fully bipedal and free-standing gait, occasionally using their hands or adopting a zig-zag path to negotiate steep surfaces in their descent (Mietto et al., 2003). The depth and shape of the footprints indicate that they were impressed in a freshly deposited, soft but cohesive, volcanic ash that was still loose and unwelded during impression (Fig. 2).

The preservation of the ash layer on a steep-sided slope (>50°) coupled with the lack of gullying and/or droplet impact features indicate that the ash layer and the foot impressions were subsequently consolidated in a matter of days to a few weeks, or that they were capped by a subsequent protective volcanic layer very soon after deposition. A similar conclusion was derived from the mineralogical study of secondary zeolitization at the footprint site indicating that lithification of the ash layer occurred shortly after deposition (Cappelletti et al., 2006). These are concurrent evidence that the footprint makers probably witnessed the Brown Leucitic Tuff eruption

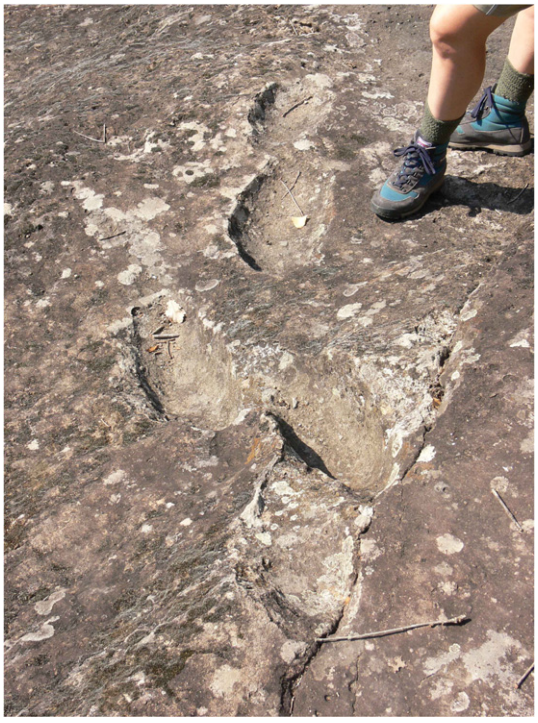

Fig. 2. Photograph of the first five footsteps of a long descending trackway made on an indurated ash deposit on the slopes of the Quaternary Roccamonfina volcano, southern Italy. This fossil trackway was made by the modern human predecessor, *Homo heidelbergensis*, 345 kyr ago.