Historical Biology
An International Journal of Paleobiology

ISSN: 0891-2963 (Print) 1029-2381 (Online) Journal homepage: www.tandfonline.com/journals/ghbi20

The oldest plant fossils from Tenerife Island? The case of the Pliocene lava tree moulds from San Roque, La Laguna, Spain

C. A. Góis-Marques, M. C. Velasco-Flores , M.C. Martín-Luis & C. Castillo-Ruiz

To cite this article: C. A. Góis-Marques, M. C. Velasco-Flores , M.C. Martín-Luis & C. Castillo-Ruiz (21 May 2026): The oldest plant fossils from Tenerife Island? The case of the Pliocene lava tree moulds from San Roque, La Laguna, Spain, Historical Biology, DOI: 10.1080/08912963.2026.2666160

To link to this article: https://doi.org/10.1080/08912963.2026.2666160

Published online: 21 May 2026.

HISTORICAL BIOLOGY
https://doi.org/10.1080/08912963.2026.2666160

Taylor & Francis
by informa

BRIEF REPORT

OPEN ACCESS Check for updates

The oldest plant fossils from Tenerife Island? The case of the Pliocene lava tree moulds from San Roque, La Laguna, Spain

C. A. Góis-Marques [1,2,3,4], M. C. Velasco-Flores[5], M.C. Martín-Luis[5] and C. Castillo-Ruiz[5]

[1]Madeira Botanical Group (GBM), Faculdade de Ciências da Vida, Universidade da Madeira, Funchal, Portugal; [2]BIOPOLIS Program in Genomics, Biodiversity and Land Planning, CIBIO, Vairão, Portugal; [3]CIBIO, InBIO Laboratório Associado, Universidade dos Açores, Ponta Delgada, Portugal; [4]Instituto Dom Luiz (IDL), Laboratório Associado, Universidade de Lisboa, Lisboa, Portugal; [5]Departamento de Biología Animal, Edafología y Geología, Facultad de Ciencias, Universidad de La Laguna, Tenerife, Spain

ABSTRACT
Lava tree moulds are fossils found in association with basaltic (s.l.) lava flows worldwide and can provide interesting palaeoecological and volcanological data. In the volcanic Macaronesian Islands, these fossils are known since the 19th century but rarely mentioned in the literature, despite their potential to reveal the past presence of trees and forested ecosystems. One mention to plant moulds associated to the Anaga basalts was known, but further details were never published. Here, we describe and illustrate for the first time lava tree moulds preserved within the Pliocene Anaga shield volcano (4.89 to 3.95 Ma) a'a lava flow. The size and stem habit indicate that these belonged to phanerophytes, implying the presence of a forest ecosystem during the Pliocene of Tenerife. When compared to the palaeobotanical record of Tenerife Island, these fossils are, so far, the oldest known published plant fossils from this island. Unfortunately, due to total combustion of the wood, taxa identification is not possible. Despite this, the locality should be further assessed as a potential geosite or other form of conservation for the Canary Islands' palaeontological heritage. Further prospection in Mio-Pleistocene Anaga shield volcano will certainly yield new palaeobotanical data for Tenerife and the Canary Islands.

ARTICLE HISTORY
Received 28 February 2026
Accepted 18 April 2026

KEYWORDS
Lava flow; Macaronesia; oceanic island; palaeobotany; taphonomy; paleoforest

HANDLING EDITOR
Dr André Jasper, Programa de Pos-Graduacao em Ambiente e Desenvolvimento, Centro Universitario Univates, Lajeado, Brazil

Introduction

Volcanic activity is known to promote the formation of ideal taphonomical settings that can lead to plant fossilisation, especially when associated with pyroclastic deposits of explosive volcanism (e.g. Burnham & Spicer, 1986; Fritz, 1986; Lockley, 1990; Spicer, 1989, 1991). However, an unexpected place to search for plant fossils is within solidified lava flows. These, when flowing, present high temperatures (up to 1200°C) and possess a destructive force that seems almost incompatible with biota fossilisation (e.g. 2021 eruption in La Palma, Canary Islands; see Carracedo et al., 2022; Troll et al., 2024). Despite this first impression, in fact, low viscosity basaltic *s.l.* lava flows can interact with forested areas and engulf tree trunks and stems and fossilise them. These peculiar fossils are found worldwide (Lockwood & Williams, 1978; Bella & Gaál, 2007; Carveni et al., 2011; Bell & Williamson, 2016 and references therein), with a record at least since the Early Jurassic, although older records might exist (Bell & Williamson, 2016; Oh et al., 2024).

The interaction between lava flows and plants with woody trunks and stems can promote the fossilisation within lava flows as four main fossil diagenetic types (Bell & Williamson, 2016; Friedrich, 1968): (1) fossil trees: anatomically conserved tree trunks and stems preserved within lava flows as charcoalified or permineralised wood (e.g. Oh et al., 2024); (2) lava trees: upright, solidified, tube-shaped crusts created when lava solidifies around a tree, and as the lava flow subsides, it leaves behind a protruding structure (e.g. Moore & Richter, 1962; Lockwood & Williams, 1978, plate I); (3) lava tree moulds: horizontal to vertical cavities found in lava flows due to full combustion of tree trunks/stems (e.g. Bell & Williamson, 2016; Carveni et al., 2011); and (4) lava tree casts: formed when lava tree moulds are infilled by lava of the same or subsequent volcanic events (Bell & Williamson, 2016, fig 2a-d).

Depending on the geological age of the flow, size of the trunk/stem, heat resistance and oxygen availability, charcoal can be found or not associated with these structures. Furthermore, according to Lockwood and

CONTACT C. A. Góis-Marques c.goismarques@gmail.com Madeira Botanical Group (GBM), Faculdade de Ciências da Vida, Universidade da Madeira, Campus da Penteada, Funchal 9000-390, Portugal

Published online 21 May 2026

Williams (1978) and Bell and Williamson (2016), plant fossils preserved in lava flows are useful as they provide, among others, evidence for volcanic quiescence, the existence of lava flowing and respective lava flow directions, and can provide charcoal for geological dating recent lava flows (see Bell & Williamson, 2016 for a detailed discussion).

In the volcanic Macaronesian archipelagos (i.e. Azores, Madeira, Selvagens, Canary and Cabo Verde archipelagos), there is an interesting but poorly explored palaeobotanical record ranging from mega to mesofossils (e.g. Álvarez et al., 2019; Anderson et al., 2009; Castillo-Ruiz et al., 2019; García-Talavera et al., 1995; Góis-Marques et al., 2018, 2020, 2023; Góis-Marques, Martín-González, et al., 2025; Góis-Marques, Mitchell, et al., 2019; Góis-Marques, Rumsey, et al., 2025; Marrero, 2013; Suárez-Rodríguez, 2013; Vegas et al., 2013) to microfossils (e.g. Castilla-Beltrán et al., 2019, 2023; Martin-Ramos et al., 2025; de Nascimento et al., 2009; Nogué et al., 2013). Particularly, lava trees and lava tree moulds are reported for the Azores and the Canary archipelagos, but their volcanostratigraphy and palaeobotanical importance are seldom discussed in detail (Bell & Williamson, 2016; Góis-Marques, de Nascimento, et al., 2019). Briefly, in the Azores, these are noted in Quaternary lava flows at São Miguel (Hyde, 1951), Terceira (Góis-Marques, de Nascimento, et al., 2019), Pico (Forjaz et al., 1970; França, 2002), Faial (Forjaz, 2008), São Jorge (Forjaz et al., 1970) and Graciosa Islands (Prieto et al., 2007). In the Canary Islands, charcoal, lava tree moulds and lava trees are known in Pleistocene and Holocene lava flows from El Hierro (e.g. Becerril et al., 2016; Martín-González et al., 2019; Risica et al., 2022), La Palma (e.g. Chicharro Fermín, 2022; Guillou et al., 1998), Gran Canaria (e.g. Kissel et al., 2015; Rodríguez-González, 2009; Rodriguez-Gonzalez et al., 2009; Troll et al., 2019) and Tenerife (e.g. Boulesteix et al., 2012; Carracedo, 2013; Fritsch, 1864; Fritsch & Reiss, 1868; Kissel et al., 2015). Interestingly, in the Canary Islands, lava tree moulds are also known to be used by birds as nesting or resting sites, especially by rock-dwelling raptors (F. Siverio, personal communication).

Overall, in Tenerife Island, published palaeobotanical accounts are still scarce (e.g. Álvarez et al., 2019; Bravo, 1962; Castillo-Ruiz et al., 2019; de Nascimento et al., 2009; Garcia-Talavera et al., 1989; Velasco-Flores et al., 2026), despite the existence of a palaeobotanical record (see Anderson et al., 2009, supporting information appendix S1). Remarkably, García-Talavera et al. (1995) and later Navarro et al. (2012) briefly state the existence of plant fossils associated to the basalts of the Series I Anaga. However, the exact location, stratigraphy and illustration of such fossils were, as far as is known, never published.

In this paper, we aim to describe, illustrate and frame stratigraphically lava tree moulds recently found by serendipity in San Roque, La Laguna (Tenerife Island), within the Anaga shield volcano, and discuss their palaeoecological implications, compare them to the Canary Island fossil record and call attention to the needed conservation of this new palaeobotanical site.

Brief geological background

The Canary Archipelago is located in the eastern central Atlantic Ocean within the NW sector of the Nubian tectonic plate, with the closest island (Fuerteventura) *ca.* 100 km of the SW Morocco coast. The archipelago is composed of eight islands, namely, El Hierro, La Palma, La Gomera, Tenerife, Gran Canaria, Fuerteventura, Lanzarote and La Graciosa (Figure 1A). The volcanic origin of this archipelago is currently best understood, as the volcanic manifestation of a hot spot track with a ca. NE–SW trend (Figure 1A): Fuerteventura and Lanzarote (ca. 24 Ma), Gran Canaria (14.6 Ma), Tenerife (11.9 Ma), La Gomera (9.4 Ma), La Palma (1.7 Ma) and El Hierro (1.1 Ma) (Carracedo & Troll, 2016; but see; Anguita et al., 2025 for a discussion of an alternative model).

The Tenerife Island is approximated triangular in shape, 84 km long and 50 km wide, with an area of *ca.* 2034 km^2 and the highest peak, the Teide at 3718 m above sea level (a.s.l.). According to Carracedo and Troll (2016), the volcano-stratigraphy of Tenerife Island can be summarised into two main stages. The first stage corresponds to the development of three subaerial Mio-Pliocene shield volcanoes: a Miocene Central shield volcano with 11.9–8.9 Ma, and two lateral shield volcanoes, the Teno with 6.4–5.1 Ma and Anaga with 4.89–3.95 Ma (Figure 1B; Guillou et al., 2004). The second stage corresponds to a rejuvenation with the Las Cañadas Volcano 3.5–0.169 Ma, the Teide Volcanic Complex, rift volcanism and associated lateral collapses (see Carracedo & Troll, 2016 for a detailed account).

Material and methods

Recent palaeobotanical prospection of Tenerife Island, focusing on sites mentioned in the literature, led us to prospect the San Roque locality, at the city of La Laguna. This locality is mentioned by José de Viera y Clavijo (1731–1813) in his posthumous work '*Diccionario de Historia Natural de las Islas Canarias*' (Viera y Clavijo,

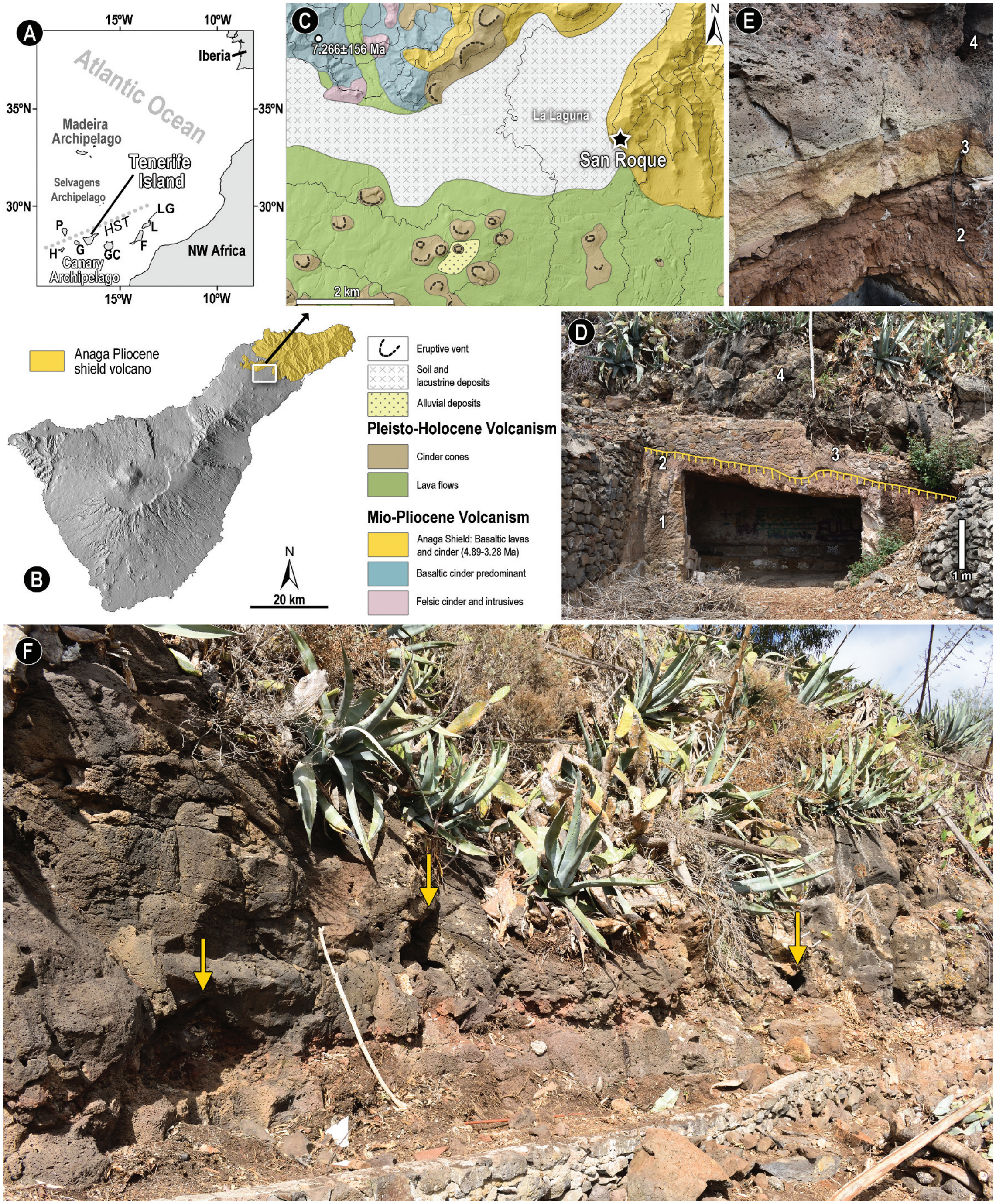

Figure 1. Geographical location of the Canary Archipelago and geological setting of the San Roque lava tree moulds. A, location of the Canary Archipelago and the Tenerife Island: L: Lanzarote; F: Fuerteventura; GC: Gran Canaria; G: La Gomera; P: La Palma; H: El Hierro; HST: hot spot track; B, Tenerife island and the location of the Anaga Pliocene shield volcano based on GEODE, Mapa Geológico Digital continuo de España (Bellido Mulas et al., 2007) and Guillou et al. (2004); C, geological map of La Laguna area, adapted from Carracedo et al. (2011, Supplemental material: Geological map: the northeast rift zone of Tenerife); D, San Roque outcrop, 1: lapilli tuff; 2: palaeosol; 3: lapilli tuff; 4: a'a lava flow with a basal breccia. The lava tree moulds are found in the first metre of the flow above or in contact with the basal breccia; E, lateral variation of the same outcrop shown in D. Note the absence of the basal breccia in the lava flow (no.4); F, Overview of San Roque outcrop with the lava tree tubes (yellow arrows).

1869, 1968) where he states having possessed a petrified '*cárdon*' (possibly a *Euphorbia canariensis* L. fossil) collected in this locality. Due to a recent clearing of the invasive plants (mainly *Opuntia* (L.) Mill and *Agave* L.), several lava flows outcrops became visible and accessible to be studied in detail. Circular hollows and tubes associated with a basaltic s.l. lava flow were detected by one of us (CCR) on the 7 September 2024. The lava flow was

Table 1. Field measurements of the San Roque lava tree moulds.

Lava tree mould	Diameter	Maximum measured depth
1	28 × 40 cm	258 cm
2	3 cm	22 cm
3	11 × 9 cm	50 cm
4	7 cm	3 cm
5	15 × 19 cm	65 cm
5a	5 × 6 cm	21 cm
6a	17 × 12 cm	105 cm
6b	10 × 11 cm	110 cm
6c	15 × 13 cm	140 cm
7	1.5 × 1 cm	19 cm
8	4 × 3.5 cm	62 cm
9a-9 g	ca. 1 cm	Not measured
10	32 cm	89 cm
11	9.3 × 8.7	42 cm

then further prospected for the presence of more hollow tubes. The detected tubes were photographed using a Nikon D5500. The camera flash was used to obtain a higher depth of field to illustrate the interior walls of the larger tubes. Diameter (if the mould was circular-shaped in cross-section) or height and width (if it was oval shaped in cross-section) were obtained using a measuring tape. The minimum depth of the moulds was measured using a measuring tape attached to wooden stick. Tubes were compared with the reference works on lava tree tubes (e.g. Bell & Williamson, 2016; Bella & Gaál, 2007; Honda, 1999, 2016; Lockwood & Williams, 1978).

Results

The prospection of the lava flow outcrops revealed the presence 18 lava tree tubes of variable sizes (Table 1), visible along ca. 20 m of the base of an a'a lava flow near the San Roque viewpoint (GPS coordinates: 28° 29.190′N, 16° 18.596′W; Figure 1C).

Local volcano-stratigraphy (Figure 1D,E), from the base to the top: (1) yellowish (altered) lapilli-tuff with >2.4 m thickness (Figure 1D, no. 1); (2) reddish baked palaeosol with ca. 0.5 m, developed on top of the lappili-tuff (Figure 1D, no. 2), displaying prismatic structures and whitish root traces (Figure 1D, no. 2); (3) altered lapilli tuff- ca. 0.5 m; (4) basaltic a'a lava flow of variable thickness, locally presenting a basal breccia presenting lava tree moulds.

Lava trees moulds are horizontal to sub-horizontal, mostly exposed in cross section and with an approximate orientation of W-SW (Figure 2A-J). The largest specimen (Figure 2A-B) is in cross section 28 × 40 cm and up to 258 cm depth (minimum measured depth) and the smallest, ca. 1 cm in cross section (see Table 1). Externally, the lava trees present rims formed by the lava engulfing the tree trunks/stems. The internal wall of the lava trees moulds, especially the larger ones, present a ribbed to ropy texture (e.g. Figure 2B,E,G).

Discussion

The cylindrical hollow tubes found in San Roque can be interpreted as lava tree moulds due to the local volcanostratigraphy, the external, and internal morphology of the tubes and their spatial relationship. First, as pointed by Bell and Williamson (2016), lava tree moulds are found associated with lava flows that flowed into a palaeoforest and its respective palaeosol. This is the case with the fossiliferous lava flows of San Roque, where a well-developed palaeosol with root remains (Figure 1D-E) is present, and is overlain by a lapilli tuff, possibly from the same volcanic eruption that produced the lava flow that engulfed the trees and preserved them as lava tree moulds. Furthermore, in cross section, some of the tubes exhibit external rims formed by lava flowing and engulfing the stems/trunk's trees (see Figure 2). In addition, internal walls of the moulds display a ribbed to ropy texture (e.g. Figure 2B,E,G). Similar features are found in lava tree moulds elsewhere (see Bella & Gaál, 2007; Honda, 2016), although the tubes found in San Roque present more frequently an interior ropy texture. The origin of this texture is possibly linked to the interaction of gases released by the burning tree engulfed by the lava and the surface tension of the mould when still hot and plastic (see 'confinenment gas diffusion type' in Honda, 1999, 2016). Finally, the lava tubes 6a, b and c (Figure 2D,E) present an unusual characteristic of three diverging tubes, suggesting that these moulds are the hollows left by branches of the same parent tree/shrub.

García-Talavera et al. (1995) were the first to briefly mention the existence of plant fossils within the basalt flows from the Pliocene of Anaga (Serie I), providing a general age of 4–5 Ma for these. However, until now, no further information, has ever been published on

Figure 2. Lava tree moulds found in the Pliocene lava flow at San Roque, La Laguna, Tenerife Island. A–F, larger lava tree moulds: A, Mould no. 1 with a diameter of 40 cm and up to 258 cm depth; B, detail of the interior wall of the mould no. 1 displaying the typical ribbed surface; C, moulds no. 4 and no. 5; D, moulds no. 6a, b and c, with preserved moulds of apparently diverging branches of a single tree; E, detail of 6a and 6b displaying the typical ribbed surface; F–J, smaller lava tree moulds: F, mould no. 10; G, mould no. 2; H, mould no. 3; I, mould no. 9a-f; J, mould no. 8. Note: hammer in A and D ca. 30 cm; Coin ø in G, 2.325 cm.

these fossils. According to the geological map of Tenerife (MAGNA 50: Araña et al., 1978) the fossiliferous lava flows that crop out in the San Roque area belong to the upper Serie I (β^{13} basaltic lava flows), Pliocene in age, and are part of the Anaga shield volcanism. Further geochronological data have constrained the age of the Anaga shield volcano to 4.89–3.95 Ma (Carracedo et al., 2011; Guillou et al., 2004). When compared to the available palaeobotanical data, the San Roque lava tree moulds, with an age of 4.89–3.95 Ma, are indeed the oldest plant fossils found in Tenerife Island, as already mentioned in García-Talavera et al. (1995). Published deep-time palaeobotanical accounts for the Canary Islands are still sparse and infrequent (e.g. Castillo-Ruiz et al., 2019; Góis-Marques, Martín-González, et al., 2025; Martín-González et al., 2025). For Tenerife Island, these are even rarer, with fossils (micro to macro in size) studied ranging from mid-Pleistocene to present (Álvarez et al., 2019; Bravo, 1962; Castillo-Ruiz et al., 2019; de Nascimento et al., 2009; Garcia-Talavera et al., 1989). Until now, the oldest plant fossils for Tenerife were the undescribed 1.69 Ma plant moulds, found associated with El Pris ignimbrite deposits (Anderson et al., 2009, and references therein). The San Roque lava tree moulds now described are the empirical confirmation of the Pliocene plant fossils associated with the Anaga shield volcano, as already stated by García-Talavera et al. (1995). Furthermore, and according to the review presented by Bell and Williamson (2016), description of lava trees/lava tree moulds worldwide are rare for the Neogene (i.e. 23.04–2.58 Ma), making this insular evidence an important addition to the scarce worldwide record.

Due to the total combustion of the wood, resulting in a lack of charcoal, and the absence of other biological characters on the interior walls of the moulds, identification of taxa or inference of the vegetation growing in the site is not possible. Still, the now reported lava tree moulds are a direct palaeoecological indicator of the presence of phanerophytes and possibly a forest ecosystem, already growing in the area during the Pliocene and that were engulfed and preserved within a basaltic lava flow. Within the Canary Islands, so far, the best indication of tree fossils of similar age, are those found within the Pliocene of Gran Canaria (e.g. Anderson et al., 2009; Kunkel, 1976; Marrero, 2013; Schmincke, 1967, 1968), although detailed xylological studies of these fossilised trees have never been published.

The San Roque lava tree moulds reveal an interesting palaeontological, taphonomical and volcanological history of Tenerife Island, being located in an easily accessible and privileged location near the historic centre of the city of La Laguna. Yet, this makes these fossils vulnerable to any human intervention (see Góis-Marques, Elias, et al., 2019 for an example of a destructive intervention). Given the criteria proposed by Castillo et al. (2000) to evaluate the Canarian palaeontological heritage, the San Roque locality and the lava tree moulds should be immediately protected. Further evaluation is needed to determine if the San Roque lava tree moulds can become a long-term protected area or even as an official protected geosite, providing awareness for the Canarian palaeontological heritage (e.g. Castillo et al., 2000; Castillo, Casillas, et al., 2001; Castillo, Martín González, et al., 2001; Esther Martín et al., 2009; Martín-González et al., 2019, 2025), and specifically calling attention to the still poorly studied palaeobotanical record of Tenerife and the Canary Islands.

Conclusion

As pointed out by Bell and Williamson (2016), the discovery of Neogene lava tree moulds is a serendipitous event, as exposed and accessible outcrops of basaltic s.l. lava flows are seldom searched for fossils. The now reported San Roque lava tree moulds are, so far, the oldest plant fossils found in Tenerife Island, with an age of 4.89 to 3.95 Ma (Pliocene). Despite these fossils being unidentifiable, they represent an interesting piece of the palaeobiological and volcanological history of the Tenerife Island. They provide direct evidence of the Pliocene flora interacting with a subaerial lava flow that build part of the Anaga shield volcano. This makes them an interesting new palaeontological site in the Canary Islands, thus warranting urgent conservation. Further focused prospection in the Pliocene Anaga shield volcano, and in the older parts of the island such as the Mio-Pliocene Teno and Roque del Conde shield volcanoes, will certainly yield new palaeobotanical data for Tenerife and the Canary Islands.

Acknowledgments

We would like to thank Pedro Correia (UTAD, Portugal) and two anonymous reviewers for their comments, which improved an earlier version of this manuscript and Felipe Siverio (Canary Islands' Ornithology and Natural History Group) for sharing data on raptors using tree lava tubes on Canary Islands. CAG-M would like to acknowledge financial support from Fundação para a Ciência e Tecnologia (FCT, Portugal) Individual Call to Scientific Employment Stimulus contract 2022.00017.CEECIND (https://doi.org/10.54499/2022.00017.CEECIND/CP1730/CT0001), the project UIDB/50027/2020 and to the 'Plan de incentivación de la actividad investidadora 2024' from the 'Vicerrectorado de Investigación y Transferencia', University of La Laguna. This work was also supported by the project "De la extirpación hacia nuevas oportunidades: análisis espaciotemporal comparativo y modelización multiescenario en base a variables climáticas futuras", PID2024-157622NB-I00, financed by Ministerio de Ciencia e innovación (MICINN).

Author contributions

CRediT: **C. A. Góis-Marques:** Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing; **M. C. Velasco-Flores:** Investigation, Writing – review & editing; **M.C. Martín-Luis:** Investigation, Methodology, Supervision, Writing – review & editing; **C. Castillo-Ruiz:** Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Writing – review & editing.

Disclosure statement

The author Carlos A. Góis-Marques (CAG-M) is an associate editor of the journal. CAG-M had no involvement in the peer review or editorial decision-making process for this manuscript, which was handled independently by other members of the editorial team. The co-authors declare no conflicts of interest.

Funding

Fundação para aCiência eTecnologia (FCT, Portugal) Individual Call to Scientific Employment Stimulus contract 2022.00017.CEECIND (https://doi.org/10.54499/2022.00017.CEECIND/CP1730/CT0001), the project UIDB/50027/2020 and to the 'Plan de incentivación de la actividad investidadora 2024' from the 'Vicerrectorado de Investigación yTransferencia', University of La Laguna. This work was also supported by the project "De la extirpación hacia nuevas oportunidades: análisis espaciotemporal comparativo ymodelización multiescenario en base avariables climáticas futuras", PID2024-157622NB-I00, financed by Ministerio de Ciencia einnovación (MICINN).

ORCID

C. A. Góis-Marques http://orcid.org/0000-0002-0255-7641

References

Álvarez, A., Coello-Bravo, J. J., Gil, J., Siverio, F., González-Rodríguez, A., & Martín-González, E. (2019). Fósiles de vegetales en depósitos carbonáticos de la Rambla de Castro (norte de Tenerife, islas Canarias). *Vieraea Folia Scientiarum Biologicarum Canariensium*, *46*, 171–202. https://doi.org/10.31939/vieraea.2019.46.tomo01.09

Anderson, C. L., Channing, A., & Zamuner, A. B. (2009). Life, death and fossilization on Gran Canaria – implications for Macaronesian biogeography and molecular dating. *Journal of Biogeography*, *36*(12), 2189–2201. https://doi.org/10.1111/j.1365-2699.2009.02222.x

Anguita, F., Fernández, C., Márquez, Á., León, R., Casillas, R. (2025). The Canary hotspot revisited: Refutation of the Hawaii paradigm and an alternative, plate-based hypothesis. *Earth-Science Reviews*, *261*, 105038. https://doi.org/10.1016/j.earscirev.2024.105038

Araña, V., Carracedo, J. C., Caraballo, J. M., Fúster, J. M., & Cacho, L. G. (1978). *Mapa geológico y Memoria de la Hoja nº 1.104-1.105, I-IV (Santa Cruz de Tenerife). Mapa Geológico de España E. 1:25.000. Segunda Serie, Primeira edición*. Instituto Geologico y Minero de España.

Becerril, L., Ubide, T., Sudo, M., Martí, J., Galindo, I., Galé, C., Morales, J. M., Yepes, J., & Lago, M. (2016). Geochronological constraints on the evolution of El Hierro (Canary Islands). *Journal of African Earth Sciences*, *113*, 88–94. https://doi.org/10.1016/j.jafrearsci.2015.10.012

Bell, B. R., & Williamson, I. T. (2016). Fossil trees, tree moulds and tree casts in the Palaeocene Mull Lava Field, NW Scotland: Context, formation and implications for lava emplacement. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, *107*(1), 53–71. https://doi.org/10.1017/S175569101700007X

Bella, P., & Gaál, Ľ. (2007). Tree mould caves within the framework of cave genetic classification. *Nature Conservation*, *63*, 7–11.

Bellido Mulas, F., Gómez Sainz de Aja, J. A., & Barrera, J. L. (2007). *Mapa Geológico Digital continuo E. 1:25.000, Zona Canarias - Tenerife. (Zona-2913), GEODE*. Mapa Geológico Digital continuo de España Instituto Geológico y Minero de España.

Boulesteix, T., Hildenbrand, A., Gillot, P.-Y., & Soler, V. (2012). Eruptive response of oceanic islands to giant landslides: New insights from the geomorphologic evolution of the Teide–Pico Viejo volcanic complex (Tenerife, Canary). *Geomorphology*, *138*(1), 61–73. https://doi.org/10.1016/j.geomorph.2011.08.025

Bravo, T. (1962). El circo de Las Cañadas y sus dependencias. *Boletín de La Real Sociedad Española de Historia Natural*, *60*, 93–108.

Burnham, R. J., & Spicer, R. A. (1986). Forest litter preserved by volcanic activity at El Chichon, Mexico; a potentially accurate record of the pre-eruption vegetation. *PALAIOS*, *1* (2), 158. https://doi.org/10.2307/3514509

Carracedo, J. C. (2013). The last 2 ky of eruptive activity of the teide volcanic complex: Features and trends. In J. C. Carracedo & V. R. Troll (Eds.), *Teide volcano: Geology and eruptions of a highly differentiated oceanic stratovolcano* (pp. 129–153). Springer.

Carracedo, J. C., Guillou, H., Nomade, S., Rodríguez-Badiola, E., Pérez-Torrado, F. J., Rodríguez-González, A., Paris, R., Troll, V. R., Wiesmaier, S., Delcamp, A., & Fernández-Turiel, J. L. (2011). Evolution of ocean-island rifts: The northeast rift zone of Tenerife, Canary Islands. *Geological Society of America Bulletin*, *123*(3–4), 562–584. https://doi.org/10.1130/B30119.1

Carracedo, J. C., & Troll, V. R. (2016). *The geology of the Canary Islands*. Elsevier.

Carracedo, J. C., Troll, V. R., Day, J. M. D., Geiger, H., Aulinas, M., Soler, V., Deegan, F. M., Perez-Torrado, F. J., Gisbert, G., Gazel, E., Rodriguez-Gonzalez, A., & Albert, H. (2022). The 2021 eruption of the Cumbre Vieja volcanic ridge on La Palma, Canary Islands. *Geology Today*, *38*(3), 94–107. https://doi.org/10.1111/gto.12388

Carveni, P., Mele, G., Benfatto, S., Imposa, S., & Salleo Puntillo, M. (2011). Lava trees and tree molds ("cannon stones") of Mt. Etna. *Bulletin of Volcanology*, *73*(6), 633–638. https://doi.org/10.1007/s00445-011-0446-3

Castilla-Beltrán, A., de Nascimento, L., Fernández-Palacios, J. M., Fonville, T., Whittaker, R. J., Edwards, M., & Nogué, S. (2019). Late Holocene environmental change and the anthropization of the highlands of Santo Antão Island, Cabo Verde. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *524*, 101–117. https://doi.org/10.1016/j.palaeo.2019.03.033

Castilla-Beltrán, A., Monteath, A., Jensen, B. J. L., Nascimento, L. D., María Fernández-Palacios, J., Strandberg, N., Edwards, M., & Nogué, S. (2023). Taming Fogo Island: Late-Holocene volcanism, natural fires and land use as recorded in a scoria-cone sediment sequence in Cabo Verde. *The Holocene*, *33*(4), 371–381. https://doi.org/10.1177/09596836221145442

Castillo, C., Casillas, R., Ahijado, A., Gutiérrez, M., & González, E. M. (2001). Síntesis Geológica y Paleontológica de la Isla de Fuerteventura: itinerarios científicos de las XIV jornadas de Paleontología. *Revista Española de Paleontología*, *10*(3), 59–80.

Castillo, C., González, E. M., & Hernández, Z. (2000). Criterios para la valoración del patrimonio paleontológico de Canarias. *Geotemas*, *1*(2), 305–308.

Castillo, C., Martín González, E., & Martín Oval, M. (2001). Valoración del patrimonio paleontológico de Canarias: Propuesta de puntos de especial interés paleontológico. *Revista española de paleontología Nº Extra*, *10*, 105–115.

Castillo-Ruiz, C., Castro-Rosa, J. R., González-Montelongo, C., & Santos-Guerra, A. (2019). Fossil-Lagerstätte de plantas en terrenos volcánicos. In B. Martínez-Navarro, P. Palmqvist, M. P. Espigares & S. Ros-Montoya (Eds.), *Libro de Resúmenes de las XXXV Jornadas de Paleontología* (pp. 55–58). Institut Català de Paleoecologia Humana y Evolució Social & Universidad de Málaga.

Chicharro Fermín, N. (2022). *IC6028: Moldes de troncos de pino en las lavas del San Juan de 1949*. Inventario Español de Lugares de Interés Geológico Instituto Geólogico y Minero de España.

de Nascimento, L., Willis, K. J., Fernández-Palacios, J. M., Criado, C., & Whittaker, R. J. (2009). The long-term ecology of the lost forests of La Laguna, Tenerife (Canary Islands). *Journal of Biogeography*, *36*(3), 499–514. https://doi.org/10.1111/j.1365-2699.2008.02012.x

Esther Martín, G., Carolina Castillo, R., & Francisco García-Talavera, C. (2009). Yacimientos paleontológicos de las islas Canarias declarados bienes de Interés Cultural. *Vieraea Folia scientiarum biologicarum canariensium*, *37* (Vieraea 37), 127–140. https://doi.org/10.31939/vieraea.2009.37.12

Forjaz, V. H. (2008). *Na rota dos vulcões da ilha do Faial*. OVGA–Observatório Vulcanológico e Geotérmico dos Açores.

Forjaz, V. H., Mojardino, J. L., & Fernandes, N. S. M. (1970). Contribuição para o estudo das jazidas fossilíferas das ilhas do Faial, Pico, S. Jorge e Terceira (Açores). *Comunicações dos Serviços Geologicos de Portugal Tomo*, *LIV*, 27–37.

França, Z. (2002). *Origem e Evolução Petrológica e Geoquímica do Vulcanismo da ilha do Pico, Açores*. Câmara municipal de São Roque do Pico.

Friedrich, W. L. (1968). Tertiäre Pflanzen im Basalt von Island. *Meddelelser fra Dansk Geologisk Forening*, *18*, 265–276.

Fritsch, K. W. G. V. (1864). Zur Geologie der Canaren. *Zeitschrift der Deuschen Gesellschaft*, *XVI Band*, 114–120.

Fritsch, K. W. G. V., & Reiss, W. (1868). *Geologische Beschreibung der Insel Tenerife: ein Beitrag zur Kenntniss vulkanischer Gebirge*. Wurster.

Fritz, W. J. (1986). Plant taphonomy in areas of explosive volcanism. In T. W. Broadhead (Ed.), *Notes for a short course: Studies in geology organized by R.A. Gastaldo, 07/19 ed.* (Vol. 15, pp. 1–9). University of Tennessee Department of Geological Sciences.

Garcia-Talavera, F., Gil, R. P., & Oval, M. M. (1989). *Catálogo-Inventario Yacimientos paleontológicos: Provincia de Santa Cruz de Tenerife*. Instituto de Estudios Canarios (C.E.C.E.L.).

García-Talavera, F., Sáchez-Pinto, L., & Socorro, S. (1995). Vegetales fósiles en el complejo traquítico-sienítico de Gran Canaria. *Revista de la Academia Canaria de Ciencias*, *VII*, 77–91.

Góis-Marques, C. A., de Nascimento, L., Fernández-Palacios, J. M., Madeira, J., & Menezes de Sequeira, M. (2023). Description and systematic affinity of flower and seed fossils of *Erica* sect. *Chlorocodon* (Ericaceae) from the early Pleistocene of Madeira Island, Portugal. *Taxon*, *72*(2), 375–392. https://doi.org/10.1002/tax.12881

Góis-Marques, C. A., de Nascimento, L., Menezes de Sequeira, M., Fernández-Palacios, J. M., & Madeira, J. (2019). The Quaternary plant fossil record from the volcanic Azores Archipelago (Portugal, North Atlantic Ocean): A review. *Historical Biology*, *31*(10), 1267–1283.

Góis-Marques, C. A., Elias, R. B., Steinbauer, M. J., de Nascimento, L., Fernández-Palacios, J. M., Menezes de Sequeira, M., & Madeira, J. (2019). The loss of a unique palaeobotanical site in Terceira Island within the Azores UNESCO global geopark (Portugal). *Geoheritage*, *11*(4), 1817–1825. https://doi.org/10.1007/s12371-019-00401-1

Góis-Marques, C. A., Madeira, J., & Menezes de Sequeira, M. (2018). Inventory and review of the Mio-Pleistocene São Jorge flora (Madeira Island, Portugal): Palaeoecological and biogeographical implications. *Journal of Systematic Palaeontology*, *16*(2), 159–177. https://doi.org/10.1080/14772019.2017.1282991

Góis-Marques, C. A., Martín-González, E., Postigo-Mijarra, J. M., Velasco-Flores, M. C., Castillo Ruiz, C., & Menezes de Sequeira, M. (2025). How old is the presence of the Canary Pine forests in the Canary Islands? *Journal of Biogeography*, *52*(3), 532–543. https://doi.org/10.1111/jbi.15059

Góis-Marques, C. A., Mitchell, R. L., de Nascimento, L., Fernández-Palacios, J. M., Madeira, J., & Menezes de Sequeira, M. (2019). *Eurya stigmosa* (Theaceae), a new and extinct record for the Calabrian stage of Madeira Island (Portugal): $^{40}Ar/^{39}Ar$ dating, palaeoecological and oceanic Island palaeobiogeographical implications. *Quaternary Science Reviews*, *206*, 129–140. https://doi.org/10.1016/j.quascirev.2019.01.008

Góis-Marques, C. A., Rubiales, J., de Nascimento, L., Menezes de Sequeira, M., Fernández-Palacios, J. M., & Madeira, J. (2020). Oceanic Island forests buried by Holocene (Meghalayan) explosive eruptions: Palaeobiodiversity in pre-anthropic volcanic charcoal from Faial Island (Azores, Portugal) and its palaeoecological implications. *Review of Palaeobotany and Palynology*, *273*, 104116. https://doi.org/10.1016/j.revpalbo.2019.104116

Góis-Marques, C. A., Rumsey, F. J., Madeira, J., & Menezes de Sequeira, M. (2025). In situ volcanically baked killarney fern fossils (Hymenophyllaceae) from the late Holocene of the Azores archipelago (Portugal). *Review of Palaeobotany and Palynology*, *334*, 1–10. https://doi.org/10.1016/j.revpalbo.2024.105254

Guillou, H., Carracedo, J. C., & Day, S. J. (1998). Dating of the Upper Pleistocene–Holocene volcanic activity of La Palma using the unspiked K–Ar technique. *Journal of Volcanology and Geothermal Research*, *86*(1–4), 137–149. https://doi.org/10.1016/S0377-0273(98)00074-2

Guillou, H., Carracedo, J. C., Paris, R., & Pérèz Torrado, F. J. (2004). Implications for the early shield-stage evolution of Tenerife from K/Ar ages and magnetic stratigraphy. *Earth and Planetary Science Letters*, *222*(2), 599–614. https://doi.org/10.1016/j.epsl.2004.03.012

Honda, T. (1999). Classification of lava tree molds with/witout remelted inner surface according to its formation process. In *Proceedings of the 9th international symposium on volcanospeleology, Catania*. International Union of Speleology.

Honda, T. (2016). The role of surface tension on the formation of lava stalactite and lava stalagmite. In *Proceedings of the 17th international vulcanspeleology symposium*. Hawaii, USA (pp. 47–53). Organising Committee of the 17th International Symposium on Vulcanospeleology for the Commission on Volcanic Caves, International Union of Speleology.

Hyde, H. P. T. (1951). Tree trunks preserved in a volcanic flow in the Northern Cameroons. *The American Journal of Science*, *249*(1), 72–77. https://doi.org/10.2475/ajs.249.1.72

Kissel, C., Laj, C., Rodriguez-Gonzalez, A., Perez-Torrado, F., Carracedo, J. C., & Wandres, C. (2015). Holocene geomagnetic field intensity variations: Contribution from the low latitude Canary Islands site. *Earth and Planetary Science Letters*, *430*, 178–190. https://doi.org/10.1016/j.epsl.2015.08.005

Kunkel, G. (1976). Biogeography and ecology in the Canary Islands. In J. Illies (Ed.), *Monographiae biologicae*, (p. 511). Junk.

Lockley, M. (1990). How volcanism affects the biostratigraphic record. In M. Lockley & A. Rice (Eds.), *Volcanism and fossil biotas geological society of America* (pp. 1–12). Geological Society of America.

Lockwood, J. P., & Williams, I. S. (1978). Lava trees and tree moulds as indicators of lava flow direction. *Geological Magazine*, *115*(1), 69–74. https://doi.org/10.1017/S0016756800041005

Marrero, Á. (2013). Aportaciones a la flora pliocena de la isla de Gran Canaria: avances a los estudios florísticos y paleoambientales. *Vieraea Folia scientiarum biologicarum canariensium*, *41*(Vieraea 41), 371–384. https://doi.org/10.31939/vieraea.2013.41.24

Martín-González, E., Coello-Bravo, J. J., Castillo, C., González-Rodríguez, A., Galindo, I., & Vegas, J. (2019). Revisión del patrimonio paleontológico del Geoparque Mundial de la UNESCO de El Hierro. *Geogaceta*, *65*, 11–14.

Martín-González, E., Cruzado-Caballero, P., Cadavid-Melero, E., Velasco-Flores, M. D. C., Aponte, M., Tagua, V. G., & Castillo, C. (2025). Fósiles conservados en islas de lava: estado actual del conocimiento del registro fósil de las Islas Canarias. *Memorias de la Real Sociedad Española de Historia Natural (Segunda Época)*, *18*, 81–104.

Martin-Ramos, P., Castilla-Beltrán, A., Davtian, N., Fernández-Palacios, J. M., Fernández-Palacios, E., Naranjo-Cigala, A., Nogué, S., Villanueva, J., Wilmshurst, J. M., & de Nascimento, L. (2025). Millennial-scale climatic variability and fire regimes and their impacts on vegetation in Gran Canaria since 28 cal ka BP. *Quaternary Science Reviews*, *369*, 109576. https://doi.org/10.1016/j.quascirev.2025.109576

Moore, J. G., & Richter, D. H. (1962). Lava tree molds of the September 1961 eruption, Kilauea Volcano, Hawaii. *Geological Society of America Bulletin*, *73*(9), 1153–1158. https://doi.org/10.1130/0016-7606(1962)73[1153:LTMOTS]2.0.CO;2

Navarro, F. P., Sánchez, Á. V., & Sánchez, L. G. (2012). *Tercer Inventario forestal nacional 1997-2007: La transformación Histórica del paisaje forestal en Canarias*. Ministerio de Agricultura, Alimentación y Medio Ambiente.

Nogué, S., de Nascimento, L., Fernández-Palacios, J. M., Whittaker, R. J., & Willis, K. J. (2013). The ancient forests of La Gomera, Canary Islands, and their sensitivity to environmental change. *The Journal of Ecology*, *101*(2), 368–377. https://doi.org/10.1111/1365-2745.12051

Oh, C., Woo, J., Philippe, M., Bomfleur, B., Kang, D., Lee, J.-H., & Lee, J. I. (2024). Taxonomic revision of in situ tree trunks and silicified wood from the Early Jurassic Kirkpatrick Basalt in the Mesa Range area, northern Victoria Land, Antarctica. *Review of Palaeobotany and Palynology*, *329*, 105160. https://doi.org/10.1016/j.revpalbo.2024.105160

Prieto, R., Ferraz, R., Luís, S., Pereira, S., Nunes, J. C., & Dores, V. R. (2007). *Candidatura da Ilha Graciosa a Reserva da Biosfera (v. 3.4) Governo dos Açores*. Governo dos Açores.

Risica, G., DiRoberto, A., Speranza, F., Carlo, P. D., Pompilio, M., Meletlidis, S., & Todrani, A. (2022). Reconstruction of the subaerial Holocene volcanic activity through paleomagnetic and 14C dating methods: El Hierro (Canary Islands). *Journal of Volcanology and Geothermal Research*, *425*, 107526. https://doi.org/10.1016/j.jvolgeores.2022.107526

Rodríguez-González, A. (2009). *El vulcanismo holoceno de Gran Canaria: aplicación de un sistema de información geográfico, Física. Las Palmas de Gran*. Universidad de Las Palmas de Gran Canaria.

Rodriguez-Gonzalez, A., Fernandez-Turiel, J. L., Perez-Torrado, F. J., Hansen, A., Aulinas, M., Carracedo, J. C., Gimeno, D., Guillou, H., Paris, R., & Paterne, M. (2009). The Holocene volcanic history of Gran Canaria Island: Implications for volcanic hazards. *Journal of Quaternary Science*, *24*(7), 697–709. https://doi.org/10.1002/jqs.1294

Schmincke, H.-U. (1967). Mid-Pliocene fossil wood from Gran Canaria. Preliminary note. *Cuadernos de Botánica*, *2*, 19–20.

Schmincke, H.-U. (1968). Pliozäne, subtropische Vegetation auf Gran Canaria. *Die Naturwissenschaften*, *55*(4), 185–186. https://doi.org/10.1007/BF00591034

Spicer, R. A. (1989). The formation and interpretation of plant fossil assemblages. In J. A. Callow (Ed.), *Advances in botanical research* (pp. 95–191). Academic Press.

Spicer, R. A. (1991). Plant taphonomic processes. In P. A. Allison & D. E. G. Briggs (Eds.), *Taphonomy: Releasing the data locked in the fossil record* (pp. 71–113). Plenum Press.

Suárez-Rodríguez, C. (2013). Registro fósil de Dracaenites Saporta en el Plioceno de Gran Canaria, islas Canarias. *Vieraea Folia scientiarum biologicarum canariensium*, *41* (Vieraea 41), 385–388. https://doi.org/10.31939/vieraea.2013.41.25

Troll, V. R., Aulinas, M., Carracedo, J. C., Geiger, H., Perez-Torrado, F. J., Soler, V., Deegan, F. M., Bloszies, C., Weis, F., Albert, H., Gisbert, G., Day, J. M. D., Rodríguez-Gonzalez, A., Gazel, E., & Dayton, K. (2024). The 2021 La Palma eruption: Social dilemmas resulting from life close to an active volcano. *Geology Today*, *40*(3), 96–111. https://doi.org/10.1111/gto.12472

Troll, V. R., Rodriguez-Gonzalez, A., Deegan, F. M., Perez-Torrado, F. J., Carracedo, J. C., Thomaidis, K., Geiger, H., & Meade, F. C. (2019). Sacred ground; the Maipés necropolis of north-west Gran Canaria. *Geology Today*, *35*(2), 55–62. https://doi.org/10.1111/gto.12262

Vegas, J., Channing, A., Anderson, C. L., Pais, J., Santos, A., & Hernández, M. V. (2013). Los fósiles vegetales de la caldera de Taburiente: Investigación, geoconservación y divulgación del patrimonio paleontológico en la isla de La Palma. In J. Vegas, A. Salazar, E. Díaz-Martínez & C. Marchán (Eds.), *Patrimonio geológico, un recurso para el desarrollo* (pp. 353–360). Instituto Geológico y Minero de España.

Velasco-Flores, M. C., Sender, L. M., González-Montelongo, C., Santos, A., Cruzado-Caballero, P., Martín-Luis, M. C., Alfayate, C., Góis-Marques, C. A., & Castillo, C. (2026). Life-position succulent euphorbia L. fossils buried in pleistocene explosive volcanic deposits from Tenerife, Canary Islands, Spain. *Review of Palaeobotany and Palynology*, *349*, 105535. https://doi.org/10.1016/j.revpalbo.2026.105535

Viera y Clavijo, J. D. (1869). *Diccionario de Historia Natural de las Islas Canarias*. Imp. de la Verdad.

Viera y Clavijo, J. D. (1968). *Diccionario de Historia Natural de las Islas Canarias*. Imp. de la Verdad.