

A UNIQUE GEOSITE OF A LAVA SUBFOSSIL FOREST IN THE GALÁPAGOS

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Abstract: The Galápagos archipelago is an extraordinary place known for its bio- and geodiversity, especially due to its extensive volcanic origin. Very frequently, a volcanic disaster or hazard may not only destroy parts of its environment, but it may also conserve parts of it. Hereby, in the northern caldera rim of the Sierra Negra volcano on Isabela Island, a remarkable discovery was made of a geosite, where lava flows with an age of some 3,000 years enabled the preservation of subfossil structures with more than 80 lava trees and tree moulds along 50 sites in a main area of some 2400 m². Such structures develop when very liquid, low-viscosity basaltic pahoehoe lava flows surround the existing trees and while they burn them to the ground, they may crystallize by solidifying the basaltic pahoehoe flow, impregnating the outer texture of the trees, forming a lava tree, prior to draining down with the residual viscous to fluid basaltic lava flow. In case of tree molds, they form when lava does not drain away, while a cylindrical hollow remains in the ground. In the study area, after georeferencing all these structures, they have been subsequently described in detail. Lava trees and tree molds vary slightly in the diameter of these cylindrical structures, while they demonstrate considerable depths of 25 to 215 cm until reaching either the base or their root ball. Lava tree piles may reach above-ground altitudes of up to 60 cm. Based on our findings, lava trees and tree moulds appear in an area of approximately several dozen square meters between the caldera rim and a circumferential fissure. The altitude difference is about 17 m and the lava flow which covered most of the trees, has a thickness exceeding two meters, having a clear flowing direction downhill, meaning away from the caldera rim. The endemic flora which gave rise to lava trees and moulds were mainly candelabra cactus (*Jasminocereus thouarsii* var. *sclerocarpus* (Schum.) Anderson & Walk) and *Scalesia* (*Scalesia cordata* A. Stewart) in the development phase. These subfossil structures is a relevant discovery due to the enormous quantity of these features, being unique in the Galápagos.

Keywords: lava trees, mold trees, Sierra Negra volcano, paleobotanic indicator, Holocene volcanism

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INTRODUCTION

The Galápagos represent various criteria of outstanding universal value (OUV) and has therefore been inscribed since 1978 as the first UNESCO World Heritage site. Their origin is predominantly volcanic due to an underlying hotspot. Volcanoes may be dangerous centers due to the expulsion of various types of pyroclastic materials of high temperature and volumes, which are able to destroy the complete surrounding ecosystems but simultaneously, such volcanic activity may conserve extraordinary sites of cultural and natural value (Guffanti et al., 2009; Toulkeridis & Zach, 2017; Del Moral & Grishin, 1999; Dale et al., 2005; Crisafulli et al., 2015; Lavigne & Gunnell, 2006; Edwards, 2005; Turner et al., 1997). Hereby, in cases of effusive type of activity, some of the surrounding vegetation, especially trees, may not only be burned or covered, but may even be somehow preserved as lava trees or tree molds (Biren et al., 2020; Bella & Gaál, 2007) or as lava tunnels (Bella & Gaál, 2007; Ogawa et al., 1999). Such features can allow the reconstruction of ancient vegetation systems, and they can indicate the flowing direction of the lava flows and may also preserve sometimes material like charcoal or carbonized wood which can be used to date the volcanic event (Lockwood & Williams, 1978; Lockwood & Lipman, 1980; Bell & Williamson, 2016) or as a geotourist attraction (Wright et al., 2023; Rucińska & Lechowicz, 2014; Tanaka et al., 2021; Erfurt-Cooper, 2010; Kuri & Suppasri, 2018). Lava trees and tree moulds have been first time reported at Kīlauea Iki (old crater) within the Hawaiian volcano Kīlauea (Lyman, 1849), but were first time been observed at Etna volcano in 1865 and 1867 (Reclus, 1865, Silvestri, 1867). Since, they have been the subject of multiple further studies in the USA (western US, Hawaii, Mariana

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Islands; Fosberg & Corwin, 1958; Walker, 1995; Woodcock & Kalodimos, 2005; MacCaughey, 1917; Moore & Richter, 1962; Mustoe & Dillhoff, 2022) and Italy (Carveni et al., 2011; Harris et al., 2022), as well as in other volcanic regions all around the world, such as in Slovakia (Gaal, 2003), Romania (Gaál, 2016), Scotland (Bell et al., 2016), Iceland (Óskarsson & Riishuus, 2013), Wallis Islands of France (Stearns, 1945), the Azores of Portugal (Nunes, 2020), New Zealand (Bartrum, 1925; Hayward, 2021), Japan (Bella & Gaál, 2007; Lockwood & Williams, 1978; Wasilewski et al., 2000), Korea (Kim, 2008), Vietnam (Hoang et al., 2018; Tuat et al., 2022), Mexico (Straub et al., 2013), Costa Rica (Alvarado & Soto, 2002), Easter Island of Chile (Wofford, 2006) and the Democratic Republic of the Congo (Durieux, 2003) amongst other.

Lava trees are generated when low-viscosity, very fluid, usually basaltic pahoehoe lava floods vegetated areas (Stearns, 1928; Finch, 1931), and rarely in the case of high-temperature metric basaltic andesite bombs related to bomb and ash flow pyroclastic flows (Alvarado & Soto, 2002; Alvarado et al., 2023). Hereby, the lava flow is surrounding the tree and usually it burns the organic part down to the ground and often beyond, but simultaneously, the fluid lava cools at the contact with the tree, while it solidifies (Figure 1e-h). During solidification, the cooled lava allows it to preserve the texture of the outer crust of the enclosed tree. When all the organic material has burned off, the remaining structure becomes hollow. Finally, usually the surroundings still fluid lava, subsides and drains away leaving the solidified but empty morphology in the form of a pillar. These regular vertical structures, which were able to resist the lava flow, keep being rooted, except if the tree fell and remained in a horizontal position and lava wrapped the trunk. These lava trees are an adequate indicator of the height of the incoming lava flow. Nonetheless, when lava does not drain away, then a cylindrical hollow remains in the ground, being named tree mold (Stearns, 1928; Finch, 1931). These pipe-like structures are exclusively vertical or slightly inclined. Later, these open features may be filled with rubble or ashes of following erosional or volcanic events.

However, if unfilled, these lava trees or tree molds may indicate the ground level or surface of the tree or if it burned further below, it may indicate the tree's root area (Figure 1a-d). As this area is unique in the Galápagos and continental Ecuador, it subsequently converts to a remarkable geosite like other geosites in Ecuador and worldwide (Toulkeridis et al., 2025a; Verdugo et al., 2025; Toulkeridis et al., 2021; Herrera-Franco et al., 2022; Quesada-Valverde & Quesada-Román, 2023). A geosite is defined as a specific location, area, or territory with unique geological or geomorphological features that possess significant scientific, educational, or cultural value. As crucial elements of Earth's heritage, geosites provide tangible evidence of geological processes and are conserved to protect their intrinsic value and aid in understanding Earth's history (Štrba et al., 2015; Brilha, 2016; Zorina & Silantiev, 2023).

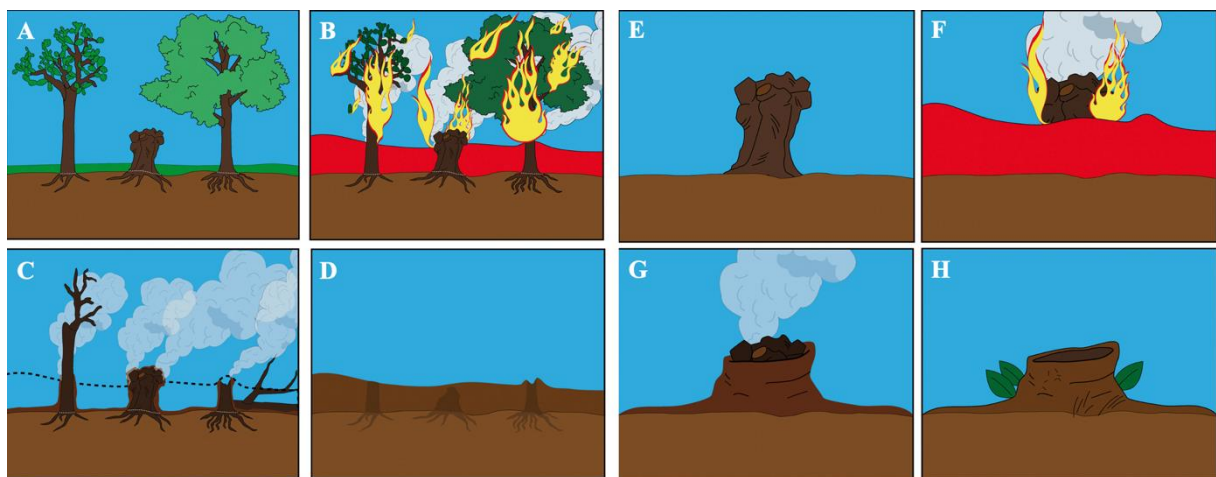


Figure 1. Schematic illustration of the formation of lava trees and tree molds (Toulkeridis, 2011)

Based on the aforementioned context, we realized detailed fieldwork in the Isabela Island of the Galápagos, where a new lava forest was discovered. Therefore, the main objective of the current research has been to describe and characterize the lava trees and tree molds of the Sierra Negra volcano. The findings may allow us to reconstruct the volcanic event on this geosite as well as to evaluate the biological data of the tree trunks preserved in time, as subfossils for the moment.

Geodynamic Setting, Local Geology and the Most Recent Volcanic Activities

The Galápagos archipelago is situated some 1000 km west of the Ecuadorian continental platform, where active volcanism is characterized predominantly by the Galápagos hot spot, besides other origins on top of the oceanic Nazca plate (Figure 2; White et al., 1993; O'Connor et al., 2007; Harpp & Weiss, 2020; Rojas-Agramonte et al., 2022). There are various types of volcanoes present, of which the most prominent are some two dozen of voluminous shield volcanoes, above a huge flood basalt, besides a few thousand monogenetic, parasitic (tuff, cinder, spatter) cones and other types of minor volcanoes (maar, fissure) (McBirney & Williams, 1969; Harpp et al., 2003; Toulkeridis, 2011; Toulkeridis & Angermeyer, 2019). The Galápagos drifts eastwards forming after volcanic activity ceases, a volcanic alignment of aseismic seamounts called the Carnegie Ridge (Harpp et al., 2003; Pilger, 1984). Therefore, as the active hotspot is situated on the western rim of the Galápagos archipelago, the most active volcanoes are located on the western side, where the islands Fernandina and Isabela carry the seven hugest volcanoes with calderas, named El Cumbre (Fernandina) and Cerro Azul, Sierra Negra, Alcedo, Darwin, Wolf and Ecuador, just west of the Santiago volcano

(Figure 3; Filson et al., 1968; Munro et al., 1996; Geist et al., 2014; Nordlie, 1973). Activity of these volcanoes occurs roughly once a year at one place but sometimes coincides with more than one volcano being simultaneously active.

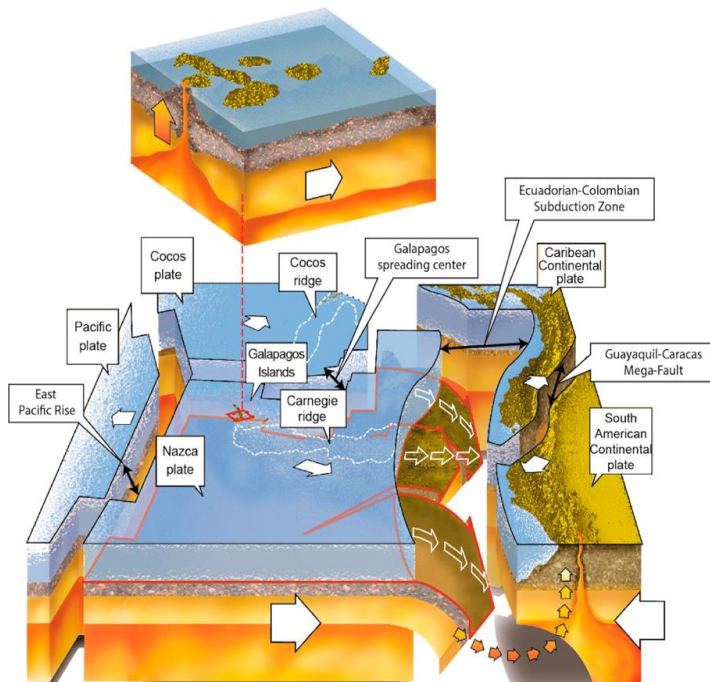


Figure 2. The geodynamic situation of Ecuador with its associated tectonic plates, corresponding separating plate boundaries and volcanic aseismic ridges (Source: Toulkeridis et al., 2021)

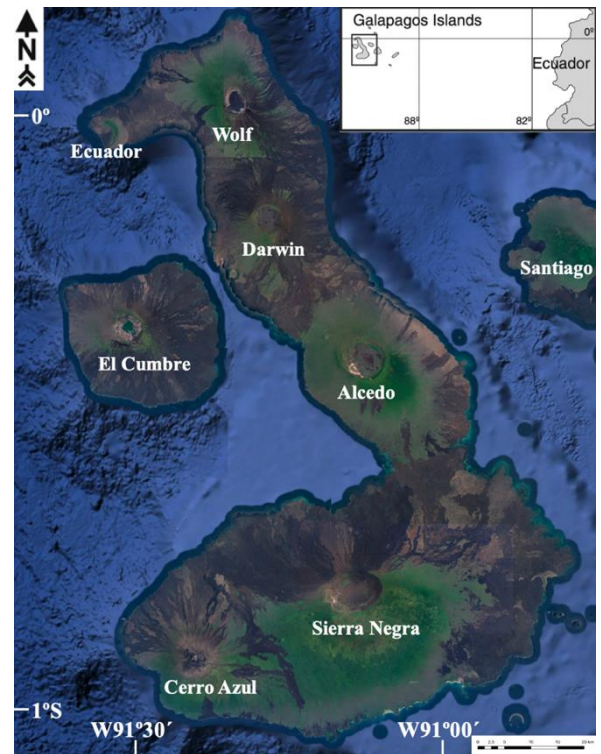


Figure 3. Location of the Sierra Negra volcano within the westernmost shield volcanoes of the Galápagos. (Source: Image from Google Earth Pro)

The active shield volcano Sierra Negra is 60 to 40 km wide and has a 7 to 10 km-wide caldera, the largest and simultaneously the shallowest (elliptical) caldera of all volcanoes of the Galápagos (Figure 4; Acocella et al., 2025). Eruptive centers and different lava fields have been subdivided into five distinctive age groups, all being younger than 6000 years old (Reynolds et al., 1995). These are alkaline to tholeiitic lava flows that erupted from east to northeast trending circumstantial and radial fissures situated on both sides of the summit caldera on the upper flanks and on the western and eastern lower flanks. The caldera itself has undergone several episodes of collapse, upheaval and deformation (Geist et al., 2006; Jónsson, 2009; Goff et al., 2000). Ten historic eruptions occurred and some involved a frequently visited caldera rim fissure zone called Volcán Chico (Delaney et al., 1973). Nine known volcanic episodes have occurred in the last 120 years (1911, 1948-49, 1953-54, 1954, 1957, 1963, 1979-1980, 2005, 2018).

These explosive phases of the past have given rise to frothy pumice, which was followed by the formation of agglutinate cones and voluminous lava flows. In the surrounding of Volcán Chico appear many volcanological features such as solidified volcanic lava fountains (lava blobs) of up to three meters in altitude, cascades of lava, small lava ponds, transitions from pahoehoe to aa, small often completely intact lava tubes, bigger often collapsed lava tubes, remarkable caves, the new discovered accumulation of lava trees and certainly the famous ongoing fumarolic activity and all covered by a thin layer of scoria (Padrón et al., 2012; Debut et al., 2021; Constantin et al., 2019; Miller et al., 2020; Toulkeridis et al., 2025). The former last eruptive activity took place at the end of October 2005 and lasted a week, after 26 years of silence (1979). Previous signs of the last reactivity included, a relatively strong seismic event a few hours before the explosion (VEI=3) and uplift of the caldera floor months prior to the event, among others.

Similar to the previous eruptive phase of 1979, a seismic event shortly before the main explosion has occurred on the 22nd of October 2005 (United States Geological Survey, 2005; Global Volcanism Program, 1979; Global Volcanism Program, 2005). The seismic event of about 5.5 Mw on the Richter scale occurred at 14.38 (local time), was felt by locals and was registered by the United States Geological Survey (USGS), besides other international seismic monitoring stations while the main explosion occurred at 17.30. The ongoing eruption resulted in a mushroom-shaped plume, which reached a height of around 18 km (Geist et al., 2008; Gregg et al., 2018). The eruption coincided with an extension, and a shortening of the caldera's floor registered a few years prior to the explosive event. With the explosion a series of vents at the caldera's north-northeastern rim opened along a 2 km fissure resulting in an effusive event lasting one week, producing around 0.05 km of lava covering an area of around 14 km mainly the eastern part of the caldera's floor and a minor part of the northern outer part of Sierra Negra's caldera (Figure 4). Lava flows ceased on the 30th of October 2005, but minor skylights and red glowing rocks remained present for another two weeks. The gas flux emitted from the main vent remained productive for an even longer time. The most recent volcanic episode occurred on 26 June 2018, as part of a new magmatic event (Gregg et al., 2022; Davis et al., 2021). Like the previous two eruptive events in

1979 and in 2005, a strong seismic precursor gave a clear sign of the rise of fresh magma (Mohammadnia et al., 2025; Landolfi et al., 2025). This rise generated a general uplift in the central area of the caldera floor. One minor and four main fissures, some of various kilometres in length, on the northwestern side of the caldera have been the initial zones of lava flows, reaching even the ocean (Figure 4). These lava flows lasted for almost two months and covered more than 30km².

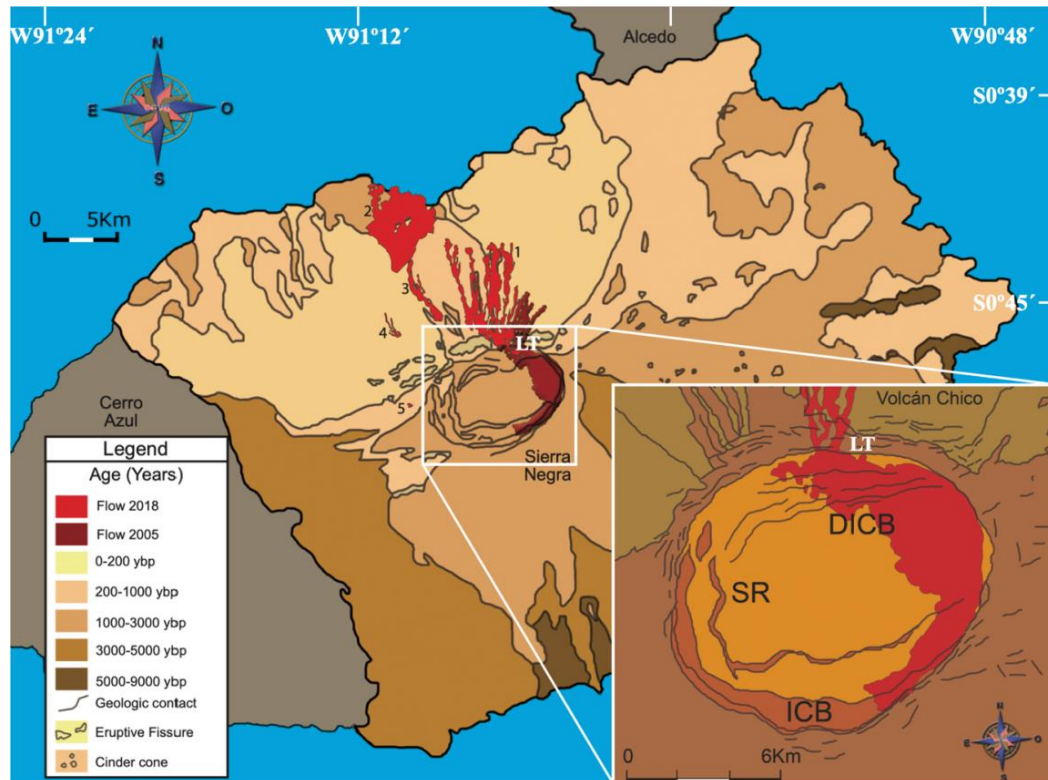


Figure 4. Schematic geological overview map of the volcano Sierra Negra, southern side of Isabela Island. LT = site of lava trees.

Note that the last events occurred on the eastern and northern sides of the caldera. 1-5 are the fissures of the most recent event of 2018.

YBP = years before present. Adapted and modified from Toulkeridis & Angermeyer (2019), Reynolds & Geist (1995), Global Volcanism Program (2018) and Global Volcanism Program (2005). Inlet: Caldera structure of Sierra Negra volcano.

In red lava from the 2005 activity. ICB = Inter caldera bench, DICB = Discontinuous inter caldera bench, SR = sinuous ridge, LT = site of lava trees. Taken from Toulkeridis (2011), modified after Munro & Rowland (1996)

Native and Endemic Vascular Flora of Isabela Island

The native plants of the Galápagos Islands trace their origins to mainland species, which likely arrived on the islands through various means, while the endemic plants possibly evolved on the islands to give rise to these unique plant species. Six endemic genera are recorded in the Galápagos, being *Scalesia*, *Darwiniothamus*, *Macraea*, and *Lecocarpus* (Asteraceae); *Brachycereus* and *Jasminocereus* (Cactaceae) (Stöcklin, 2009). The diversification of plants in the Galápagos Islands is related to the different vegetation zones in which they are generally found. The endemic and native plants that have colonized Isabela Island are distributed in five zones, based on the altitude from sea level areas up to the highlands.

The lowest is the littoral zone at sea level, which is a coastal territory, partly flooded and the arid zone of up to 300 m a.s.l., which is characterised by being a dry zone, dominated mainly by xerophytic succulent plants (León-Yáñez et al., 2011; Restrepo et al., 2012; Jaramillo et al., 2011). In this territory the following endemic species are encountered: *Alternanthera echinocephala*, *Alternanthera filifolia*, *Cardiospermum galapageium*, *Castela galapageia*, *Chrysanthellum pusillum*, *Euphorbia viminea*, *Darwiniothamnus renuifolius*, *Exodeconus miersii*, *Galvezia leucantha*, *Jasminocereus thouarsii* var. *sclerocarpus* (Schum.) Anderson & Walk, *Lantana peduncularis*, *Lycium minimum*, *Nolana galapagensis*, *Opuntia echios*, *Passiflora vesicaria* var. *galapagensis*, *Pectis subsquarrosa*, *Scalesia affinis*, *Sesuvium edmonstonei*, *Zanthoxylum fagara* and *Solanum cheesmaniae*. Among the natives, the following are recorded: *Avicennia germinans*, *Batis maritima*, *Bursera graveolens*, *Capraria biflora*, *Jelí Conocarpus erectus*, *Cordia lutea*, *Cyperus ligularis*, *Erythrina velutina*, *Neltuma juliflora*, *Heliotropium curassavicum*, *Hibiscus tiliaceus*, *Hippomane mancinella*, *Ipomoea pes-caprae*, *Jasminocereus thouarsii* var. *sclerocarpus* (Schum.) Anderson & Walk, *Laguncularia racemosa*, *Rhizophora mangle*, *Scaevola plumier*, *Scutia spicata*, *Senna occidentalis*, *Sesuvium portulacastrum*, *Sporobolus virginicus*, *Tournefortia psilostachya*, *Tricerna octogonum* and *Vachellia rorudiana*. The Transition Zone, from 300 to 600 m a.s.l., is also dry land, but receives more moisture than the previous zones, with a predominance of shrubby and thorny plants, including the following endemic species: *Croton scouleri*, *Darwiniothamnus renuifolius*, *Jasminocereus thouarsii* var. *sclerocarpus* (Schum.) Anderson & Walk, *Gossypium darwinii*, *Ipomoea habeliana*, *Opuntia echios*, *Psidium galapageium* and *Varronia leucophlyctis*. Native plants in this zone include: *Pisonia floribunda*, *Plumbago zeylanica*, *Senna pistaciifolia*, *Vachellia macracantha*, *Psychotria rufipes* and *Vallesia glabra*.

In the vegetation zone corresponding to the sector of the Sierra Negra volcano, the humid zone extends from 900 to 1200 m a.s.l. and the high zone is above 1200 m a.s.l., with a subtropical climate, cool and with greater humidity, in which more species of trees develop forming green forests. In this territory the following endemic species are recorded: *Ageratum conyzoides*, *Chiococca alba*, *Jasminocereus thouarsii* var. *sclerocarpus* (Schum.) Anderson & Walk, *Psidium galapagaeum*, *Psidium galapagaeum*, *Scalesia cordata*, *Tournefortia pubescens*, *Tournefortia rufosericea*, *Volkameria mollis* and *Waltheria ovata*. There the native plants include: *Bidens Pilosa*, *Darwiniothamnus tenuifolius*, *Justicia galapagana*, *Pleuropetalum darwinii* and *Zanthoxylum fagara* (Jaramillo et al., 2025; Jaramillo et al., 2011; Tye, 2006; Jørgensen et al., 1999; Wiggins & Porter, 1971; Bensted-Smith, 2002).

Hereby, the endemic plants native to the highlands of Isabela Island close to the study area are *Jasminocereus thouarsii*, *Zanthoxylum fagara*, *Tournefortia rufosericea*, *Tournefortia pubescens*, *Scalesia cordata*, *Psychotria rufipes*, *Psidium galapagaeum*, *Pleuropetalum darwinii*, *Darwiniothamnus renuifolius*, *Volkameria mollis* and *Varronia leucophlyctis* (Jaramillo et al., 2025; McMullen, 1999; Porter, 1976; Wiggins et al., 1971). Nonetheless, trees that appear, but are somewhat scarce at this geosite, include candelabra cactus (*Jasminocereus thouarsii* var. *sclerocarpus* (Schum.) Anderson & Walk), Galápagos guava (*Psidium galapageium* Hook. F), and *Scalesia* (*Scalesia cordata* A. Stewart) (Philipp et al., 2010; Proença et al., 2022; Terrazas et al., 2002; Itow, 1995; Connor et al., 1978).

METHODOLOGY

Study area and fieldwork

The most prolific occurrence of lava trees and tree molds reported to date from the Galápagos is exposed just north of the main tourist path along the northern rim of the caldera rim of the Sierra Negra volcano (Figure 4). This site was discovered by the main author, during a workshop organized by the WWF and the PNG in April 2016 (FmMundo, 2016; El Comercio, 2016). The main area of this geosite extends over a north-south oriented, roughly vertical, inclined rectangular area of 60 to 40 m, where more than 50 sites of lava trees and tree molds have been recognized and georeferenced in a main area of some 2400 m² (Figure 5). The exact position of all encountered lava trees and tree molds are below <https://www.wikiloc.com/hiking-trails/molded-vegetation-sierra-negra-249361504>. All sites are encountered between the upper part of the caldera rim towards the outer part of the caldera, ending just shortly south of the first circumferential fissure. The different sites have an altitude difference of 17 m, occurring between 1012 and 1029 m above sea level (a.s.l.). However, the area, which is widely covered by pyroclastic gravel, must be much larger, as some tree molds appear approximately 110 m east of the southeastern edge of the main occurrence, along the tourist path.

Furthermore, the taxonomic identification of plant species was conducted qualitatively by comparing subfossil structures, such as the walls of lava tree molds and the shape of these hollow structures, with the morphological structures of all endemic native plants to the highlands of Isabela Island. Each plant exhibits specific shapes, dimensions, and morphological characteristics, particularly in its stem (rings, clefts, scars) and branching patterns.

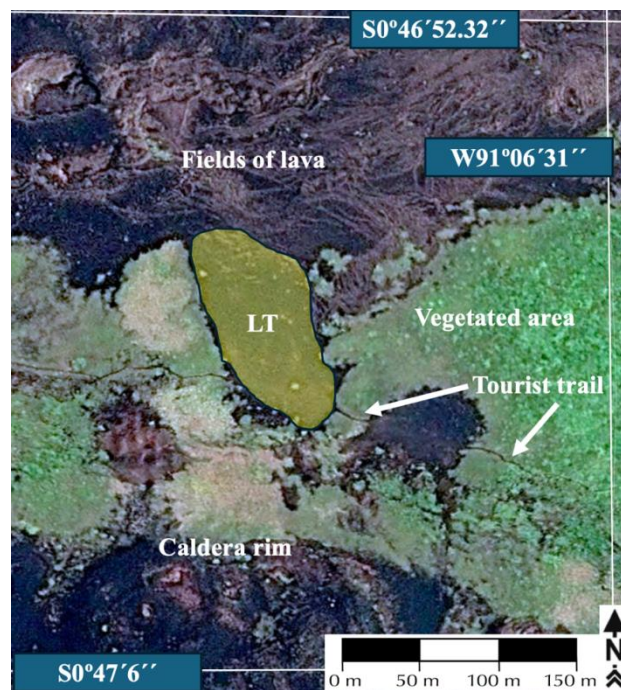


Figure 5. Principal area (LT; yellow) of the lava tree forest (Source: Image from Google Earth™)

RESULTS AND DISCUSSION

More than 80 lava trees and tree molds at 50 sites have been encountered along the northern border of the Sierra Negra caldera (Figure 6). This is a unique discovery and an enormous number of these features, as previously to 2016 only a single cactus mold in Genovesa Island and a lava tree on Cerro Azul volcano of Isabela Island were reported (Toulkeridis,

2011), besides some known tree molds in Sullivan Bay (Figure 7). The lava trees and tree molds in this rectangular field are roughly aligned to NNW-SSE, N-S and W-E directions. The distribution of all structures is in a limited field, however, many more of these structures may be expected, being either covered or hidden by vegetation or drowned in pyroclastic gravel. Most sites appear with just a single structure, while others often have two and sometimes three lava trees or tree molds. The higher number of lava trees and tree molds in a site is either generated due to the closeness of two or three trees in a close spot, or what may be also evidenced, by the branching as the natural development of trees (Figure 8).



Figure 6. Typical appearance of Lava trees and tree molds at the Sierra Negra geosite



Figure 7. Upper left: Cactus mold, Genovesa Island (credit Karen Harpp). Upper right: Up to two meters high lava tree on Cerro Azul volcano (credit Pedro Ramón). Below: Tree molds of *Maitenus octogona*, in Sullivan Bay, Santiago Island (credit Hein Angermeyer)

The hollow structure of the lava trees and the tree molds is cylindrical, the opening mouth form is often circular but may also appear in form of a heart and somehow squeezed (Chevrel et al., 2019). Molds and trees, where possible indicate a unique direction of the lava flow being from south to north, streaming downhill. This is evidenced by two facts, first being a certain kind of rampart structure due to the collision of the impacting lava flow, which got accumulated on that side and second by demonstrating the lack of a complete cylindrical form in case of the lava trees, as their northern end is open (Soule et al., 2004). The collisional side of the basaltic rock is very fine grained on its contact, while further away it may become virtuous in exhibiting bubbles of degassing of their previous given gas content.

It is also noted that part of the rampart is thickened, which may indicate that besides the tree trunk itself some more resistance was given by existing branches in time of deposition of the lava flow. The empty, cylindrical structures have either been either completely or partially filled with gravel of cinder, while most demonstrate considerable depths of 25 to 215 cm until reaching either the base or their root ball. This means that the lava flow has had also at least such thickness.

The thickness of the lava flows may have been even higher considering the pile structure of the lava trees above ground to reach up to 60 cm. Subsequently, we may conclude that the approximate age of all lava trees and tree molds in this geosite is 3,000 years, coinciding with the formation of the caldera (Figure 4). After the caldera formation no new vent was formed there to give rise to new lava flows, which followed gravity of the pre-existing morphology.

The inner wall of all lava trees and tree molds in this geosite like elsewhere is a great paleobotanic indicator of the trees which have been burned by the inflow of the lava, due to their impregnation prior disappearance (Páez-Barrera et al., 2024). However, in some cases the lava tree walls may be covered with a thin layer of vegetation (Figure 9). As this area is very remote to human settlements and almost deserted due to the high number of gravels of cinder, it is almost logical to assume that the lava tree structures resemble still existing flora of the area within this dry tropical climate (MacCaughey, 1917; Biren et al., 2020). Almost all the tree and lava tree casts exhibit a smooth wall, with or without bifurcations, while other tree casts show an unusual wall formation with evident bands or rings formed by plant scarring (Figure 8).

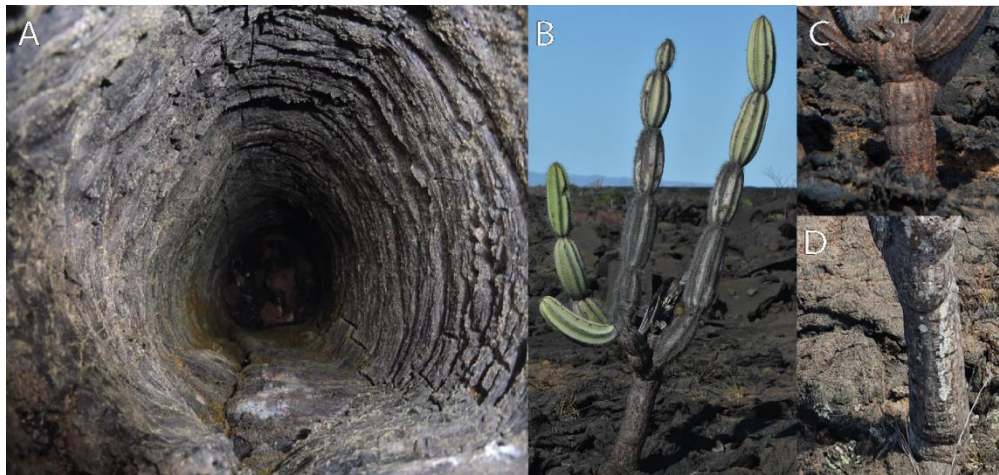


Figure 8. Tree mold formed 3,000 years ago on the Sierra Negra volcano, Isabela Island-Galápagos. A. Vertical lava tree mold with a depth of some 55cm, with clear markings of the ringed bark or ribs left by the Candelabra Cactus; Current photographs, B. Candelabra Cactus, *Jasminocereus thouarsii* var. *sclerocarpus* (Schum.) Anderson & Walk. (Picture adapted from INaturalist-Photos, Nr. 57809747, Scott, 2019). C-D. Section of the trunk of C. Candelabra, in which rings are marked and impressions of the bark texture and ribs or scars marked in the branching areas of this succulent can be observed (Picture adapted from INaturalist-Photos, Nr. 25563, Lasley, 2017; Nr. 236631905, Ondraka, 2024)



Figure 9. Lava tree molds formed 3,000 years ago on the Sierra Negra volcano. A-B. Forked lava tree mold, without striations, whose cylindrical and smooth shape would correspond to a resistant and branched wood such as that of the guayabillo endemic to this area, *Psidium galapageium* Hook. f.; C. Split and smooth lava tree mold, this element is characteristic of the mature and thin trunks of *Scalesia*, *Scalesia cordata*, which upon maturation presents deep vertical fissures or clefts which are filled with moss or lichens; D. Vertical, cylindrical, striated or ringed lava tree mold, hole left by the calcination of the trunk of a candelabra cactus, *Jasminocereus thouarsii* var. *sclerocarpus* (Schum.) Anderson & Walk; E-F Current photographs of the plant and smooth trunk and basal branching of Galápagos Guayabillo, *Psidium galapageium* Hook. F (Picture adapted from INaturalist-Photos, Nr. 61425834, csabavad., 2026; Nr. 34707122, traderj., 2024); G *Scalesia* endemic to the island, shrub-type plant (Picture adapted from SanJosé, 2026).

These ringed scars coincide with the shape of the transition zone of the trunk of the candelabra cactus (*Jasminocereus thouarsii* var. *sclerocarpus* (Schum) Anderson & Walkington) (Anderson & Walkington, 1970). There are also molds of lava trees of smaller diameter with the presence of clefts in the lateral section of the same, whose mold coincides with the stems of *Scalesia* (*Scalesia cordata* A. Stewart) in the development phase. This plant, also endemic to the Galápagos Islands, has as a morphological characteristic its rapid growth and maturation of cylindrical stems and bark with vertical cracks or clefts, spaces that allow the development of moss and lichens (Jaramillo et al., 2025; Fundación Charles Darwin et al., 2018; Tye, 2006; Tye et al., 2011).

Galapagos was declared a Natural World Heritage Site (1976), UNESCO Biosphere Reserve (1984), and Ramsar Site (2001) mainly based on the worldwide recognized extraordinary flora and fauna and the related biodiversity.

Nonetheless, an alternative may be offered based on the volcanic nature of the islands, where extraordinary geosites are able to explain past as well as recent geologic processes and events resulting from the hot spot volcanism based on an educational program offered by the local naturalist guides. Since recent times, a high amount of geosites have been recognized, including different types of volcanic cones, coastal and volcanic landscapes, volcanic hazards, sites of tectonic, mineralogical and petrological interest, pyroclasts and trails, (Kempe et al., 2021; Carrión-Mero et al., 2024; Carrión-Mero et al., 2025). Based on the discovery of a lava tree forest in the northern side of the caldera rim of the Sierra Negra volcano, the geopatrimony management and sustainable tourism in the Galápagos Islands may further focus on balancing the preservation of this unique volcanic geosite with a potential increasing visitor demand.

The studied lava tree forest may be compared with less than a handful of equivalent sites of similar importance worldwide such as the Lava Tree State Monument in Hawaii, the Lava Cast Forest in Oregon (both USA) and near Mount Etna in the Italian Sicily Island (MacCaughey, 1917; Peterson & Groh, 1969; Carveni et al., 2011).

Like on these locations, some key strategies may include evaluating tourist carrying capacity, implementing geotourism, and promoting geoeducation to protect such delicate ecosystem while benefiting the local community of Puerto Villamil, as well as natural guides, park rangers and tourist agencies from all other inhabited islands of the Galapagos (Jaya-Montalvo et al., 2024; Kelley & Salazar, 2017). The studied and very accessible geosite being unique in the Galapagos is situated along an established tourist trail, results to be ideal for teaching and learning purposes of the volcanic processes that have shaped it. Subsequently, this extraordinary geosite should be considered to be safeguarded and protected for the benefit of future generations as part of the established geoheritage.

CONCLUSIONS

Lava trees and tree moulds are unique volcanic formations created when fluid, fast-moving or slow-moving basaltic lava flows through a forested area and encases tree trunks. Such rare formations are found almost exclusively in at most two handfull regions on the planet, one of them is the newly discovered geosite in the Galapagos Islands.

Hereby, such lava trees and tree moulds provide crucial scientific value by acting as natural archives for reconstructing past volcanic dynamics, paleoenvironments, and chronological timelines.

The new discovered, remarkable 3-ka old geosite is described with a particular preservation of subfossils lava tree and tree molds structures in an area of about 0.24 ha in a pahoehoe lava field, in the northern caldera rim of the Sierra Negra shield volcano in Isabela Island. The lava trees and tree molds vary slightly in diameter size of the cylindrical structures (0.25 to 2.15 m), and altitudes of up to 60 cm. The subfossils were mainly candelabra cactus (*Jasminocereus thouarsii* var. *sclerocarpus* (Schum.) Anderson & Walkington) and *Scalesia* (*Scalesia cordata* A. Stewart), being a unique geomorphological geotourist and endemic biotourist attraction in the Galápagos.

This particular geosite of lava trees and tree moulds, is now further evidence, that detailed mapping of volcanic regions may allow the reconstruction of not only magmatic processes realized on the Earth's surface, but also of past, now fossilized ecosystems. Fossilized ecosystems provide a complete record of how ancient communities functioned, evolved, and responded to environmental shifts over the geologic time period of thousands and sometimes even millions of years.

Clearly, this geosite needs to be protected given its fragility. Furthermore, it wouldn't be surprising if other similar sites exist in the Galápagos archipelago. Subsequently, it would be of particular interest to prospect for similar fossil finds on the geologically older islands, as these could shed light on plant colonization over time.

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