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El Hierro UNESCO Global Geopark: Geological Heritage, Geoconservation and Geoturism

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Abstract

El Hierro UNESCO Global Geopark, the first declared in the Canary Islands, hosts an impressive geological heritage, represented by its Geological Interesting Places (GIPs or geosites). Most noted among these are those related to the formation of mega-landslides and the formation of extensive fields of pahoehoe lava-flows associated with the historical or prehistoric fissure vulcanism that occurred as a result of the activity of its three ridges. This interesting geological heritage has been made available to the island's community, embodied in incipient geological tourism as a complement and continuity to the sustainable growth policy initiated by the local authorities decades ago.

Keywords: Geodiversity, Megalandslides, Pahoehoe lava-flows

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Introduction

The island of El Hierro is the smallest and westernmost of the archipelago of the Canary Islands (Fig. 1). This unique territory was declared by UNESCO as a Biosphere Reserve in the year 2000, and it lives mainly from agriculture and incipient tourism, attracted not only by its natural beauties but also by a simple, quiet way of life and deep cultural roots linked to sustainable development.

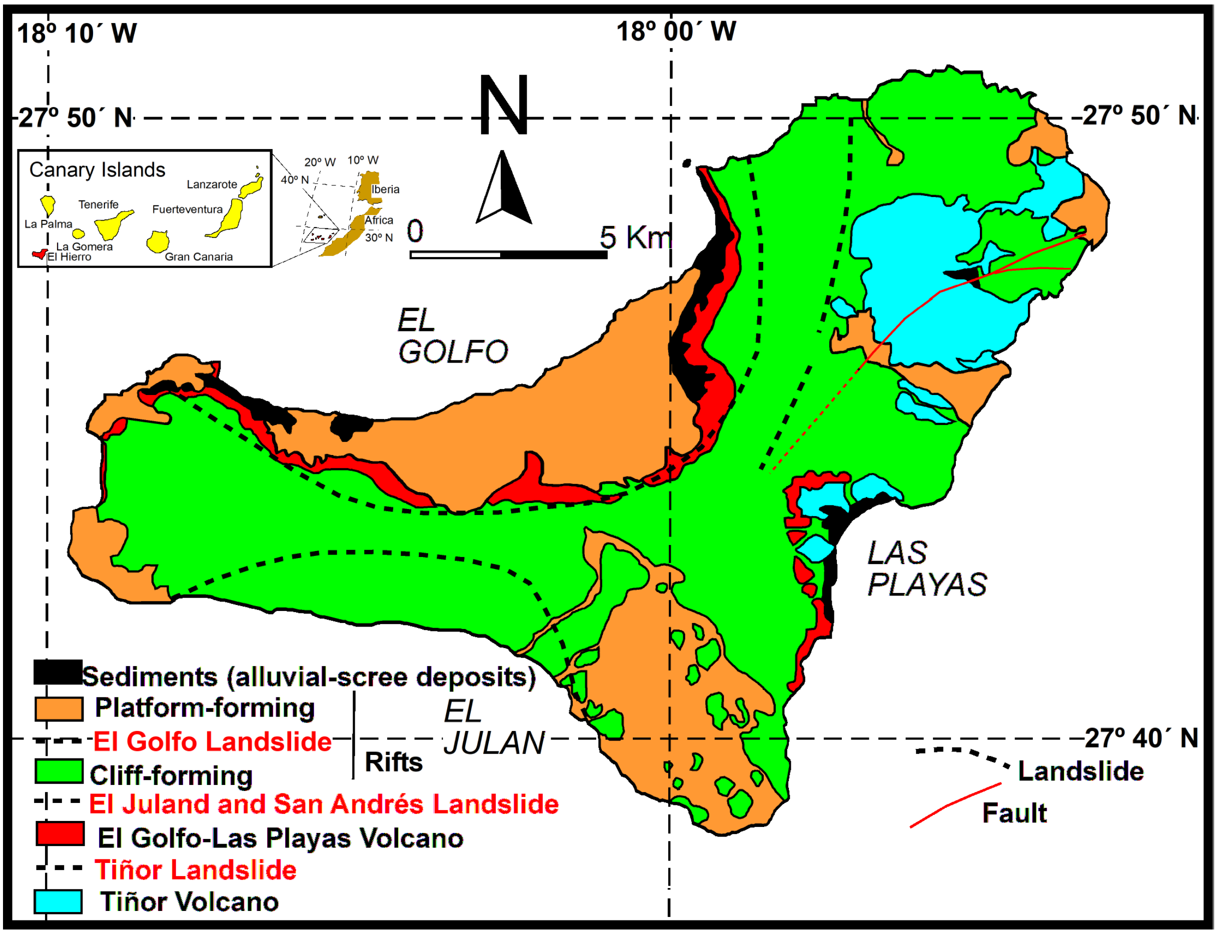

Figure 1. Schematic geological map of El Hierro Island (after Carracedo *et al*. 2001).

Added to all these attractions is a unique geological heritage, reinforced in 2011 by the submarine eruption off its coast that gave rise to a new submarine volcano that has not emerged, called Tagoro. This geological milestone motivated the implementation of an exciting project that culminated in 2014 with UNESCO's declaration of the island of El Hierro as a UNESCO Global Geopark (Minetur 2014).

The different enclaves, valued from a scientific or educational point of view or due to their unusual or scenic nature, are specified in a series of Geological Interest Places (GIP, in the sense expressed by García-Cortés *et al.* 2014) that, like witnesses in stone, tell us about the origin of the island. The objective of this work is to show the Geological Heritage of the El Hierro Global Geopark through the description of the Inventory of Geological Interest Places recently carried out in the Geopark. This inventory, like that carried out by Németh (2022), is planned to describe the geodiversity of the El Hierro Global Geopark, and it is a very useful tool for geoconservation and geotourism.

We know little or nothing about the submarine growth of El Hierro Island (Carracedo *et al.* 2001), unlike other islands of the archipelago, such as Fuerteventura, La Gomera, or La Palma, because the rocks originated from submarine eruptions and do not emerge at the surface. Since the emergence of El Hierro 1.2 million years ago, five volcanic edifices have been active (Carracedo *et al.* 2001, Fig. 1). The oldest are two shield volcanoes called Tiñor and El Golfo-Las Playas (Fig. 1). Subsequently, the eruptions were repeatedly concentrated along large fractures or fissures in the crust, which ended up forming three volcanic ridges after thousands of years. All these volcanic edifices have in common that they grew rapidly, on a geological scale, and excessively until they became unstable. This structural fragility is the origin of the gigantic gravitational landslides that took place on its flanks and that, like colossal claws, dragged the rocky materials toward the ocean floor. These landslides left behind them, like scars in the landscape, wide amphitheater-shaped depressions, like the El Golfo valley (Carracedo *et al.* 2001; León *et al.* 2017).

Tiñor Volcanic Edifice

The Tiñor Volcanic Edifice, the first to emerge on El Hierro, was formed in three stages, between 1.12 million years and 880,000 years, marking the end of its eruptive history (Fig. 1). This end was conditioned by the great collapse of its northwestern flank. The remains of this great volcano, currently very eroded, are only visible in the deep ravines of the northeastern sector of the island and inside the Las Playas escarpment. In these wild places, which correspond to the oldest part of the island, we can see the lava flows and the basalt and trachybasalt pyroclastic deposits that were part of the volcanic edifice.

Crossing these rocks, the dykes stand out in the landscape, walls of solidified magma reduced by erosion, representing the ancient conduits for the ascent of magma during eruptions.

El Golfo-Las Playas Volcanic Edifice

A new volcanic edifice, El Golfo-Las Playas, grew on the remains of the Tiñor Volcanic Edifice, after a pause in volcanic activity of about 300,000 years (Carracedo *et al.* 2001). This colossus has a diameter at its base of about 20 km and an approximate height of 2000 m. Its volcanic activity lasted from 545,000 and 158,000 years ago. The remains of this majestic volcanic edifice are today visible on the escarpments of Las Playas arc and El Golfo Valley. During the emergence of this great volcano, in its early stages of formation, the magma came into contact with seawater, leading to a very explosive and violent eruption. These hydromagmatic episodes generated many pyroclastic and volcanic deposits of basaltic composition. After this initial explosive phase, the eruptions had a calmer character throughout the thousands of years in which the El Golfo-Las Playas Volcanic Edifice was finished. During this long period, innumerable basaltic volcanic flows accumulated, which gave way, in the final phases of construction, to trachyphonolite and trachyte flows (Carracedo *et al.* 2001).

Volcanic Ridges

After the formation of El Golfo-Las Playas Volcanic Edifice, volcanic activity was concentrated in three volcanic ridges oriented, respectively, in the East-West, Northeast-Southwest and Northwest-Southeast directions, which have been active from about 145,000 years ago to 2011–2012 and the Tagoro eruption. In these ridges, volcanic activity was concentrated in numerous fissures or cracks, which could be several kilometers long. The magma ascended through them, giving rise to different eruptive centers that built several aligned pyroclastic cones from which numerous lava flows started.

Large Gravitational Landslides

As already indicated, the geological history of the Island of El Hierro has been marked by various gravitational landslides on the flanks of its volcanic edifices. The oldest such recorded event was about 880,000 years ago when a large gravitational landslide affected the northwestern flank of the Tiñor Volcanic Edifice at the end of its eruptive history. The next gravitational landslide affected the southwestern flank of the El Golfo-Las Playas Volcanic Edifice in the Julan sector. This created the head of the great amphitheater, which is heavily covered by lavas from the Western Volcanic Ridge, so its exact age has yet to be discovered, but it must have been more than 158,000 years ago (Carracedo *et al.* 2001).

The southeastern sector of the island has been affected by several gravitational landslides, some of which were aborted and which are responsible for the Las Playas escarpment and the normal fault system that runs through the southeastern sector of the island, in a Northeast-Southwest direction, like the San Andrés fault . The study of the seabed deposits, in which the avalanches of rocks from this sector of the island accumulated, allows us to distinguish two successive landslides: Las Playas-I and Las Playas-II, which occurred more than 145,000 years ago (Carracedo *et al.* 2001).

The most recent landslides recorded on the island generated the wide El Golfo depression (León *et al.* 2017). This vast geographic amphitheater appears to have originated through two successive giant gravitational slides, the first about 83,000 years ago and responsible for forming the largest escarpment, and the second 23,000 years ago, the last landslide.

Geological Heritage

On October 1, 2012, after the end of the eruption of the Tagoro submarine volcano, the Island Council of El Hierro presented the application for El Hierro Island to be a member of the "European Geoparks Network (EGN)" and the "Global Geoparks Network" (GGN). In this way, and under the auspices of UNESCO, the Island of El Hierro was declared as a Geopark and is included in the EGN and GGN networks. In November 2015, at the 38th General Conference of UNESCO, approval of the "International Program for Earth Sciences and Geoparks (PIGG)" was ratified. With that, El Hierro Geopark was included in the UNESCO Global Geoparks Network, being called, from that time a UNESCO Global Geopark.

The geological history of the Island of El Hierro can be understood through 61 Geological Interest Places (Casillas *et al.* 2022, GIP or geosites) (Fig. 2), which are representative of the growth and destruction of an oceanic island in an intraplate environment. The geological heritage (Németh 2022) represented by these geosites has as foremost examples those related to the formation of mega-landslides and the formation of extensive fields of pahoehoe lava-flows associated with historical or prehistoric fissure vulcanism that occurred in association with the activity of its three ridges (Fig. 3).

One of the selected GIPs was the El Golfo Valley. This very special place is included as Global Geosite VC010 "The El Golfo Landslide (El Hierro)". The El Golfo Valley is also included in the Global Geosite Inventory for Spain (García-Cortés *et al.* 2000). This Global Inventory of Earth's Geological Heritage was an IUGS project with support from ProGEO, IUCN and UNESCO. The Valley of El Golfo is also representative of the geological framework nº 14 "Morphologies and volcanic constructions of the Canary Islands" of Spain (Barrera 2009).

Appendix A(Presented at end of references) shows the inventory of geosites proposed for the El Hierro UGG (their location is shown in Fig. 2), included in the geological contexts they represent (shield vulcanism, ridge volcanism, central volcanic complexes; prehistoric and history; alluvial and fluvial-torrential processes and deposits; gravitational processes and deposits; littoral processes and de-

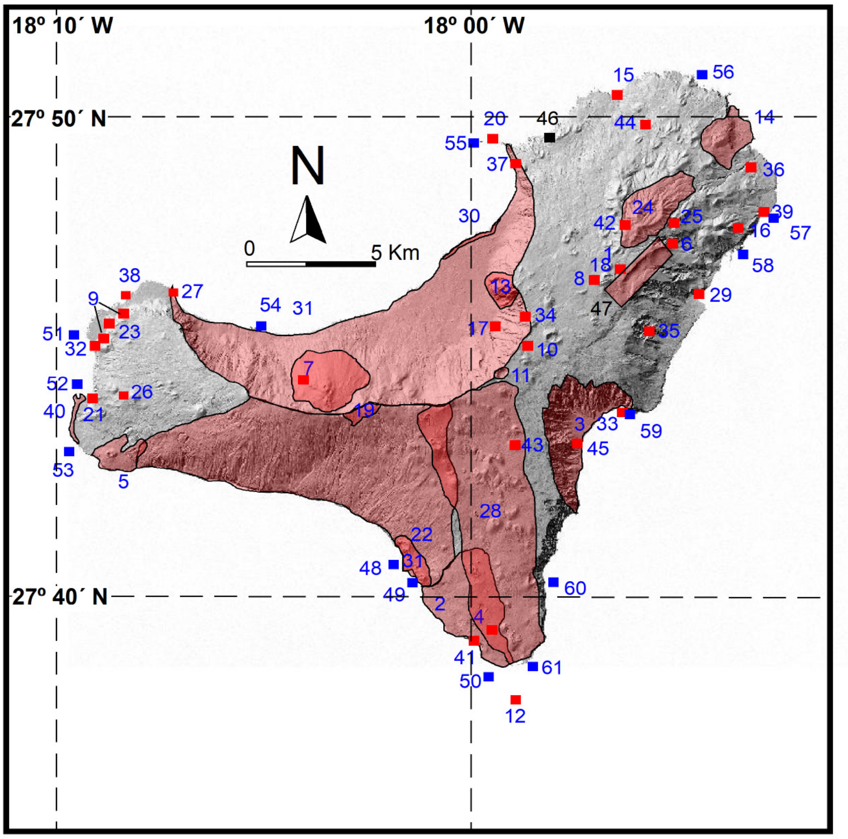

Figure 2. Position of the GIPs or Geosites included in the inventory of El Hierro UGG (points and areas with a transparent red grid, according to Casillas *et al.* 2022).

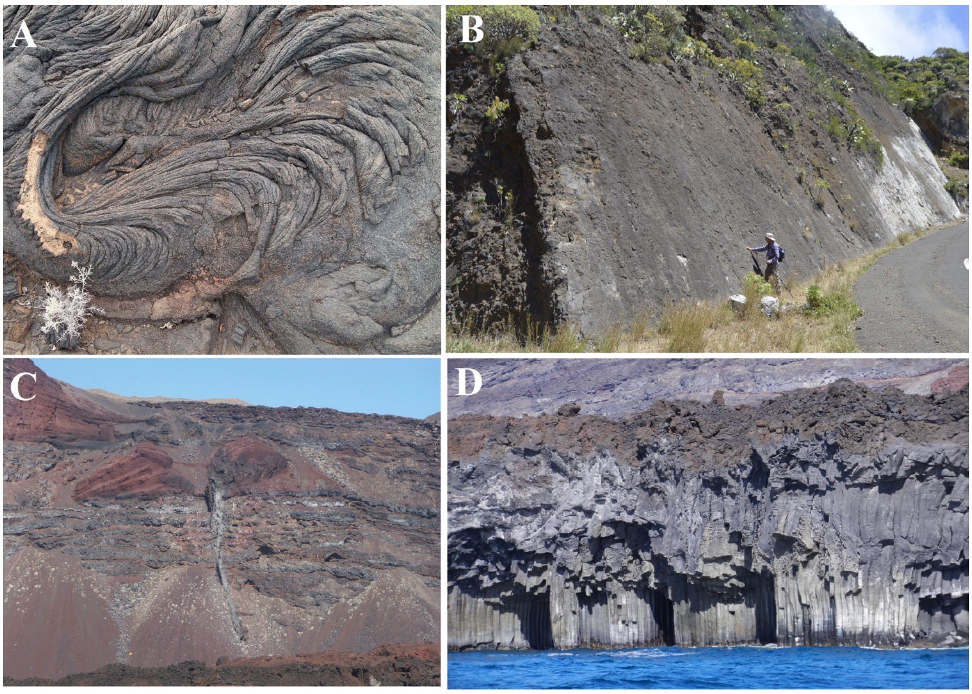

Figure 3. Some GIP or Geosites of the inventory of El Hierro UGG (Casillas et al. 2022): **A)** Pahoehoe lavas from geosite EH-002 El Lajial; **B)** San Andreas fault wall of the geosite EH-006 the San Andreas fault in the Barranco de Tiñor; **C)** The dissected pyroclastic cones of the cliffs (EH-021, La Punta de los Reyes); **D)** Spectacular coastal caves with columnar joints of the EH-040 Coastal columnar joints in the Cachopo area.

posits; geological elements submerged below sea level; volcanic or sedimentary aquifers; paleontological sites; tectonic structures; soils) and ordered according to the main geological interests of each geosite.

Geotourism Potential

Geoturism has become important since UNESCO declared El Hierro Island as a UNESCO GLOBAL Geopark, as noted not only by scientists (Dóniz-Páez *et al.* 2011; Dóniz-Páez *et al.* 2023) but also by many people interested in geological history and landscape. Also, as they realize they are in a geopark because of the signs, ordinary tourists ask about this UNESCO designation. They feel curious about the unique value of El Hierro geology.
The Geoparks Interpretation Centre (in La Restinga) is one of the most visited on the island. Ordinary tourists now want to discover the island's history and its ancient culture, as well as its geological history. And they try to understand that we live in an active land and that a new volcano can surprise us anytime. The last time was a submarine eruption in 2011–2012 (Pérez-Torrado *et al.* 2012), but it can also be a terrestrial one like the one on the nearby island of La Palma in 2021. El Hierro has appeared in different magazines and tv programs worldwide since Tagoro's submarine eruption, which means more people want to visit the island.

It is also important to talk about the island's economy. People learning about El Hierro geology is a new type of tourism, especially quality tourism that respects our environment. Visitors stay at least one week on the island and want to discover our culture, historical heritage, and gastronomy. These people will not put our environmental treasures in danger and will not hesitate to pay for local products. It has also been a new opportunity for guides and enterprises offering experiences. Geotourism has been a diversification factor.

If we talk about the effects on the life and culture of local people, now the inhabitants of El Hierro are more conscious about the land they live in. They respect "rocks" more and have learned a lot about geological culture. An example of this is the great reception that the national "Geolodía" initiative has had in recent years; this is an activity promoted by the Geological Society of Spain to make geology and the geology profession visible through field trips aimed at the general public, carried out in each of the provinces of the Spanish state on the second Saturday or Sunday of May each year, and which is an activity of scientific dissemination, financed by the FECYT, that mobilizes the most people in the same event. In El Hierro, since 2018, when it held a Geolodía by boat (the only one that has been held by this means of transport in Spain), the annual attendance has been around 35 people, which, if we take into account that the island has a total population of about 9000 people, represents a high percentage of participation. Now they know about volcanoes, magma, and lava flows. They must understand that the Earth is alive, and something can happen anytime.

Since UNESCO declared El Hierro as a Global Geopark, environmental programs at schools and also with local communities have been improved with new definitions. Geology has always been a subject in some courses. However, it is now an experience for every child in their first school year. And this experience continues during school life because every year, Geopark staff offer different activities to schools to improve the geological knowledge of El Hierro inhabitants.

Conserving El Hierro Geopark: Actions, Solutions and Limitations

The Canary and El Hierro Governments have always had a policy of respecting and protecting the environmental values of the island. It is no coincidence that El Hierro is the Canary Islands with the highest percentage of protected natural space, 58.1% of its total surface. That is why they did not hesitate to invest in a renewable energy project, in which geology is crucial, a hydro wind power station with two water reservoirs, one of which is a volcano crater that has been waterproofed.

The work of protecting and helping to discover the value of our territory as a Geopark is more straightforward thanks to the collaboration of different networks, which are deeply related: the Spanish, European and Global Geopark networks are really important in our work.

Government and Local Authority Approach and Policy

To be a geopark represents an enormous value for El Hierro Island, which is why the government and geopark management bodies continue working on education. They also collaborate in research on El Hierro geology, not only by investigating on our own, but also collaborating with different universities (La Laguna University, Las Palmas de Gran Canaria University, Barcelona University, Complutense de Madrid University) and welcoming scientists from all over the world. Our best goal will be that everyone living or visiting the island realizes the enormous treasure that geology renders to El Hierro.

We will continue working together with Global, European and Spanish Geoparks Networks, because we consider that we could not reach our objectives alone. We need the help and support of the other geoparks because we have a common purpose: to protect and preserve geology everywhere.

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Appendix A. Inventory of Geological Interest Places (Geosites) of El Hierro Geopark, ordered according to their geological context (Casillas *et al.* 2022). In parentheses, the secondary geological frameworks and the secondary main geological interests.

Geological framework of El Hierro UGG.	**Main geological interest representative of each geological frameworks**	**Code.**	**Geosite denomination.**
(1)-Shield Vulcanism.	Vulcanological (Vul).	EH-001	El Golfo Valley. (6). (Geo).
		EH-003	Las Playas Valley. (6). (Geo).
		EH-009	Remains of the Hoya del Verodal tuff ring.
		EH-021	The pyroclastic cones dissected from the cliffs (La Punta de los Reyes).
		EH-022	El Julan. (6). (Geo).
		EH-024	Ventejís Volcano.(Geo).
		EH-036	Lava-flows loaded with xenoliths from La Caleta.(Pe-Ge).
		EH-037	The trachyte lava-flow of the El Golfo Volcanic Edifice. (Pe-Ge).
	Geomorphological (Geo).	EH-034	The dyke of Jinama Landview
(2)-Rift Vulcanism.	Vulcanological (Vul).	EH-011	La Hoya de Fireba. (Geo).
		EH-014	The Montaña del Tesoro Volcano, its lava-flows and the Tamaduste lava platform. (Geo).
		EH-015	El Pozo de la Calcosas. (7). (Geo).
		EH-025	La Caldereta. (Geo)
		EH-026	El Juaclo de las Moleras. (10). (Geo-Pal).
		EH-028	The field of volcanoes of the Suthern Ridge. (4). (Geo).
		EH-031	The Cala de Tacorón. (Geo).
		EH-041	The montaña de Puerto Naos. (Geo).
		EH-043	The Pico de la Mata cave. (10). (Geo-Pal).
		EH-044	The Curascán cave. (10). (Geo-Pal).
(3)-Central Volcanic complexes.	Vulcanological (Vul).	EH-007	The Tanganasoga volcano. (Geo, Pe-Ge).
		EH-019	The Malpaso salic deposits. (Pe-Ge).

Geological framework of El Hierro UGG.	**Main geological interest representative of each geological frameworks.**	**Code.**	**Geosite denomination.**
(4)-Prehistoric and historical vulcanism.	Vulcanological (Vul).	EH-002	El Lajial. (2). (Pe-Ge).
		EH-004	The Don Justo cave. (2). (Geo).
		EH-005	Orchilla volcanic group-eruptive fissures. Cliffs. (2). (Geo).
		EH-012	The Tagoro Submarine volcano. (2, 8).
		EH-023	The Lomo Negro volcano. (2).
(5) Alluvial and fluvial-torrential processes and deposits.	Sedimentological (Se).	EH-013	The Fuga de Gorreta. (Geo).
		EH-045	The colluviums of the Barranco de las Arenas. (Pal).
	Geomorphological (Geo).	EH-046	Los Jables.
(6)-Gravitational processes and deposits.	Sedimentological (Se).	EH-017	The debris-avalanche deposits from the 2nd gravitational slide responsible for the El Golfo Valley formation.
(7)-Littoral processes and deposits.	Vulcanological (Vul).	EH-015	The Pozo de la Calcosas. (2). (Geo).
		EH-029	Pillow-lava and hyaloclastic rocks at the base of the Tiñor Edifice in Timijirate. (1, 10). (Se, Pal).
	Geomorphological (Geo).	EH-020	The Roques de Salmor. (1). (Vul).
		EH-030	La Maceta. (4).
		EH-033	The Roque de la Bonanza. (1).
		EH-038	Coastal stone arches (Puntas de Gutiérrez). (4).
		EH-040	Coastal columnar joints in the Cachopo area. (4).
	Sedimentological (Se).	EH-027	The Arenas Blancas paleobeach. (4). (Vul, Pal).
		EH-032	The Verodal beach. (4). (Vul).
		EH-039	La Caleta paleobeach. (4). (Vul, Pal).

Geological framework of El Hierro UGG.	Main geological interest representative of each geological frameworks.	Code	Geosite denomination.
(8)-Geological elements submerged below sea level.	Geomorphological (Geo).	EH-048	El Salto. (2, 7). (Vul).
		EH-049	El Diablo Cave. (2, 7). (Vul).
		EH-050	El Bajón. (2, 7). (Vul).
		EH-051	Baja Bocarones. (1, 7). (Vul).
		EH-052	El Arco. (2, 7). (Vul).
		EH-053	La Hoya. (2, 7). (Vul).
		EH-054	Baja de la Palometa. (2, 7). (Vul).
		EH-055	El Charco Manso. (Vul). (2, 7). (Vul).
		EH-056	La Caleta. (2, 7). (Vul).
		EH-057	El Bajón del Puerto. (1, 7). (Vul).
		EH-058	El Roque de la Bonanza. (1, 7). (Vul).
		EH-059	La Baja de Anacón. (2, 7). (Vul).
		EH-060	Los Negros. (2, 7). (Vul).
		EH-061	El Barbudo. (2, 7). (Vul).
(9)-Vulcanic or sedimentary aquifers.	Hydrogeological (Hy).	EH-042	The Garoé. (1). (Vul).
(10)-Paleontological sites	Paleontological (Pa).	EH-008	The log molds of the Montaña Chamuscada lava flows. (4). (Vul).
(11)-Tectonic.	Tectonic (Tec).	EH-006	The San Andrés fault (in the Barranco de Tiñor). (6). (Geo).
		EH-016	The San Andrés fault (in the road to Puerto de la Estaca, in Morro del Jayo). (6). (Geo).
		EH-035	Antithetical faults of the Barranco de las Playecitas. (6). (Geo).
		EH-047	The graben between San Andrés-Tiñor road and La Cumbrecita. (6). (Geo).
(12)-Edaphic.	Edafological (Eda).	EH-010	El Jorado.
		EH-18	Jordana.