Municipal geosites proposal in the coast of Gáldar (NW of Gran Canaria island)

Alejandro Jesús

Rodríguez Rubio

Curso

2023/2024

José Mangas Viñuela

Trabajo Fin de Título para la obtención del título de Grado en Ciencias del Mar

Index

ABSTRACT

The municipality of Gáldar, to the NW of the island of Gran Canaria, has a coastal strip characterized, mainly, by strombolian volcanic eruptions of the Plio-Quaternary Post-Roque Nublo magmatic cycle. With cliffs numerous that reach tens meters high, coastal rocky platforms, caves, erosive remains and occasional beaches of pebbles and sands. Along the 24 km of coastline, 4 geosites have been proposed in which especially volcanic materials of middle Pleistocene age and, to a smaller amount, sedimentary materials, and geoforms and structures with erosive characteristics of marine abrasion along with current sedimentary deposits. In addition to the current geosites proposal, a general coastal georoute has been defined that is divided into 3 stages of about 8 km each, along trails and dirt roads, with more than 20 viewpoints and places of geological relevance. This georoute unites the different geosites and offers the possibility of being an essential tool for geotourism. Likewise, due to the great accessibility and cultural/natural heritage of one of these geosites (Bahía de Sardina), an inclusive route has been proposed for people with physical disabilities (visual impairment and reduced mobility). Finally, a maritime geological route by boat has been proposed and complete the Camino Santiago between the volcanoes of Gran Canaria on the coast of Gáldar (Sardina Lighthouse). The research carried out on the Gáldar coast is original and unpublished in this municipality and will be fundamental in future geoconservation, scientific transfer and coastal management strategies.

Key words: Middle Pleistocene strombolian vulcanism, Geoheritage, Georoutes, Gáldar municipality, NW of Gran Canaria

RESUMEN

El municipio de Gáldar, al NO de la isla de Gran Canaria, cuenta con una franja litoral caracterizada, principalmente, por erupciones volcánicas estrombolianas del ciclo magmático plio-cuaternario Post-Roque Nublo. Con acantilados que alcanzan decenas de metros de altura, plataformas rocosas costeras, cuevas, restos erosivos y ocasionales playas de cantos rodados y arenas. A lo largo de los 24 Km de litoral se han propuesto 4 lugares de interés geológico (LIGs) en los cuales se pueden encontrar materiales volcánicos del Pleistoceno medio y, en menor proporción, sedimentarios, y geoformas y estructuras erosivas de abrasión marina junto con depósitos sedimentarios actuales. Además de la propuesta de LIGs se ha definido una georuta costera general, que se divide en 3 etapas de unos 8 km cada una, por senderos y caminos de tierra, con más de 20 miradores y lugares de relevancia geológica. Esta georuta une los diferentes LIGs y brinda la posibilidad de ser una herramienta esencial para el geoturismo. Del mismo modo, debido a la gran accesibilidad y patrimonio cultural/natural de uno de estos LIGs (Bahía de Sardina), se ha propuesto una ruta inclusiva para personas con discapacidad física (discapacidad visual y movilidad reducida). Por último, se ha propuesto una ruta geológica marítima en barco y finalizar el camino de Santiago entre volcanes de Gran Canaria en la costa de Gáldar (Faro de Sardina). La investigación realizada es original e inédita en este municipio y es fundamental en futuras estrategias de geoconservación, difusión científica y gestión costera.

Palabras clave: Vulcanismo estromboliano del pleistoceno medio, Geopatrimonio, Georutas, municipio de Gáldar, NO de Gran Canaria

1. INTRODUCTION

Research on geological heritage began at the end of the 19th century in Great Britain, a period when the first natural conservation movements began, which later led to a consideration of the geological elements in the natural environment, together with the biological and cultural ones. All these actions led to a conservationist movement in Spain at the beginning of the 20th century, with the declaration of the first national park (Montaña de Covadonga declared in 1918) and nature reserves. The concept of geoconservation consists of safeguarding the geological elements of interest in a particular area, in addition to cataloguing them as geosites, geoparks, natural monuments, among other protection figures. However, in order to bring geological heritage in Spain to the public eye, and thus geoconserve it, legislation was needed, namely Law 42/2007 on natural heritage and biodiversity. This law replaces and improves the previous law 4/89 on Natural Spaces and Flora and Fauna, thus modifying several concepts and giving special importance to the elements related to geoconservation.

The main novelties introduced by Law 42/2007 are of three types[1]:

1) express mentions of geology, geological heritage, geodiversity, geoconservation and geotourism in areas where they were not previously mentioned.
2) those that represent a concrete advance in the inventory, valuation and conservation of geological heritage and geodiversity.
3) those referring to the definition of protection figures that include geological features.

On the other hand, this law defined concepts such as geodiversity and geological heritage, among others. The former, as "the variety of geological elements, including rocks, minerals, fossils, soils, landforms, geological formations and units, and landscapes that are the product and record of the evolution of the Earth" and the latter as "the set of geological natural resources of scientific, cultural and/or educational value, whether geological formations and structures, landforms, minerals, rocks, fossils, soils and other geological manifestations that allow us to know, study and interpret: (a) the origin and evolution of the Earth, (b) the processes that have shaped it, (c) past and present climates and landscapes, and (d) the origin and evolution of life".

[1] (IGME) https://www.igme.es/patrimonio/PG/patrimonioG.htm

1.1. Background

The cataloguing of geosites in the Canary Islands is extremely recent, as the Spanish Geological and Mining Institute (IGME) studied them in the autonomous community of the Canary Islands in the 2010s, and included them in its web repository (https://info.igme.es/ielig/), from 2020. However, when the IGME made the geological map of Gran Canaria, which was published in 1992 (Balcells et al., 1992), it already included 10 geological points of interest to be considered and conserved on the island. On the other hand, the different maps of the island of Gran Canaria at a scale of 1:25,000, published by the IGME in 1990 (Balcells et al. al., 1990), do not include the geological points of interest. In this sense, there are currently no geosite defined on the NW coast of Gran Canaria (mainly in the municipality of Gáldar), hence this research work.

1.2. Objectives

The main objective of this work is the definition of geosite and propose geoheritage diffusion strategies in the coastal strip of the municipality of Gáldar, within the Delimitation of the Maritime-Terrestrial Public Domain (Law 2/2013), thus covering a wide area that goes from the intertidal zone to about 200 metres inland, and along the entire coastal perimeter of Gáldar. However, in order to achieve the general objective, the following specific objectives are necessary:

a) A search for documentation on the geology of the island of Gran Canaria, in general, and of the coast of Gáldar, in particular.
b) Carrying out fieldwork along the entire Gáldar coastline, where an inventory of the different geological materials, geomorphologies and existing structures will be carried out.
c) Characterization, diagnosis and evaluation of the different geological elements found on this coastline.
d) Selection of the most significant and singular geosites in the study area, being the most representative due to their geodiversity and which help to understand the geological history of this coast.
e) Definition of strategies for transferring the results obtained in the research, both in scientific and educational forums, and to the general public.

2. Study area and geological framework

The island of Gran Canaria is located within the Canary archipelago, which is made up of eight islands and several islets located between latitudes 27 and 30º N (Fig.

1). This archipelago has a magmatic origin and are intra-oceanic plate volcanic islands, associated with a mantle anomaly in this area (hot spot), which has been active for the last 142 Ma (Van den Bogaard, 2013) and has given rise to a score of submerged mountains distributed to the north and south of the archipelago. Islands and submerged mountains appear over a Jurassic oceanic crust, 165 Ma ago. The Canary Islands have been formed from thousands of submerged and subaerial eruptions, with the oldest submarine volcanic rocks appearing in Fuerteventura some 34 Ma ago (Oligocene) and the most recent eruption of the Tajogaite on La Palma (2021). The islands with the oldest subaerial eruptions (from the Miocene, with the oldest ages of 22.4 Ma, to the present day) are the eastern islands (Fuerteventura, Lanzarote, Gran Canaria and Tenerife) and the most modern are the western islands (La Palma and El Hierro) with volcanism from the Quaternary, with the oldest ages of 1.7 Ma, to the present day. The study area is located in the northwest of the island of Gran Canaria, more specifically in the municipality of Gáldar, with materials associated with middle Pleistocene subaerial volcanic eruptions (less than 0.8 Ma).

Figure 1. Location map of the study area on the coast of Gáldar, Gran Canaria (Canary Islands) (Map prepared with GoogleEarth).

2.1. Geological framework of Gran Canaria

The island of Gran Canaria has a long geological history as it has volcanic and subaerial sedimentary materials, together with different geomorphologies and structures formed from 14.5 million years ago (middle Miocene) to the present day (Balcells et al., 1990 a and b; Ancochea et al., 2004; Carracedo and Troll, 2016; Mangas, 2020). The submerged materials from the seabed to the sea level surface have not yet been studied in detail. This island shows Miocene igneous stages of shield building and alkaline decline (14.5 to 7.3 Ma), Mio-Pliocene erosional (7.3 to 2.6 Ma), and Plio-Quaternary volcanic reactivation (5.3 Ma to present) (Fig. 2). The first stage, known as the shield-building phase, was an effusive volcanic process lasting 400,000 years (McDougall and Schmincke, 1976). In this phase there was practically only emission of basaltic lava flows with few pyroclastic deposits. These emissions resulted in lava piles of up to 1 km, so that the volume emitted was about 1,000 km^3 (Schmincke, 1976 and 1990).

In the next stage, the alkaline decline phase, the island has an emptying of the magmatic chamber and leads to a collapse of the edifice, forming the Tejeda caldera. This collapse was followed by effusive and explosive volcanic episodes with lavas and ignimbrites of trachytic-riolitic and trachytic-phonolitic compositions. This eruptive phase lasted 6.8 Ma, giving rise to lava piles (effusive) and ignimbrites (explosive), with a volume of about 1000 km^3 (Fuster et al., 1968; Balcells et al., 1990; Freundt and Schmincke, 1995; Schirnick et al., 1999). This magmatic constructive stage was followed by a phase of volcanic inactivity, known as the erosional phase, which lasted approximately 2 Ma (7.3 to 5.3 Ma. upper Miocene). During this phase, numerous gullies were generated and sedimentary deposits of the fandelta type were formed at the mouth, giving rise to the Detritic Las Palmas Formation (upper member). This erosive stage was followed by a period of volcanic reactivation which lasted until 70 A.D., with the last volcanic eruption in the Pico and Caldera de Bandama (Fuster et al., 1968; Pérez-Torrado et al., 1995; Guillou et al., 2004). In this stage of island rejuvenation, the Roque Nublo Group was formed, with the formation of a Pliocene stratovolcano, active between 5.3 and 2.8 Ma, and emitting a total volume of lavas and ignimbrites of about 220 km^3 (Pérez-Torrado et al., 1995). In the final stages of the Roque Nublo cycle, eruptions related to the post Roque Nublo Group (Guillou et al., 2004), with a smaller volume of volcanic materials, about 10 km^3, where basanitic and basaltic lavas and pyroclasts predominate, associated with Pliocene fissural effusive volcanism (less than 2.8 Ma), monogenetic volcanoes with platform lavas in the Lower Pleistocene (less than 1, 8 Ma), and strombolian eruptions with flows and pyroclastic deposits and, to a lesser extent, hydromagmatic eruptions of the same composition, which are dispersed throughout the island, with ages ranging from the middle Pleistocene (<0.8 Ma) to the Holocene (<0. 01 Ma). It should also be noted that in this phase of more modern volcanic reactivation (post Roque Nublo Group) there were erosion and sedimentation processes contemporaneous with the volcanic stages, as evidenced by the sedimentary deposits included in the middleand upper members of the Detritic Formation of Las Palmas (Ancochea et al., 2004).

2.2. Geological framework of Gáldar

The study area has approximately 24 km of rocky coastline, made up of middle Pleistocene volcanic materials (cones, lava flows and pyroclastic deposits) of the Post

Roque Nublo Group, which have been subsequently eroded giving rise to cliffs, coastal platforms, islets and other erosional morphologies, together with subaerial sedimentary deposits (paleosols, eolianites, alluvium and colluvium) and marine deposits (paleobeaches). The geochemical composition of the volcanic rocks of the coast varies from ultramafic (basanites) to mafic (basalts and tephrites) and they are part of the Pleistocene volcanic reactivation stage of the island. On the other hand, Holocene (<0.01 Ma) morphologies and structures associated with the erosive action of the sea can be observed in the study area (cliffs, coves, caves, sinkholes, etc.) and in the small coves and beaches, associated with the mouths of ravines, there are deposits of sand and pebbles. There are also alluvial deposits in the present-day ravines, colluvial deposits on their slopes and soils in the interfluves and flat areas. From a cartographic point of view (Fig. 3), practically the entire surface of the study area on the coast is volcanic material from the Post Roque Nublo cycle, with an ultramafic and mafic composition, with morphologies of lava piles and, to a lesser extent, volcanic edifices. The surface area occupied by sedimentary deposits and morphologies is minimal in this area, almost negligible, as the small outcrops are often not mapped on IGME geological maps (Balcells et al., 1990 a and b).

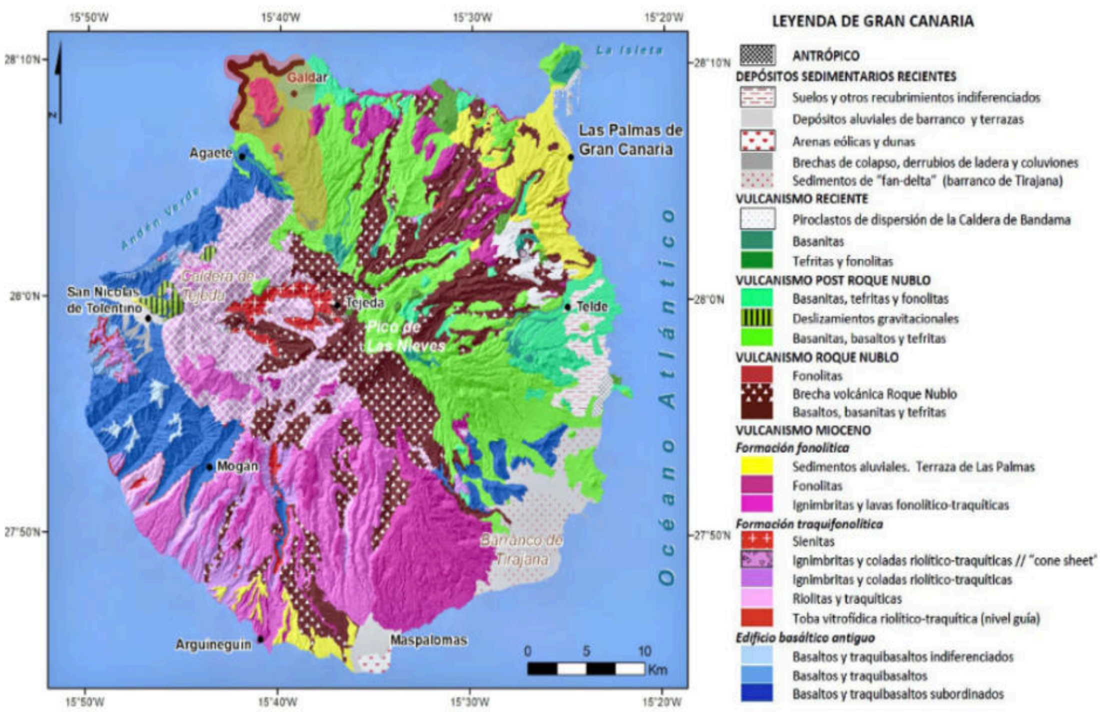

Figure 2. Geological map of Gran Canaria where the shaded area shows the municipality of Gáldar and the study area is the black line (IGME 2015).

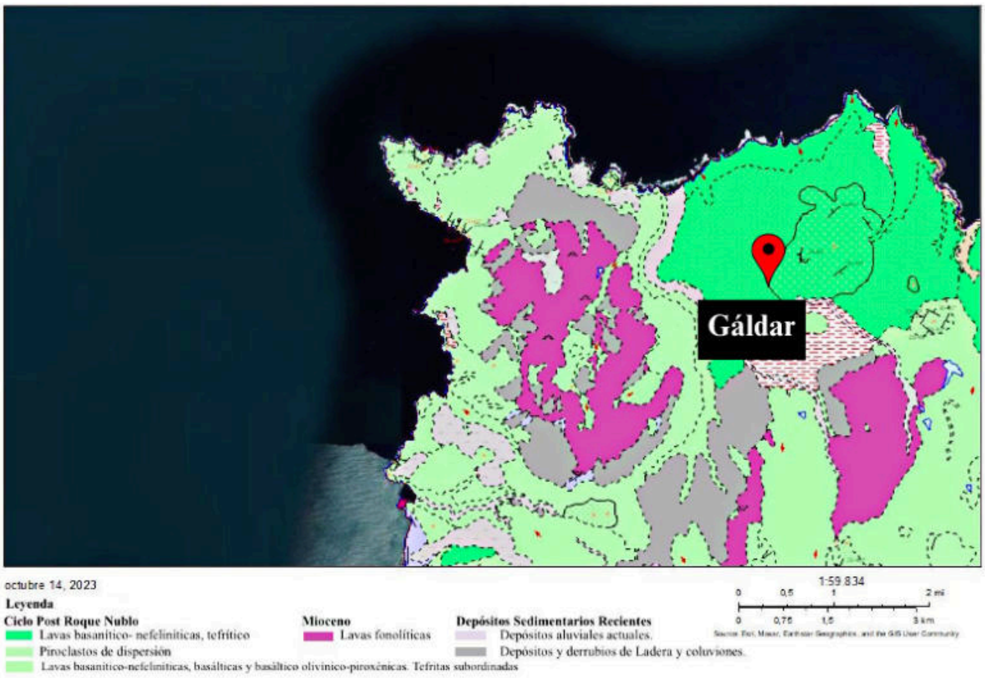

Figure 3. Geological map of Gáldar in the NW of Gran Canaria (Map prepared with the IGME viewer).

3. Methodology

The methodological document for the elaboration of the Spanish Inventory of geosites (IELIG) of the Spanish Geological Survey (García-Cortés et al., 2018) has been taken as a reference for this work. However, it will be used with modifications, since some sections of the document, such as, for example, the surveys to specialists on the geodiversity of the study area and the processing of the data results, would require more time.

The steps that have been taken to carry out this work are as follows:

3.1. Scale of work and establishment of the study area

Initially, the aim of this research was to study the coastal geological features of the municipalities of Gáldar and Guía, but in view of the variability of the geodiversity of the 24 km long stretch of the coastline of Gáldar, it was decided not to analyse the geological features of the coast of Guía.

3.2. Bibliographic and documentary compilation

In this section, a search was carried out for scientific, educational and cultural documents on the geological heritage and geology of the study area, mainly in databases available on the internet and in publications referenced in the libraries of the ULPGC. In general terms, it can be said that the documents are scarce, with geological maps and their descriptive memories of the northwest of the island and some scientific publications of nearby areas that can be interrelated with the geology of the Gáldar coast standing out.

3.3. Field campaigns

A dozen field trips were planned to identify materials (rocks, minerals, sediments and fossils), describe geomorphologies and analyse geological structures along the 24 km of coastline, one of the objectives of this study. The campaigns also involved taking notes of the geological features encountered, taking general and detailed photographs, and compiling vulcanostratigraphic columns. At all times, geological cartographies at 1:100,000 and 1:25,000 scale were used, and in places with internet coverage, the websites of GRAFCAN (idecanarias), Google Earth, among others.

3.4. Study and description of the geosites, and diffusion strategies of coastal geological heritage

The descriptive results obtained in the field campaigns were studied and interpreted in the office, together with the bibliographic documentation compiled previously. In this way, the sites and places where the geological elements were most representative of the geological history of the study area were selected, those which were singular, unique and significant due to their geological characteristics, their state of conservation, their location and access with respect to urban infrastructures and agricultural and livestock farms, and their relationship with other elements of natural and cultural heritage were analysed. This work of description, analysis and selection was carried out by the work team (tutor and student), and the decision was taken to establish 4 geosites along the entire coastline. Likewise, it was considered not to make the descriptive sheets of the geosites established in the Spanish Inventory of Places of Geological Interest (García-Cortés et al. 2018), as in this case the geosites were of a municipal and local nature.

On the other hand, with all the geodiversity results obtained, several georoutes have been established to bring this geological knowledge to scientists, teachers and the general public, with the aim of developing geotourism and geoconservation actions in this natural heritage.

4. Results

In the field campaigns, all the geological information of the Gáldar coast was collected (study and interpretation of materials, geoforms and geological structures), and in the office, bibliographic documents on local geology and articles and documents dealing with geological heritage and geodiversity in general and at a more local level were analysed. Data processing and after much deliberation, 3 geosites were first estimated on the west coast and named Barranco del Juncal-Punta Gorda, Costa Botija and Bahía de Sardina-Cumbrecillas del Faro. Subsequently, noting that we had not defined any geosite on the north coast of the municipality, and knowing the socio-cultural public use that takes place in this area, and thinking about future strategies for the dissemination of geological heritage and the determination of municipal geoconservation figures, we added another geosite on the north coast, called Caleta de Abajo-La Furnia (Fig. 4).

The geological elements (materials, geomorphologies and structures) of the proposed coastal geosites are described below.

Figure 4. Cartography of the definitive coastal geosites for the municipality of Gáldar (map produced with GoogleEarth).

4.1. Geosite 1 Barranco del Juncal-Punta Gorda

This first geosite is located in the southernmost part of the coast of the municipality and is the bay of Juncal, and more specifically, the north wall. This is because the southern wall corresponds to the municipality of Agaete (outside our study area). However, it is to consider the possibility of joining the whole bay as a single geosite because on its south wall there is a unique endogenous phonolitic dome which is a small magmatic chamber, consisting of a felsic plutonic rock with microcrystals of clinopyroxene and feldspar, and fragments of larger basaltic xenoliths and light shades (Arencibia-Pérez and Mangas, 2019). This dome is genetically related to the Miocene alkaline decline stage of the Cruz Grande stratovolcano (1st magmatic cycle of Gran Canaria), in areas outside the Tejeda caldera. Topographically, it stands out as an erosive remnant on the southern slope of the bay of El Juncal, as it is a more homogeneous and harder rock in the face of marine erosion, compared to the materials that make up the cliff to the north, which are piles of basaltic mafic lavas and pyroclasts, which are more heterogeneous and softer in the face of the sea. The basaltic materials show phenocrysts of orange-toned oxidised olivine and black pyroxenes on a matrix of greyish volcanic glass, also containing a small proportion of empty or filled vacuoles of secondary neo-formation minerals (ceolite and carbonate minerals). These rocks are of middle Pleistocene age and are associated with the stage of island volcanic reactivation (Post Roque Nublo Group, which is the Plio-Quaternary 3rd magmatic cycle of the island). The area of this geosite is 281.8 square metres, considering the whole bay, thus including the phonolitic dome to the south and the lava flows and pyroclasts to the north. In the northern cliff, formed by materials originating from basaltic strombolian eruptions, we can distinguish different massive lava flows with columnar disjunction, breccias and slags associated with the bases and roof of the lava flows, and levels of fall pyroclasts deposits (Fig. 6 A, B and D) and a level of bombs of decimetric sizes, which appear in a small valley in the upper part of the cliff (Fig. 6 C), all of them related to nearby emission centres (El Cardonal cone) (Fig. 5 A). From a geomorphological point of view, the coastal abrasion platform is currently active and visible in the intertidal zone, together with sinkholes, caves and embayments produced by marine erosion at the base of the cliff. Juncal beach is an example of a pebble beach of metric dimensions in the intertidal and subtidal zones, with clean and transparent waters, which indicates that throughout the year there is an essentially erosive marine dynamic. On the other hand, in the Juncal ravine, conglomeratic deposits of alluvium are observed in the channel and colluvium on the slopes.

This geosite was chosen because of the presence of felsic (phonolites unique to the whole Gáldar coast) and mafic (basaltic) magmatic materials together with distinct outcrop morphologies and structures, with the variety of marine erosional geoforms, in a relatively small area.

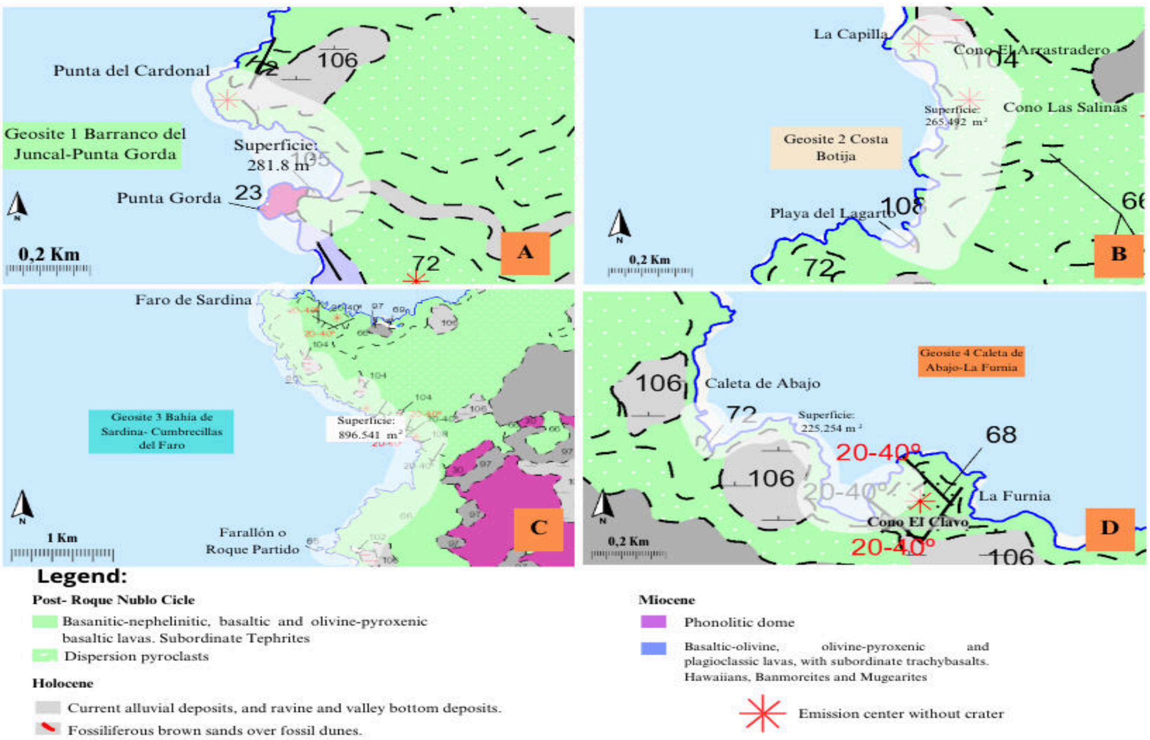

Figure 5. Continuous Geological Map of Spain at scale 1: 25,000 of Geosite 1, 2, 3 and 4, with the proposed area shaded in white (IGME).

4.2. Geosite 2 Botija Coast

This geosite is located 1.5 km north of the El Juncal ravine and runs from the Lagarto beach to the point known as La Capilla, with a surface area of 265,5 square metres. This geosite presents along its coastal route a sample of several middle Pleistocene strombolian volcanic cones, cut by marine erosion known as Las Salinas and El Arrastradero (Fig. 5 B), whereby the deposits of fall pyroclasts of different sizes (lapilli, scoria and bombs) with different inclinations can be distinguished (Fig. 7 F and G). Likewise, in the cliffs there are lava piles of olivine-pyroxene basalts (Fig. 7 A), most of which are of the malpais type (aa lava flows), with massive flows in the centre and very vesicular scoriaceous areas, both at their base and at their top (Fig. 7 D, F and G). Geomorphologically, small coves with sandy beaches and boulders are visible, and the cliffs appear in intertidal zones with marine abrasion platforms, caves, sinkholes and giant marmites (Fig. 7 C and D). In the upper parts of the cliffs there are Pleistocene paleosoil deposits, with sandy and silty granulometries, without stratifications, and containing remains of land snails of the genus *Theba*, scarce rhizolites and anthophora nests, whose origin is controversial, but believed to be lobster (Fig. 7 B and E), giant kelp.

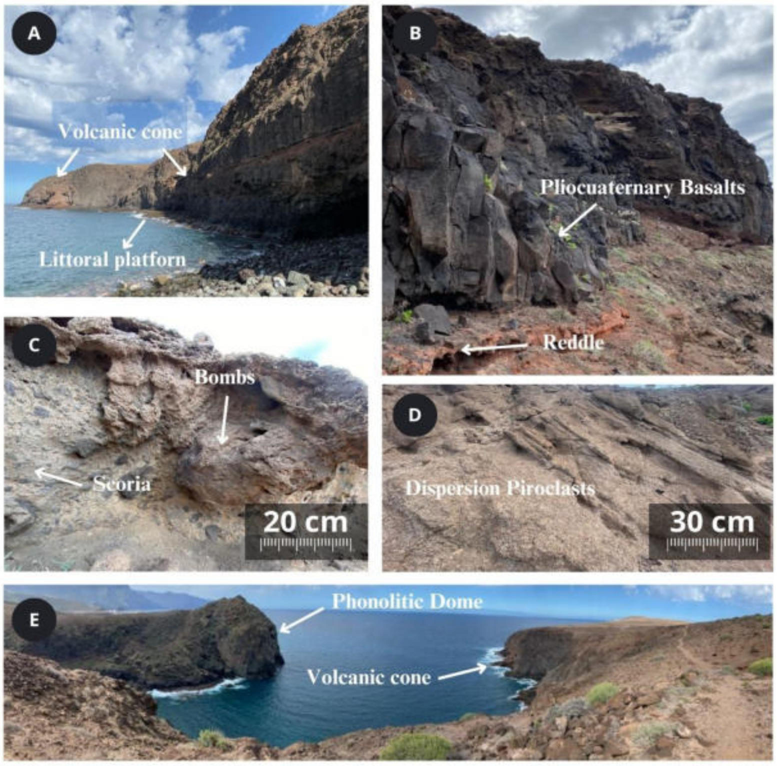

Figure 6. A) Northern cliff wall of El Juncal Bay with lava and pyroclastic piles. B) Quaternary basaltic lava with columnar disjunction and reddish paleosol level (almagre). C) Detail of the valley at the top of the cliff with the presence of scoriaceous pyroclasts and decimetric bombs. D) Laminated lapilli-sized scattered pyroclasts in the upper part of the northern cliff. E) Panoramic view of Juncal Bay showing the variety of materials and geoforms on the two cliff slopes, and the coastal path which forms part of the Galden georoute defined in this work.

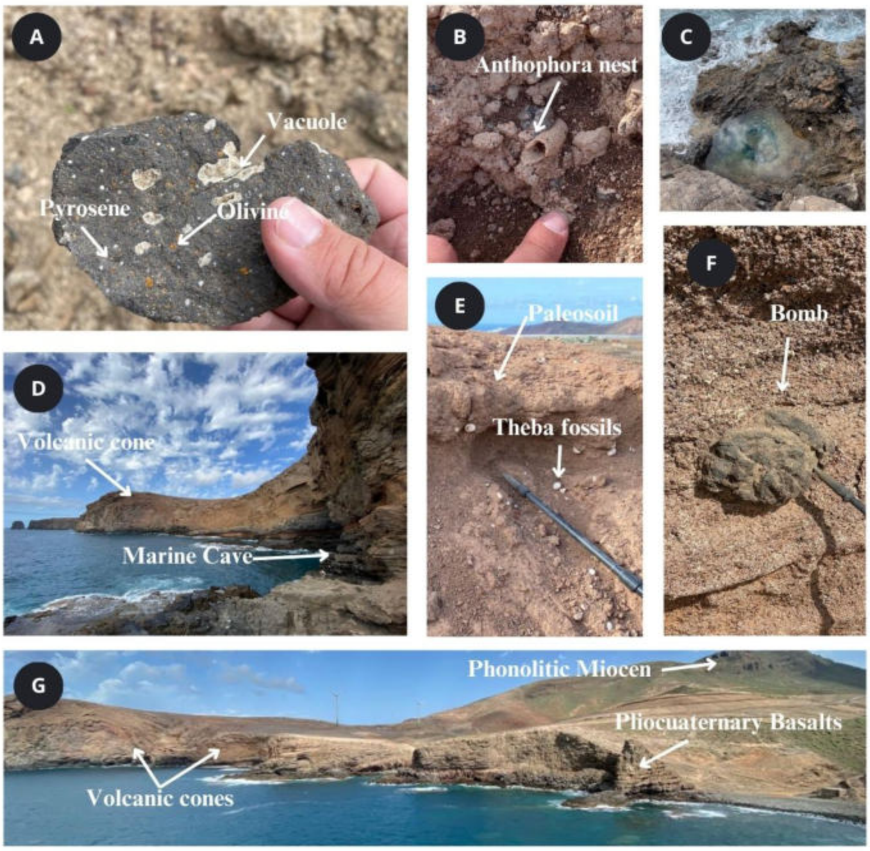

Figure 7. Geosite 2 A) Detail of a sample of olivine-pyroxene basaltic lava. B) Middle and Upper Pleistocene palaeosol containing anthophoran nests. C) Giant marmite morphologies in the intertidal zone of the Botija area. D) Northern view of the cliffs of the Botija coast with Quaternary volcanic, lava and pyroclastic materials of basaltic composition. E) Paleosol with land snails of the genus *Theba* in the area of La Capilla. F) Detail of a volcanic bomb within pyroclastic debris in the area of the mouth of the Cueva Lapa ravine. G) Panoramic view of the Bay of Botija coast, essentially of Quaternary basaltic volcanic composition, with pebble and sandy beaches and in the background the Natural Park of the Miocene phonolithic massif of Amagro.

4.3. Geosite 3 Bahía de Sardina-Cumbrecillas del Faro

This geosite is the largest of the four defined in this work and runs from El Arrastre to the Punta del Faro de Sardina, with a coastal length of 4.6 km and occupying a total area of 896,541 square metres (Fig. 5 C). The volcanic materials that have been identified along the coastline of this geosite are associated with middle Pleistocene strombolian volcanic eruptions of the Post Roque Nublo Group. Therefore, several conical volcanic edifices, subvolcanic dykes, pyroclastic fallout deposits and scoriaceous lava flows have been observed (Fig. 8 A, B, C, F and G). Quaternary marine erosion has generated cliffs tens of metres high in the materials of Post Roque Nublo) and sand and boulders have been deposited in the inlets and coves. The normal retreat of the cliff over time forms monoliths and erosional remains such as the Farrallón (Roque Partido), together with coastal platforms of marine abrasion, erosional corridors, sinkholes and caves (Fig. 8 A, B, C and F). In subaerial areas, sedimentary dynamics associated with the action of surface water, gravity and wind have given rise to sandy deposits of eolianites (paleodunes) with remains of anthophora nests and fragments of land snails of the genus *Theba* and paleosoils of cream-coloured sandy silts with the same fossil remains (Fig. 8 D). These sedimentary deposits have been exploited throughout the 20th century for construction aggregates and only small outcrops and in extreme cases, only the surfacer with machinery marks remein.

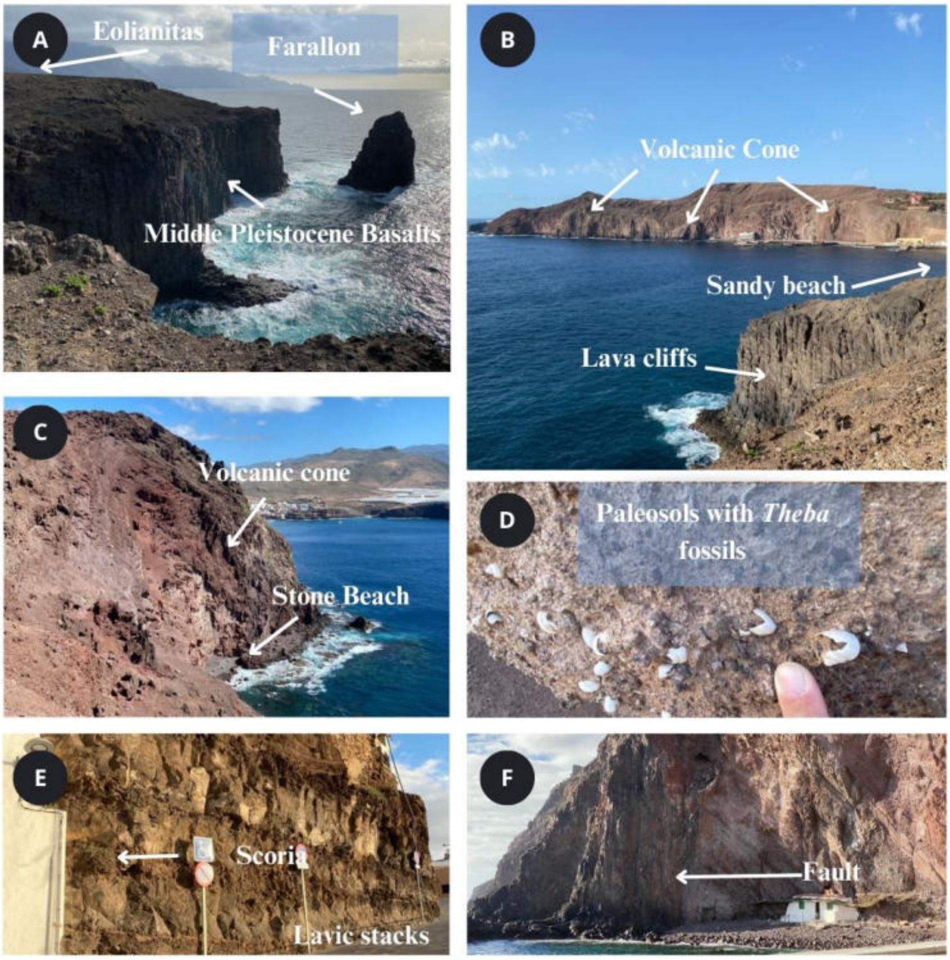

Figure 8. Geosite 3 A) Detail of the southern view of Sardina Bay with lava cliffs with columnar disjunction and the Farallon erosional monolith. B) View of the northern cliff face of the bay, showing a series of several strombolian volcanic cones partly dismantled by marine erosion. C) Detail of the cliff showing the interior of a volcanic edifice with pyroclasts of different granulometry. D) Pleistocene paleosol with fossil remains of land snails of the genus *Theba*. E) View of a pile of scoriaceous lavas (aa-type malpais), with a massive centre and slag at the top and base, on the descent to Sardina beach. F) Detail of a fault at the end of the Sardina promenade where inclined pyroclastic levels associated with a volcanic cone and a feeder dyke come into contact.

4.4. Geosite 4 Caleta de Abajo-La Furnia

The northernmost coastal geosite in the municipality of Gáldar is "Caleta de Abajo-La Furnia" and stands out because it is the one with the greatest geodiversity, as the only hydromagmatic volcano (Fig. 9 C) in the study area, intertidal marine palaeobeach (Fig. 9 A, B and D) and terrestrial palaeosoils have been identified, as well as various strombolian volcanic edifices, , the best preserved volcanic cone being that of Punta del Clavo (Fig. 9 E and F). It also shows diverse geomorphologies and structures associated with the geological action of the sea, surface waters and gravity. Thus, along the coastal strip there are frequent littoral platforms, islet erosive remains, rocky landslides and cliffs of several metres in height where the different volcanic materials are shown. In the bays and coves there are occasional accumulations of detrital sediments forming pebble beaches and golden sands. At the mouths of some ravines and gullies that reach the coastal area, conglomeratic levels of alluvium and colluvium are observed on the slopes together with anthropic debris deposits. The coastal length of this geosite is 1.45 km and the total area is 225,3 square metres (Fig. 5 D).

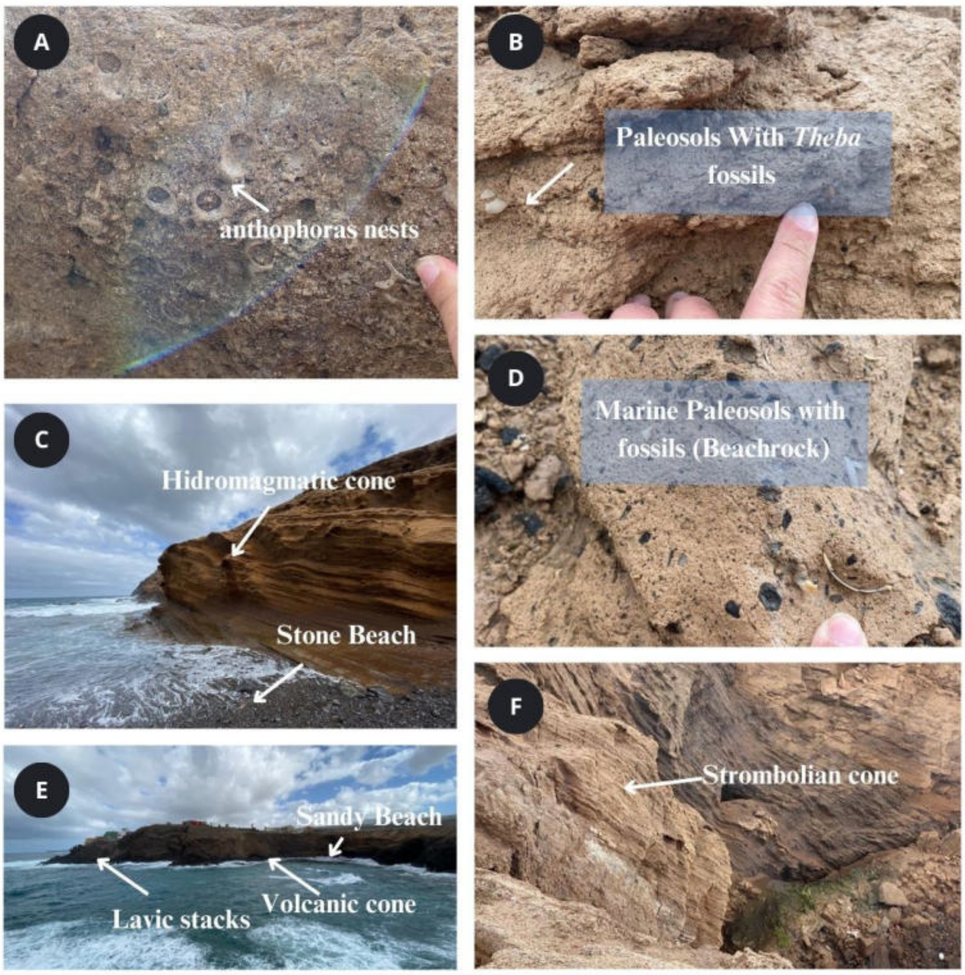

Figure 9. Geological elements of the geosite Caleta de abajo- La Furnia. A) Detail of anthophora nests in a level of eoliantia in the La Trinchera area. B) Palaeosols containing fossil remains of the genus *Theba*.

C) Coastal cliff in the Caleta de Abajo beach area, showing the pyroclastic bands of water-magma interaction of the only hydromagmatic cone in Gáldar, next to a pebble beach. D) Marine paleo-level with remains of marine molluscs (beachrock). E) General view of cliffs with lava flows and pyroclastic deposits associated with a Strombolian cone in the bay of El Clavo. F) Detail of basaltic pyroclast lamination related to a strombolian cone found in the El Clavo area.

4.5. Rest of the coastal coastline of the municipality of Gáldar

The above geosites include the areas with the greatest geological diversity and are part of the geological heritage of the municipality. However, there are several places with certain unique geological elements that should be pointed out, although it does not form a geosite. Thus, in the area between Dos Roques and Caleta de Arriba (area of the pediment), there are several geological elements such as, for example, a sedimentary beachrock deposit (Fig. 10 A, B and D), sandy beaches, sedimentary paleo-levels with rhizolites (Fig. 10 C), and lavas morphologies with alteration structures in onion peels (Fig. 10 E). However, these areas do not have a significant geological diversity and therefore it has not been decided to propose further geosite in addition to those named above. Nevertheless, thanks to the multi-stage georoute it is possible to visit and get to know all these specific points of high geological interest.

Figure 10. A) Conglomeratic beachrock near Bocabarranco beach. B) Beachrock on one side of Bocabarranco beach. C) Lava cliffs separated by reddish paleosoil levels (almagres) in the Frontón area. D) Marine paleo-level with remains of marine fossils (beachrock) on the Agujero beach. E) Detail of lavas with onion peel alteration in the Frontón area.

5. Diffusion of the coastal geological heritage of Gáldar

Due to the lack of scientific studies on the geology of the public maritime-terrestrial domain in the municipality of Gáldar, there is no written or telematic document on the geodiversity of this coastal strip and its geological heritage. Over the years, especially in the 20th century, the materials, geoforms and geological structures present on the coast of Gáldar have been significantly altered by residential, infrastructure, agricultural and industrial uses. This has led to the degradation of some of the geosites or specific points outside these geosites, such as, for example, the exploitation of the eolianite and paleosoil deposits which were found in geosite 3 (Bahía de Sardina-Cumbrecillas del Faro) and which have partially or completely disappeared as they were used for construction aggregates. In order to disseminate the geological heritage described in the results section, a series of georoutes have been defined so that the general public, either freely or with outings organised by environmental guides, can follow them and learn to observe, recognise and enjoy all the coastal geological wealth of the municipality. In addition, it is essential to bring these geological elements closer to the students, especially those in the 1st, 2nd and 4th years of ESO, baccalaureate, vocational training and university.

5.1. Georutes

During the different field campaigns carried out in this research, the best access routes were analysed in order to reach as easily as possible both the 4 geosites defined and the geological points of interest, which are distributed along the 24 km of the municipality's coastline. In this sense, several georoutes have been defined: i) a complete coastal route along the Gáldar coastline divided into 3 stages (Fig. 13); ii) inclusive for people with disabilities at the access to the beach of Sardina (Fig. 11); iii) maritime by boat along part of the coast (Fig. 14 A); iv) Jacobean route between volcanoes to the coast of Gáldar, which would connect the Jacobean route from Maspalomas in the south of the island of Gran Canaria to the church of Santiago Apóstol, in the municipal capital of Gáldar, until reaching the coast at the point of the Sardina lighthouse (Fig. 14 B). A brief description of each of these is given below.

5.1.1. Georuta along the coastline of the municipality of Galdar

The entire 24 km coastal trail can be completed in one day or subdivided into shorter stages, each of 8 km approximately, to be completed in a more leisurely fashion. This georoute runs along mostly dirt tracks and is of a low degree of difficulty for the general public. The trail would start in the village of Caleta de Arriba and end in the Barranco del Juncal or vice versa. The complete trail includes the most significant materials, geomorphologies and geological structures described in this work, which represent an important part of the geological history of the municipality of Gáldar and, to a lesser extent, of the island of Gran Canaria. In order to provide participants in this georoute with basic geological information, a page has been set up on Wickiloc. Here, hikers can recognise and identify the path they have to follow, the most notable elements of geodiversity are described, illustrated with some general and detailed photographs. The route can be viewed at the following link:

https://es.wikiloc.com/rutas-senderismo/ruta-geologica-por-el-litoral-del-municipio-de-galdar-georuta-153266020

In the link above you can see the Georute along the coastline of the municipality of Gáldar. However, we recommend the completion of this trail in 3 smaller stages (Fig. 13), which are:

1. The first stage begins in the village of Juncal, although it is possible to start from the port of Agaete, up to the Bay of Sardina. This stage has been called the Georuta of the ancient Canary Islanders, as it is possible to see several pre-Hispanic settlements in the area. The journey takes 9 km and 5 to 6 hours.
2. The second stage starts from Sardina beach to Dos Roques beach. This stage has been called the hydromagmatic Georute, because in this stage it is possible to appreciate the only hydromagmatic volcano in the municipality. The journey is 8 km long and takes 4:30 to 5:30 hours.
3. The last stage, called Georute de las Olas, starts in Caleta de Arriba and goes through the fronton area to Los Dos Roques, where it is possible to see waves of considerable height. It is a 7 km, 3 to 4 hour trip.

It should be noted that the time mentioned is a guideline and is calculated considering stops and short breaks.

Later on in time, and with economic means provided by the municipal or island administration, more geological information would have to be offered to hikers, both in written documents such as a triptych-brochure or municipal-insular web page and by placing different types of signage (signs with the route and point where one is on the route, geological information of the place in text or QR code, figures of topographical sections, geological diagrams, illustrative geological photographs, among other elements).

5.1.2. Georute Sardina-Inclusive

The bay of Sardina del Norte is very well communicated by road from the GC-3, arriving in 5.4 km by the local road GC-202. It has easy parking for cars and buses, and to reach the coast there is an asphalted road with access only for residents with cars, although it can be used on foot by the general public. It is one of the blue flag beaches on the island, and the only one in the municipality of Gáldar, so to obtain this award it is necessary to meet a wide range of quality requirements. In this sense, people with disabilities can easily use the public infrastructures to access the beaches (there are lifts and special pavements for the visually impaired) and various docks containing tourist facilities of different kinds. If we add to these quality features, the fact that along the access, different geological elements can be seen on the slopes of the road and at several viewpoints, it was decided to develop an inclusive georoute (Figs. 11 and 12). The itinerary of this route is short, approximately 2 km, with a downhill and flat topography, which can be carried out on foot, as well as in wheelchairs, and returned by motorized means. From a geological point of view, it is possible to explain the strombolian eruptive processes of the Post Roque Nublo Group, from the middle Pleistocene (less than 800.000 years before the present), since the cliffs show the remains of three volcanic cones that have been partially dismantled by marine erosion, and where there are inclined or sub-horizontal levels of altered pyroclastic fall deposits of reddish, orange and blackish tones, of lapilli, spatter and bomb size, occasionally cut by feeder dykes, faults and fractures. There are also some piles of scoriaceous lava flows (type aa) on the cliff, and to the south the cliff coast can be seen with inlets and projections, which is made up of a powerful lava flow, with columnar disjunction, and at the tip of which is the Farallón or Roque Partido (Split Rock). At the same time, the marine dynamics have also generated several sandy beaches of blackish, reddish, brownish tones, depending on the nearby eroded pyroclasts, rocky coastal platforms and in the lower parts of the cliff there are erosive corridors, sinkholes, caves and giant marmites. Some of these geological features have been described in the triptych shown in figure 12.

Figure 11. Itinerary of the Sardina-Inclusive georoute on the northern slope of Sardina Bay.

Figure 12. Proposed triptych with information on the geodiversity that can be observed in the inclusive georoute of Sardine Bay.

5.1.3. Georute Maritime

As the study area is close to several ports (Agaete and Sardina del Norte), a maritime route has been proposed where the public could use tourist boats or catamarans, such as those operating in the southwest of the island of Gran Canaria, so that, sailing close to the coast, the main geological elements of the geosites defined in this work and those defined by Arencibia-Pérez and Mangas (2019) on the coast of the municipality of Agaete can be observed. The proposed route is shown in Figure 14 A, in red, leaving from the port of Sardina in the direction of Agaete or vice versa, depending on weather and sea conditions. The route from Sardina to the northern boundary of the municipality of Gáldar has not been proposed, as the sea conditions for navigation are generally not good. On the other hand, in both ports there is public transport or the possibility of planning private transport to get to the port of departure without having to repeat the route by boat.

5.1.2. Georute "Jacobea" (Jacobean)

In recent years, Gáldar has managed to have its church of Santiago Apóstol converted into a Diocesan Sanctuary, which means that in the Jacobean years the number of visitors to the municipality increases. On the other hand, for some years now, the route known as the ``Jacobean route between volcanoes" has been defined, which starts at the Maspalomas lighthouse in the south of the island and ends at the church of Gáldar, with numerous walkers taking it throughout the year and increasing in number in the Jacobean years. With this in mind, it was thought that the path between volcanoes could be extended to the coast, ending at the point of the Sardina lighthouse, or even in the bay of Sardina itself (Fig. 14 B).

Figure 13. Itinerary of the Georuta along the coastline of the municipality of Gáldar, divided into three stages: Georuta of the ancient Canary Islanders (red), Hydromagmatic Georuta (orange) and Wave Georuta (green).

Figura 14. Itinerary of the maritime georoute (A) and the Jacobean georoute (B) proposed from the church of Santiago Apóstol in Gáldar to the Sardina lighthouse.

This is a simile of what happens in Galicia with the end of the Camino de Santiago, in Santiago de Compostela, and then some walkers finish their journey in Finisterre (Costa de la Muerte). In this way, with the georoute proposed here, it would be possible to connect the historic centre of Gáldar with the second sub-stage of the proposed georoute (Hydromagmatic Georuta) and for walkers to enjoy the agricultural landscape of banana plantations and the coast, while learning about the geological elements that this coastal area treasures (Fig. 14 B).

6. Discussion

Gran Canaria is the island with the second highest number of geosites in the whole Canary archipelago, namely 53, included in the Spanish inventory of geosites, defined by the Department of Geological Heritage of the Spanish Geological and Mining Institute (Galindo et al., 2022, https://info.igme.es/ielig/). None of these sites are listed on the coast of Gáldar, so the 4 geosites proposed on the coast of Gáldar are of local importance, not of national importance like the previous 53. Nevertheless, the identification of these sites of municipal interest is a first step to know the most significant geological elements on the coast, and they are fundamental for the heritage department of this council and will serve as a basis for future works of natural and cultural heritage inventory, for their diffusion and to promote geo-conservation and geoturism strategies.

Studies on geodiversity and coastal geological heritage have been carried out in recent years in other municipalities of Gran Canaria, such as Aldea de San Nicolás (García-Guerra and Mangas, 2020), Agaete (Arencibia-Pérez and Mangas, 2019), Arucas (Déniz-González and Mangas, 2010) and Las Palmas de Gran Canaria (Déniz-González and Mangas, 2012). Similar research is currently underway on the coast of Telde and Artenara. In most of the previous works, 4 coastal geosites have been proposed, except in La Aldea where there were 5, and with similar surface areas (less than 0.5 km2). In the future, the aim is to complete the inventory of coastal geosites in the rest of the island, since, bearing in mind the touristification of the coastal strip since the 1960s, it is necessary and fundamental to know the geological heritage in the face of the threats posed by the unrelenting tourist industry in Gran Canaria. Therefore, it is essential to have knowledge of the natural geological heritage in these areas, in order to promote strategies for geoconservation, didactic/pedagogical diffusion for schoolchildren, scientific diffusion for researchers, and geotourism for the local and external population. All this geological heritage inventoried at municipal level is partially protected by the Coastal Law practically in its entirety, as these geosites are included within the delimitation of the maritime-terrestrial public domain up to a distance of about 200 m from the intertidal zone inland. However, they can be destroyed if coastal public works are carried out. On the other hand, some of them are protected under the 1987 Canary Islands Protected Areas Act (Law 12/1987 on the Declaration of Natural Spaces of the Canary Islands) and the Natura 2000 Network legislation (Law 41/2010), and the European Union's Special Areas of Conservation (SAC) (Law 42/2007).

7. Conclusions

This research proposes four geosites in the coastal strip of the municipality of Gáldar, being the first inventory of the most significant geological elements (volcanic and sedimentary materials, geoforms and structures) with didactic, scientific and cultural interests of this coast. In this way, this work provides results to be diffused in terms of heritage, science, education, tourism and recreation, among others.

Along the coast of Gáldar, part of the geological history of the island of Gran Canaria can be recognized, especially materials, geoforms and structures associated with strombolian eruptions from the middle Pleistocene (<800.000 years) and ultramafic and mafic eruptions (basanites-nephelinites and basalts, respectively) of geochemical composition, such as, for example, strombolian and hydromagmatic cones, scoriaceous lava flows and proximal and distal fall pyroclastic deposits, feeder dykes, columnar disjunctions, among others, in the northwest of the island, framed in the Plio-Quaternary Post-Roque Nublo Group.

In addition, the geological action of runoff water, the sea, gravity and wind in this time period has formed sedimentary deposits and geomorphologies such as fossil beaches and dunes (beachrock and eolianites, respectively) and paleosoils with terrestrial and marine fossiliferous content, together with the mouths of ravines with alluvium and colluvium forming sandy and pebble beaches, homogeneous and heterogeneous cliffs containing coastal platforms with caves, sinkholes, overhangs and giant tidepools at the base, and islets and shallows in subtidal areas.

On the other hand, with the results obtained from geodiversity, several georoutes have been proposed to promote access and dissemination of geological knowledge of this coastal natural heritage. Thus, firstly, a general georoute has been defined, which is a complete trail of the 24 km of the entire Gáldar coast where the four geosite and other points of geological value are discontinuously located. This general georoute has been subdivided into 3 stages of 8 km approximately which are georute of los antiguos canarios, georuta hidromagmática and georute de las Olas for untrained users. Secondly, an inclusive route for disabled people has been proposed in the Bay of Sardina, being the first time that this type of path has been defined in Gran Canaria Island. Thirdly, a boat route has been defined to observe the coastal strip with another perspective of observing from sea to land the elements of geodiversity existing in the intertidal zone, and which goes from the port of Sardina to Agaete or vice versa. Fourthly, the termination on the coast of the Jacobean route between volcanoes, which has been in place in Gran Canaria for several years and which would go from the church of Santiago Apóstol to the lighthouse of Sardina or the beach of Sardina, has been defined.

The results of this work confirm that there is an interesting geodiversity on the coast of Gáldar that could be valued and considered a basic scientific resource for future geological research, a didactic material for different levels of education and heritage elements that can promote local tourism. All this means that this geological heritage can be a fundamental tool used in sustainable economic strategies in this municipality and on the island of Gran Canaria.

8. Acknowledgements

I would like to thank the Faculty for all the knowledge and experiences I have gained over the years. It has been a privilege to study and grow academically in one of the most representative faculties in Spain.

In addition, my gratitude must be extended to Dr. José Mangas Viñuela for making possible the investigation of one of my favourite places, the coast of my municipality. Without him, this work would not have been possible. His experience and guidance have been fundamental pillars to carry out this research in the most enriching way.

Finally, we would like to thank Dr. Jorge Yeppes and Dr. Sara B. Santana Santana for their disinterested collaboration in this research.

9. References

Ancochea, E., J.L. Barrera, F. Bellido, R. Benito, J.L. Brändle, J.M., Cebriá, J. Coello, C.R. Cubas, J. De La Nuez, M. Doblas, J.A Gómez, F. Hernán, R. Herrera, M.J. Huertas, J. López Ruiz, J. Martí, M. Muñoz and J. Sagredo (2004). Canarias y el vulcanismo neógeno peninsular. En: Geología de España (J.A. Vera, ed.). Instituto Geológico y Minero de España (IGME) y Sociedad Geológica de España (SGE), Madrid, 637-682.

Arencibia-Pérez L. and Mangas, J. (2019). Propuesta de lugares de interés geológico para la costa del municipio de Agaete (NO de Gran Canaria). Esther Martín-González, Juan J. Coello Bravo y Juana Vegas (eds.). Actas de la XIII Reunión Nacional de la Comisión de Patrimonio Geológico. *Cuadernos del Museo Geominero, n.º 30*. Instituto Geológico y Minero de España, Madrid. 71-76.

Balcells, R.; Barrera, J. L., Gómez, J.A. and Ruiz-García, M.T. (1990). Mapa Geológico de España, escala 1:25.000, 1101-I-II, Agaete. Memoria 54 pp.

Balcells, R., Barrera, J. L., Gómez, J.A., Merlos, A. and Ruiz, M.T. (1992). Mapa Geológico de España, escala 1:100.000, 21-21/21-22, Isla de Gran Canaria. 1-323.

Carracedo, J.C and Troll, V.R. (2016). The Geology of Gran Canaria. In “The Geology of the Canary Islands”. (Ed) *ELSEVIER*, 357-469.

Déniz-González, I. and Mangas, J. (2010). Inventario y valoración de los Lugares de Interés Geológico en la costa de Arucas (N de la isla de Gran Canaria). Cuadernos del Museo Geominero 12: 75-89.

Déniz-González, I. and Mangas, J. (2012). Lugares de interés geológico en la costa de Las Palmas de Gran Canaria (Islas Canarias): inventario y valoración. Geotemas 13: 1253-1256.

Freundt, A. and Schmincke, H. U. (1995). Eruption and emplacement of a basaltic welded ignimbrite during caldera formation on Gran Canaria. *Bull Volcanol*, 56, 640-659.

Fuster, J.M., Hernández Pacheco, A., Muñoz, M., Rodríguez Badiola, E. and García Cacho, L. (1968). Geology and vulcanology of the Canary Islands, Gran Canaria, in: Instituto Lucas Mallada (CSIC) (Eds.). *International Symposium on Volcanology*, Tenerife, Sept. 1968, Special Publication, Madrid, 243.

Galindo, I. Martín-González, E. Sánchez, N. Vegas, J. Romero, C. Lozano, G. Márquez, E. Coello, J.J. Casillas, R. Martín-Luis, C. Léon, R. Vázquez, J.-T. Yepes J. and Mangas J. (2022). Inventario de Lugares de Interés Geológico de las Islas Canarias Inventory of Geological Sites of Interest in the Canary Islands. Geo-Temas, Volumen 19, 28-31.

García-Cortés, Á. Carcavilla, L.; Díaz-Martínez, E. and Vegas, J. (2018). Documento Metodológico para la Elaboración del Inventario Español de Lugares de Interés Geológico (IELIG), Instituto Geológico y Minero de España, Versión 5 (Actualización 19), 61 pp.

García-Guerra, R.B., Mangas J. and Quevedo-González, L. (2019). Propuesta de Lugares de Interés Geológico (LIG) costeros en el municipio de La Aldea de San Nicolás, oeste de Gran Canaria, España. En: Durán R., Guillén J., Simarro G. (Eds), 2019. X Jornadas de Geomorfología Litoral. Castelldefels, 69-72.

Guillou, H., Pérez-Torrado F.J., Hansen-Machin A.R., Carracedo J.C. and Gimeno, D. (2004). The Plio-Quaternary volcanic evolution of Gran Canaria based on new K-Ar ages and magnetostratigraphy. *Journal of Volcanology and Geothermal Research 135,* 221-246.

Mangas Viñuela, J. (2020). Génesis y evolución geológica de Gran Canaria: un buen ejemplo de la geodiversidad de una isla volcánica intraplaca oceánica. Gran Canaria: las huellas del tiempo. Actas XV Semana Científica Telesforo Bravo. Instituto de Estudios Hispánicos de Canarias, pp. 61-113.

McDougall, I. and Schmincke, H.U. (1976). Geochronology of Gran Canaria, Canary Islands: Age of shield building volcanism and other magmatic phases. *Bulletin of Volcanology,* 40, 1-21.

Pérez-Torrado, F., Carracedo, J.C. and Mangas, J., (1995). Geochronology and stratigraphy of the Roque Nublo Group, Gran Canaria, Canary Islands. Journal of the *Geological Society* 152 (5), 807-818.

Schirnick, C., Bogaard, P. and van den Schmincke, H.U. (1999). Cone sheet formation and intrusive growth of an oceanic island.The Miocene Tejeda complex on Gran Canaria (Canary Islands). *Geology*, 27-3, 207–210.

Schmincke, H.U. (1976). The geology of the Canary Islands. EN: Kunkel, G. (Ed.): Biogeography and Ecology in the Canary Islands, 167-184.

Schmincke, H.U. (1990). Geological field guide, Gran Canaria. En: International Volcanological Congress, IAVCEI. *Mainz, Germany,* 2-209.

Van den Bogaard, P. (2013). The origin of the Canary Island Seamount Province - New ages of old seamounts. *Scientific Reports, 3*, 2107-2107.

Webpages:

- Inventario Español de Lugares de Interés Geológico (IELIG). https://info.igme.es/ielig/ (Acessed em: 4.12.2023).
- Patrimonio Geológico y minero de España. IGME. https://www.igme.es/patrimonio/PG/patrimonioG.htm (Acessed em: 29.11.2023).

Legislation:

- Ley 12/1987 de Declaración de Espacios Naturales de Canarias. BOE núm. 270, de 11 de noviembre de 1987, 33529-3359 pp. https://www.boe.es/buscar/doc.php?id=BOE-A-1987-25183 06.12.2023).
-Ley 22/1988, de 28 de julio, de Costas. https://www.boe.es/buscar/pdf/1988/BOE-A-1988-18762-consolidado.pdf
(accessed 09.10.2023).

- Ley 42/2007 del Patrimonio Natural y de la Biodiversidad [Law 42/2007 of Natural Heritage and Biodiversity]. BOE núm.299. 117 pp. https://www.boe.es/buscar/pdf/2007/BOE-A-2007-21490-consolidado.pdf (accessed 09.10.2023).
- Ley 41/2010, de 29 de diciembre, de protección del medio marino. BOE núm. 317, de 30 de diciembre de 2010, 108464-108488 pp. https://www.boe.es/buscar/doc.php?id=BOE-A-2010-20050(accessed 06.12.2023).
- Ley 2/2013 de protección y uso sostenible del litoral y de modificación de la Ley 22/1988, de 28 de julio, de Costas. BOE núm. 129. 33 pp. https://www.boe.es/buscar/pdf/2013/BOE-A-2013-5670-consolidado.pdf (accessed 09.10.2022).

VALORACIÓN PERSONAL DEL TRABAJO DE FIN DE GRADO

Descripción detallada de las actividades desarrolladas durante la realización del TFG

Las actividades desarrolladas incluyeron:

a) Revisión bibliográfica: Se realizó una búsqueda bibliográfica de la zona además de realizar una revisión de estudios previos que emplearon metodologías similares en zonas cercanas.
b) Trabajo práctico: Se realizaron varias salidas de campo en donde se recorrió todo el litoral costero del área de estudio, para así tomar todos los datos necesarios.
c) Elaboración de Georutas a partir de los datos obtenidos.
d) Realización de mapas geológicos y figuras necesarias.
e) Redacción del documento final.

Formación recibida (cursos, programas informáticos, etc.)

Durante la realización del TFG se participó paralelamente en 2 congresos en donde se recibió distinta información relacionada con la geomorfología costera y geología.

Nivel de integración e implicación dentro del departamento y relaciones con el personal

La participación del tutor en la labor de investigación ha sido completa, ya que a lo largo de las campañas de campo, congresos y otras actividades, estuvo completamente presente. Con el Dr. José Mangas se mantuvo una comunicación estable durante todo el proceso.

Aspectos positivos y negativos más significativos relacionados con el desarrollo del TFG

Existe un gran número de aspectos positivos debido a que durante el desarrollo TFG realicé el primer poster de congreso y primera ponencia, además de mis primeros artículos científicos en congresos. Para mí esto era algo totalmente nuevo y enriquecedor. Por otra parte, el aspecto negativo es claramente la falta de tiempo. Por eso mismo, se decidió reducir la zona de estudio.

Valoración personal del aprendizaje conseguido a lo largo del TFM

Estoy muy satisfecho con este trabajo, ya que pude formar parte de una investigación inédita en el litoral costero del municipio donde resido. Del mismo modo, pude adentrarme en el mundo del patrimonio geológico que, hasta la fecha, era algo casi completamente ajeno. Asimismo, poder participar con el Dr. José Mangas Viñuelas en una investigación ha sido todo una experiencia completamente satisfactoria y enriquecedora, puesto que ha sido todo un ejemplo a seguir.