Evaluation of Geoconservation in Geosites of Palaeontological Interest from Lanzarote and Chinijo Islands UNESCO Global Geopark

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Abstract

The volcanic origin of Lanzarote and the islets located to the north and their relatively young age does not allow an extensive paleontological record, which does not exceed the upper Miocene (around 7 Ma). However, the fact of being oceanic volcanic islands defines the urgent need to preserve the few paleontological sites that allows us to reconstruct the evolution of the Paleobiodiversity of the Canary archipelago. In this chapter a review of the legal framework that protects the paleontological heritage of the Canary Islands is made, considering the main figures of protection and the management that has been carried out on them up to this moment. In addition, a brief description of the marine and terrestrial geosites of paleontological interest of the UNESCO Global Geopark of Lanzarote and Chinijo Islands is added, emphasizing its state of conservation and the risks of loss that these geosites present.

Keywords

Paleontological heritage • Legal framework • Paleontological geosites • Conservation

1 Introduction

The paleontological deposits and the fossil record of the Canary Islands are very important information resources because they are testimony of the settlement of the islands by the flora and fauna, and they allow us to know how the process of evolution and extinction of the species has evolved (Castillo et al. 1996). Likewise, the formation of some deposits and the fossils that they contain empowers us to establish how global climate changes have affected the archipelago and its immediate surroundings during the last few million years (Ortiz et al. 2006; Meco et al. 2008). In addition, the stratigraphic relationship of some fossiliferous sedimentary formations with the volcanic formations allows us to reconstruct the main geological events that occurred in the formation of some islands and their evolution (De la Nuez et al. 1998).

In Lanzarote and Chinijo Islands UNESCO Global Geopark, 10 geosites of paleontological interest have been proposed according to their scientific value (Galindo et al. this volume). Some of these fossiliferous sites reflect the global climatic changes that have occurred during the last million years of the planet's history, as it's the case of the changes in sea level, generating fossil beaches or large deposits of wind sands. In other cases, the sites preserve fossils of extinct vertebrate and terrestrial invertebrate species millions or thousands of years ago. In one way or another, the life story of Lanzarote is written in these fossiliferous sites, although, as in many other places, this story is composed of chapters, some of which are incomplete or even deleted.

The need to preserve and protect the "best chapters of the Earth Planet's book" is indisputable among the scientific

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community. However, it is not easy to transmit this concern to the political administrators and managers of the territory, so that the conservation process continues to be parsimonious, due to the lack of specific legislation and the slowness of administrative procedures, delaying in time the declaration as Protected Areas. Meanwhile, important geosites disappear without leaving a trace under urban development, especially in the littoral and coastal zone. This chapter aims to record the state of conservation of the paleontological heritage of Lanzarote and Chinijo Islands UGG, not only of the sites chosen as geosites, but everywhere in general.

2 Legal Framework

If we look at the origin and nature of paleontological objects, fossils and deposits, their protection should be framed within the legislation referring to Natural Heritage, since they are natural objects not created by the action of humans. To be strictly correct, the regulations on cultural heritage should only refer to heritage elements that are the result of human activity, and fossils are not (Díaz-Martínez et al. 2013). However, there are some fossil species with undoubted cultural value due to their relationship with human evolution and activity. Therefore, the paleontological heritage should be regarded as a natural heritage, although in some cases it may have cultural interest of an archaeological and/or anthropological nature.

This duality has caused the paleontological heritage to be considered in Spain as part of the historical or cultural heritage, especially when establishing its protection regime (Delvene et al. 2018). Thus, Spanish Historical Heritage Law 13/1985, and several of the subsequent regional laws, considers the Paleontological Heritage as a part of the Archaeological Heritage, with the definition "being part of the Archaeological Heritage the geological and paleontological elements related to the history of the man and his origins and background". However, the inclusion of paleontological assets within the Historical Heritage presents some problems, such as the identification of the same with those objects and activities related exclusively to the action of humans, and not with him as a biological or natural being. This would explain the disparity of criteria (regarding the inclusion or not of the paleontological assets in the Historical Heritage) that can be seen in the different documents or regulations elaborated at the regional level.

The paleontological heritage of a region can be understood as constituted by its fossil record, formed by the set of fossiliferous sites and by the fossils contained in them, or deposited in collections (Castillo et al. 1999; Meléndez and Molina 2001). The regulation of the legal regime for the protection of paleontological goods in the Canary Islands is framed by Law 4/1999, of 15 March, on the Historical Heritage of the Canary Islands, and is the responsibility of the Canary islands Government and subsidiary of the Island Councils. According to this law, the paleontological patrimony of the islands is defined as the set "of movable and immovable assets that contain representative elements of the evolution of living beings, as well as with the geological and paleoenvironmental components of culture. The most relevant goods must be declared of cultural interest or catalogued, according to their value. Sites or places with a fossil record of irreplaceable or exceptional materials related to chronology or paleoenvironment are considered relevant". The protection instruments foreseen are: Register of Assets of Cultural Interest (ACI, BIC in Spanish), Inventory of Movable Property and, specifically, Municipal Paleontological Letters. In the case of paleontological sites declared Assets of Cultural Interest, the figure of Paleontological Zone will be applied (p.e., Matas Blancas Site in Fuerteventura island; Fig. 1a).

The other law, which allows the protection of paleontological deposits, is the Law of Soil and Protected Natural Spaces of Canary Islands (Law 4/2017, of July 13) under the figure of Natural Monuments, among which foundations of protection is the fact of containing paleontological sites of scientific interest, so that the real dimension would be specifically collected. The law does not prohibit the collection and commerce of paleontological remains, so that effective protection is subject to the conservation rules of the different plans of use and management.

Another law to be taken into account in the Canary Islands is the Coastal Law (Law 22/1988, of July 28), since many of the deposits are in the area of public domain that regulates such legislation, 100 m from the low-water line, where it controls the extraction of aggregates and the dumping of debris.

National Law 42/2007, and its modification in Law 33/2015 of Natural Heritage and Biodiversity, comes to develop a series of aspects that have been historically demanded by the community of Spanish paleobiologists and paleontologists. It explicitly states in article 34 that "Natural Monuments will also be considered singular and monumental trees, geological formations, paleontological and mineralogical sites, stratotypes and other geological elements that have a special interest in the singularity or importance of its scientific, cultural or landscape values". However, this state law has not been transposed to the Canarian legislation, so the movable property and paleontological outcrops continue to be part of the Historical Heritage, and its conservation and preservation must be assumed by the current legislation, as it happens in the rest of the autonomous communities with their own historical heritage legislation.

Fig. 1 **a** Assets of cultural interest of Matas Blancas (Fuerteventura island), outcrop with *Persististrombus latus* shells. **b** Fossil beach between Caleta de Sebo and Playa Franceses (La Graciosa island)

3 Management of Paleontological Sites

The management in the Canary Islands of the palaeontological legacy, which derives from its consideration as Historical Heritage, is the responsibility of the General Directorate of Cultural Heritage of the Canary Islands, with some functions transferred to the Island Councils, as representatives of the autonomous administration on each island. Management as a Natural Heritage is the responsibility of the Ministry of Territorial Policy, which delegates to the Island Councils as representatives of the regional administration on each island. On the other hand, the management of movable heritage (fossils) is only contemplated specifically in the legislation on Historical Heritage, while the management of paleontological sites is contemplated in the Historical Heritage law and in that of Natural Areas.

With reference to the first, there are only seven sites declared as an Asset of Cultural Interest between all the islands of the archipelago (Martín-González et al. 2009):

Barranco de los Encantados, La Guirra and Matas Blancas sites in Fuerteventura, Bujero del Silo and Puntallana sites in La Gomera, and Punta Negra and Playa del Búnker sites in Tenerife. In theory, paleontological deposits associated with archaeological sites that are inventoried or in some of the effective protection figures should also be protected, although the reality is different. In 1989 a Catalogue-Inventory of the paleontological sites of the islands was elaborated, financed by Canary Islands government, of which only the ones from the western islands is published: Tenerife, La Palma, La Gomera and El Hierro (García-Talavera et al. 1989). Theoretically it would have been the first step for the effective protection of the same, especially those indicated in this catalogue as very threatened. However, one of the deposits has already disappeared due to the construction of Los Cristianos harbour; there was another declared as an Asset of Cultural Interest, which has now been buried by a seafront, and the others have no conservation norms.

Natural Areas Law of the Canary Islands (currently included in Law 4/2017) declares a total of 114 Protected Natural Areas which, together with four National Parks, form the Natural Areas Network of the region. Out of these, 15 include among their foundations of protection the existence in their interior of paleontological deposits of scientific interest. In all of them, the paleontological deposits form only a small part of the area and of the natural values to be protected. Up to this moment there is no paleontological site collected as such, although the Natural Monument of Ajuy, in Fuerteventura Island, covers the entire surface of the homonymous paleontological site, and the Natural Monument of Los Ajaches (Lanzarote Island) does the same with the paleontological area of Papagayo beach. Regarding the general level of protection that this law provides to the Paleontological Heritage of the Canary Islands, it can be stated that, out of the 49 sites catalogued in the Western Islands by García-Talavera et al. (1989) 38.7% are within a Protected Natural Area. However, out of the 13 sites considered most important by these authors, and in need of immediate protection, only 5 are included as protected areas.

Lanzarote is one of the islands that has a greater and extensive paleontological geoheritage providing us information on the geological and evolutionary history of the archipelago from the Miocene to the Holocene. Aware of this importance, the Lanzarote council, Lanzarote Town Council and Las Palmas de Gran Canaria University, together with the University Foundation of Las Palmas de Gran Canaria, signed a collaboration agreement in 2001, in order to write a report on the paleontological sites of the islands of Lanzarote and La Graciosa, to initiate the procedure of declaration of Asset of Cultural Interest. The result of this analysis was manifested in the initiation of declaration files for ten deposits, almost all of them started in 2003.

For La Graciosa, the largest of the Chinijo Islands, two Assets of Cultural Interest were proposed, the northern fringe from the Llanos de Majapalomas to the Vallichuelo site and the western fringe from the Playa de las Conchas to the Playa de la Cocina sites, including the Baja del Salado. Thus, almost its entire extension is a large paleontological site, where both marine and terrestrial sites arise, with a large number of fossil species. For this reason, it is striking that the deposits of the south coast, where the only two little villages in the island are located, have been left out of the proposed protection area, precisely between the Playa de Franceses and Caleta de Sebo (Fig. 1b), and between this town and Pedro Barba, perhaps the best preserved on the island, and with an extraordinary scientific importance (Castillo et al. 1999, 2002; García-Talavera 2003).

In Lanzarote, the proposed paleontological sites belong to different ages and typologies, both terrestrial and marine. The oldest is the Órzola site, belonging to the Pliocene period, and whose importance we will later develop as a geosite of the UGG. Associated with the volcanic deposits of the I Series of Lanzarote (Coello et al. 1992) is an old coastline located approximately 40–50 m above the current sea level, with an age between four and nine million years, which extends from Punta del Garajao and Punta del Papagayo, on the east coast of the island, to the Salinas del Janubio (Zazo et al. 2002), on the west coast of the island. Of marine origin also, but more recent in the time, is the deposit of La Santa, another paleontological site selected as a geosite.

The remaining sites proposed for its declaration as an Asset of Cultural Interest with the category of Palaeontological Zone (Meco 2003) are terrestrial: Guinate, Timbaiba, Tiagua and Guatisea. The first two have also been included in the Lanzarote and Chinijo Islands Geopark geosites inventory (Galindo et al., this volume). The other two deposits (Tiagua and Guatisea) are palaeodunes formed during the Pleistocene, which are crowned by paleosols, and where there are fossil traces of hymenoptera and terrestrial gastropods shells such as *Hemycicla sarcostoma*, *Theba geminata* or *Rumina decollata*, well known fossil dunes of the Pleistocene and Holocene of the Eastern Canary Islands (Meco et al. 1997).

4 Geosites of Paleontological Interest in the Lanzarote and Chinijo Islands UNESCO Global Geopark

The geosites of paleontological interest of the Lanzarote and Chinijo Islands UNESCO Global Geopark can be grouped according to several criteria: age, type of deposit, type of fossils, etc. In this section, to establish an order at the time of describing them, we will group the different geosites in those

related to terrestrial deposits, first, and coastal deposits, in second place, making a brief description of each of the sets and their conservation status.

4.1 Terrestrial Paleontological Geosites

In this group the deposits of the Miocene-Pliocene paleontological area of Órzola would be integrated, the Pleistocene aeolian dunes of Jable del Medio and Timbaiba, and the palaeosoil of Gayo, and the buried dunes of Lomos de Camacho and San Andrés, although the main value of this last geosite is the geomorphological (Fig. 2).

From all of them, the oldest is that of Órzola site, with three deposits located in Valle Grande, Valle Chico and Fuente de Gusa. The deposits of highly cemented sand dunes (calcarenites) those are stratigraphically located between basaltic lava flows dating from 3.78 to 4.3 Ma (Lomoschitz et al. 2016). In these deposits, fossil remains of large eggs attributed to extinct non-flying land-bird species have been found, which were initially assigned to two groups of ratites: some belonging to the genus *Struthio* and others related to the elephant birds (*Aepyornis*) (Rothe 1964; Sauer and Rothe 1972). Subsequently, another hypothesis was postulated suggesting that they might be large-scale seabirds of the order Odontopterygiformes (García-Talavera 1990). Complete molds and egg fragments of a terrestrial tortoise attributed by Hutterer et al. (1997) to an indeterminate species of the genus *Geochelone*, a group that presents an enormous radiation in the archipelago with four extinct species. Fuente de Gusa outcrop also includes the first known snake fossil of the archipelago, a vertebra of a species of the Boidae family cited by Barahona et al. (1998). In addition, Órzola has been defined as type locality and stratum type of four new species of terrestrial gastropod molluscs (Gittenberger and Ripken 1985) whose specific names derive from Órzola, the northest village in the island (*Pupoides orzolae*, *Theba orzolae*, *Leptaxis orzolae* and *Canariella orzolae*).

The Pleistocene dunes of the Lomos de San Andres and Camacho are covered by volcanic materials from a recent and nearby eruption. These dunes are made up of fine-grained organogenic aeolian sands that in some areas are more than 22 m thick, as is the case of the Jable del

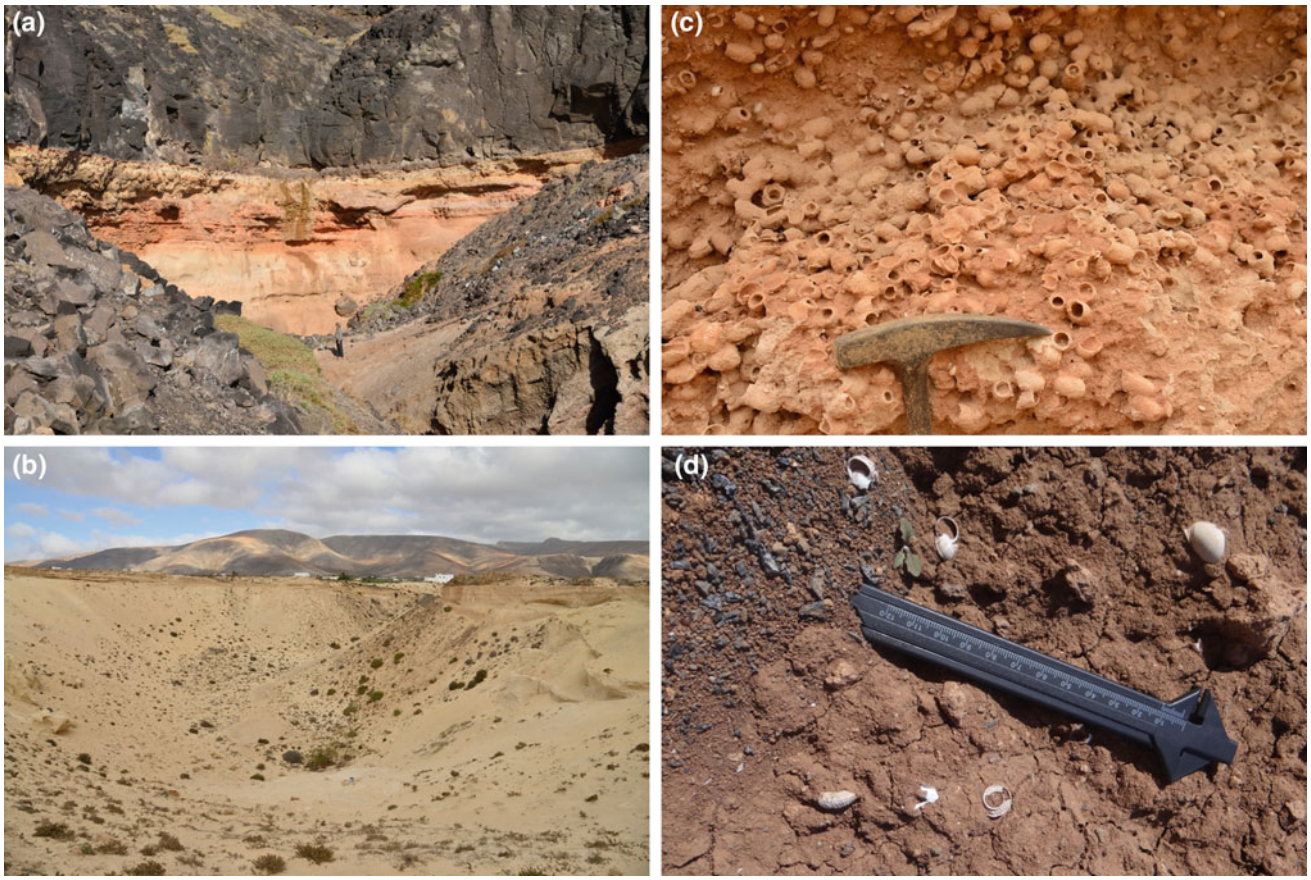

Fig. 2 Terrestrial geosites of Lanzarote and Chinijo islands UNESCO Global Geopark. **a** Valle Chico (zone Paleontological of Órzola). **b** Fossil dunes in Jable del Medio (Mala). **c** *Rebuffoichnus* fossils in Timbaiba geosite. **d** Land snails in Gayo paleosoil (northern of Lanzarote island)

Medio dunes coming from the dune fields generated by the sands that remained on the platforms of abrasion during regressive stages of sea level. The sands are lightly cemented by carbonates and have structures of crossed stratifications of aeolian type.

In the profile of the dunes different paleosols can be identified that have been analyzed and dated by several authors through the racemization of amino acids and radiometric dates C14 in order to study the palaeoclimatic changes of the Quaternary, fundamentally those that occurred during the last 50,000 years (Ortiz et al. 2006; Yanes et al. 2013). However, thermoluminescence dating has yielded an age of 130,000 years (Bouab 2001), in the case of the dunes of El Jable del Medio.

From the point of view of the fossiliferous content and its conservation, the most relevant geosite is Timbaiba, a volcanic cone of horseshoe morphology, formed during a fissure eruption in the Middle Pleistocene (Romero 2003), and built on a Plio-Pleistocene aeolian palaeodune. One of the most characteristic fossils of this deposit is the thousands of fossil traces in the shape of a thimble of different species of Hymenoptera and Coleoptera of the genus *Rebuffoichnus* (Genise et al 2013), erroneously known as *anthophora* nests. Numerous terrestrial gastropod shells of the species *Hemycicla sarcostoma*, *Theba geminata* or *Rumina decollata* are also found. In addition, bone remains and eggs have appear from the extinct shearwater *Puffinus holei*, a species originally described in southern Fuerteventura (Walker et al. 1990), as well as from the rodent *Malpaisomys insularis* Hutterer et al. (1988), extinct during the Holocene (Rando et al. 2008).

Finally, in the northwest of Lanzarote we find the last site of this group, Gayo, formed by two paleosols. The lower one, which has been dated in 23.5 ka (Yanes et al. 2013), contains abundant fossil shells of terrestrial gastropods (*Hemicycla flavistoma*, *Theba geminata*, *Monilearia monilifera* and the slug *Cryptella canariensis*), one of them new for science belonging to the genere *Theba*. In the upper paleosol, the presence of shell remains of the fossil shearwater *Puffinus holeae* stands out, dating from 2.1 to 2.7 ka, which represents the most recent age for this fossil endemic species, as well as suggesting that its extinction might be associated with the beginning of the aboriginal occupation. The chemical analysis of the composition of the shells of the gastropods reflects changes in climatic conditions during the Pleistocene-Holocene transition, so that about 20 ka climatic conditions might have been more arid, causing the drying of the flora and leading to extinction of the *Theba* species (still to be described), while towards the end of the Holocene there would be more humidity and warmer temperatures.

Regarding their conservation status, Órzola and Timbaiba sites have opened a file for their declaration as an Asset of Cultural Interest in the Paleontological Zone category by the Canary Islands Government since 2004, a statement that even after 14 years it is not firm. In addition, Órzola and Gayo are included in the protected area of the Chinijo Archipelago Natural Park of the Network of Protected Natural Areas of the Canary Islands. In the case of the dunes of Lomos Camacho and San Andrés and Jable del Medio, they are located in areas where quarries for sand extraction are allowed. Thus, they are under a serious risk of deterioration and even disappearance.

The state of conservation of these deposits is uneven, being good in the case of Gayo and Órzola, especially the deposits of Valle Chico and Fuente de Gusa due to the difficulty of access. However, the dunes that are found in the quarries for extracting aggregates from Lomo Camacho and San Andrés and from Jable del Medio, have the risk of disappearing if this activity is not controlled. Finally, in the case of Timbaiba, the dumping of rubble and the possible construction of an automobile circuit are its main problems for its preservation.

4.2 Littoral Paleontological Geosites

As with the terrestrial palaeontological geosites, we also find different chronologies, from the Mio-Pliocene deposits of Ajaches and El Valle ravine, to the Upper Pleistocene deposits of La Santa and Piedra Alta (Fig. 3). In the southeast corner of Lanzarote, to the south of the steep reliefs of Los Ajaches and above the current coastal cliffs, there is a wide platform of marine abrasion formed during the upper Miocene, which has an average altitude 40 m asl. A fluvial network of dendritic character has been built over it, in the mouth of which beaches of organogenic sands and climbing dunes have been formed and are very frequented by tourism. In the cliffs the rocks belonging to the Miocene building of Ajaches can be seen (Coello et al. 1992), being frequent the stacks of lava flows separated by paleosols and important unconformities.

On the abrasion platform and in disagreement with the basaltic materials of the Ajaches Formation, dated between 14.5 and 13.5 Ma (Carracedo et al. 2002), a sequence of biogenic sandstones and marine conglomerates with frequent rounded basaltic cobblestones were deposited, outcropping along the coast from Punta de Papagayo to Playa Quemada. According to Zazo et al. (2002) in this area up to 12 transgressive episodes can be identified from 2 to 65 m asl, six of them of Quaternary age and the rest belonging to the Mio-Pliocene. These levels contain fossils of marine species typical of tropical waters (Meco et al. 2007; Martín González et al. 2018), among which the species of gastropod mollusk *Persististrombus coronatus* stands out, together with other species of marked chronostratigraphic interest, such as *Ancilla glandiformis* and *Nerita martiniana*.

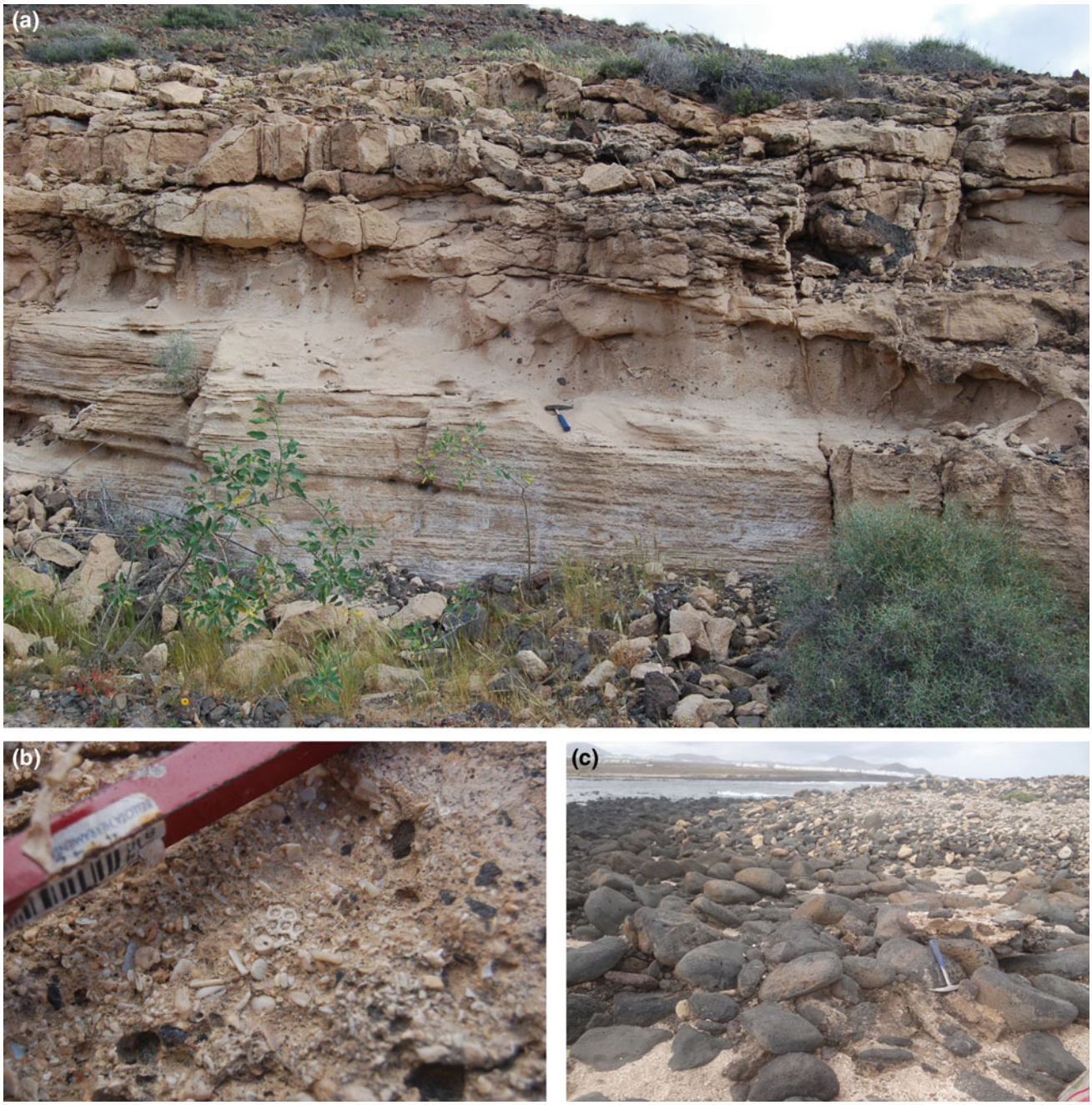

Fig. 3 Marine geosites of Lanzarote and Chinijo islands UNESCO Global Geopark. **a** Fossil beach level in Los Ajaches Paleontological zone. **b** Fossil of marine sedimentary environment in Piedra Alta deposit. **c** La Santa geosite

La Santa paleontological site is formed by fragmented coastal marine deposits (sandstones and cemented gravels) that made up an old coastline and contains abundant fossils characteristic of tropical waters (including the hermatypic coral *Siderastraea radians*) corresponding to the marine isotope stage 5e (MIS5e, approximately 125 ka) (Meco 2003; Muhs et al. 2014). This is the northernmost locality in the Atlantic where this species of coral is located, which marks the climatic change of more pronounced warm character of the Upper Pleistocene, as well as a higher sea level than at present. In addition, there are many fossils of gastropods, bivalves, echinoderms, and rhodoliths that are mostly fragmented, and whose association also corresponds to the presence of tropical waters. Another singularity of this place is La Santa islet, formed by the remains of a basaltic lava flow of cursive type, that is surrounded by beach boulders.

On the west coast of the island, in the area known as Los Charcones, the Piedra Alta deposit, also of Pleistocene age,

has been described. It consists in a conglomeratic level with boulders cemented by fossiliferous limestones located at 16–18 m asl, which has been interpreted as a tsunami deposit (Meco 2003). The origin of this tsunami is believed to be related to a mega-slip that had occurred about 480 ka (Muhs et al. 2014). The fossils that can be observed in this deposit correspond to molluscs indicative of the supramareal and intertidal zone, such as those of the genus Cursive and Saccostrea, which appear together with fragments of infralitoral corals (*Madracis pharensis*). There are also circalittoral gastropods in perfect preservation, and other minuscule species. Thus, the deposit displays a mixture of deep species with shallow coastal species, typical of the outcrops produced by high energy events, such as tsunamis.

The geosite of Los Ajaches is declared a Natural Monument by the legislation on protected natural areas of the Canary Islands and is declared as an Important Birds Area (IBA), according to the directive Habitat 79/409/CEE on the conservation of wild birds. Like the Santa, the geosites of the Ajaches platform and the Mio-Pliocene sites that it contains, have a file opened for their declaration as an Asset of Cultural Interest in the Paleontological Zone category since July 2004. On the other hand, the LIG of Barranco del Valle and Piedra Alta are not included in any protection figure.

The figures of protection in Los Ajaches and the difficulty accessing this area, as also happens in the case of Piedra Alta, has successfully contributed to the conservation of both geosites. Unlike it happens in the case of La Santa or Barranco del Valle where the construction of tourist-sports facilities has caused an important deterioration of the paleontological zone and the notorious depletion of the fossils. Another case is that of the Barranco del Valle where the installation of a livestock activity has generated a significant deterioration of the soil due to the continuous passage of the animals and the dumping of waste materials.

5 Discussion and Conclusions

The data presented highlights the extraordinary importance of the paleontological geoheritage of the Lanzarote and Chinijo Islands UNESCO Global Geopark, confirming the great diversity of sedimentary deposits and unique fossil sites that make up the basic tools for the reconstruction of the evolutionary history, both biological and geological, of the Canary archipelago. However, the situation of protection for this natural heritage does not seem to be correlated with its scientific, cultural, and social importance, with only ten paleontological sites with the opening of a declaration as an Asset of Cultural Interest under the category of Paleontological Zone that remain open after 10 years, although we are in a volcanic and insular territory, where some sites are the only witnesses of the past.

Despite this small number, these paleontological sites are not even well studied and valued (Martín-González et al. 2009). In the reports or dossiers of proposal for them to be declared as an Asset of Cultural Interest, a patrimonial valuation is needed in greater depth, where reference should be made to the assessment criteria (scientific, educative, cultural or economic) considered to justify the protection of a given deposit although these criteria were already used, even before the entry into force of the current legislation on the Historical Heritage of the Canary Islands. These documents also lack from a section describing the risks of deterioration and the conservation measures that should be developed. In this way, most of the paleontological sites mentioned have a total abandonment, without any type of signaling indicating their status, without peripheral protection zones, or, more seriously, they are affected by the dumping of rubbish and debris, tourist constructions, recreational activities, depletion, etc.

Lanzarote has a population density of 172 inhabitants/km^2 distributed unequally in its almost 846 km^2. Thus, for example, as in most of our planet, the greatest concentration occurs on the coast, with some tourist centres having been massively developed in the last 30 years. This has caused important urban pressure resulting in the disappearance of some coastal deposits, as it is the case of El Berrugo site in the town of Playa Blanca, close to the Palaeontological Zone of Los Ajaches. This site has been studied by several specialists constituting one of the best examples of the Upper Pleistocene of the eastern islands (Meco 2003). The same end can happen in the case of La Santa site, if it continues with its urban development, and indirectly, from the fossil dune deposits by the extraction of aggregates necessary for the construction of tourist developments and the annexed infrastructures. The choice of some of the paleontological geosites of the Lanzarote and Chinijo Islands UNESCO Global Geopark as geosites will undoubtedly contribute to improve their state of conservation and, at the same time, may serve as a revulsive for their better knowledge.

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