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VALORIZATION AND CONSERVATION OF GEOMORPHOLOGICAL HERITAGE: MONTE PINDO ON THE GALICIAN COAST (NW SPAIN)

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Abstract

This work focuses on the granite mountain known as Monte Pindo in the Autonomous Community of Galicia (NW Spain). It's included in the area classified as "Costa da Morte" established in the Coastal Planning Policy (Politica de Ordenación Litoral – POL) for the region of Galicia. The main objective of this research is to assess the geomorphological heritage of Monte Pindo, thus revealing its wide geodiversity and its landforms. This work aims to demonstrate the importance and interest of its granite landscape in the hope that the area will be recognised as a Geosite, with the dimension of Area. We will analyse and highlight: its scientific and educational value and its geotouristic potential in order to promote its preservation as Geological and Geomorphological Heritage, that is to say, its Geoconservation.

keywords: Geomorphological heritage, granite landscape, geosites, geoconservation, Monte Pindo-NW Spain

Resumen

Este trabajo se centra en el macizo granítico conocido como Monte Pindo, localizado en la Comunidad Autónoma de Galicia (NW España). Se engloba en el área clasificada como "Costa da Morte" siguiendo la Política de Ordenación Litoral de Galicia (POL). El principal objetivo de esta investigación es valorar su Patrimonio Geomorfológico, sus formas graníticas y su amplia geodiversidad. Para ello se resalta el interés de su paisaje granítico con la finalidad de que el Monte Pindo sea reconocido como un Geositio, con dimensión de Área. Para ello se analizarán y destacarán sus valores: científico, educacional y su potencial geoturístico, para promover su conservación como Patrimonio Geológico-Geomorfológico, que es como decir su Geoconservación.

Palabras clave: Patrimonio geomorfológico, paisaje granítico, geositios, conservación, Monte Pindo-NW España

1. Introduction

Over the last decade a knowledge base, along with the legislation that this implicitly requires, has been built up worldwide in relation to the characterization, conservation and management of both geological heritage and geodiversity. During 2007 for the first time in the history of Spain, important laws were passed by the Spanish Parliament explicitly mentioning geological heritage and geodiversity (Law

5/2007 -National Parks Network, Law 42/2007 -Natural Heritage and Biodiversity, Law 45/2007 -Sustainable Development of Rural Environment) (Costa-Casais and Caetano Alves 2013; Costa-Casais et al. 2015). The new legislative framework referring to natural conservation, supposes that inventories and on-going studies of the state of conservation of geodiversity and geological heritage be carried out. There are a multitude of concepts and definitions in scientific literature concerning geodiversity, geological heritage, geosites and geoconservation (Carcavilla et al. 2012; Gray 2008, 2013; Nieto 2001; Serrano and Ruíz Flaño 2007). Geodiversity is an important term for future geoheritage management strategies. It describes a complexity of natural attributes on all levels and represents both opportunities and challenges for management strategies (Erikstad 2013). Geological interpretation is a strategy that aims to facilitate communication between different kinds of publics, aiding the promotion of their scientific culture and the generation of feelings of esteem and protection for geoheritage (Pacheco and Brilha 2014). The identification and characterisation of sites are decisive steps in any geoconservation strategy (Brilha 2015; Henriques et al. 2011).

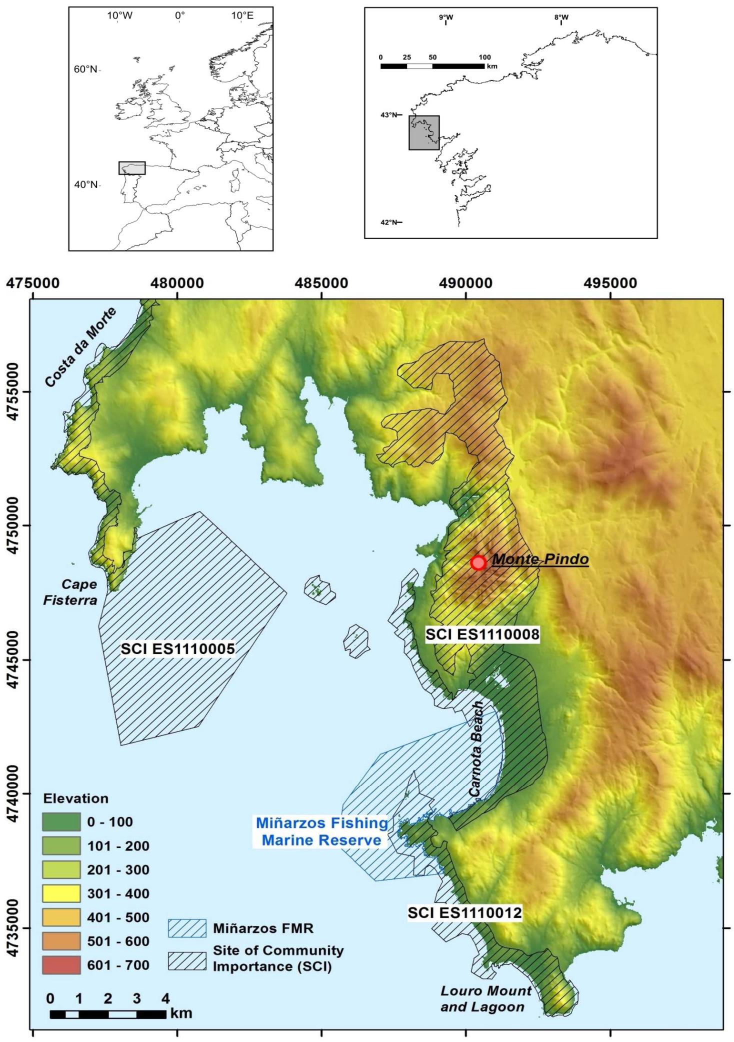


Figure 1 – Location of the study sector with the protected areas cited in the text.

This study focuses on the granite mountain known as Monte Pindo in the Autonomous Community of Galicia (NW Spain). This territory is included in the area classified as “Costa da Morte” established in the Coastal Planning Policy (Politica de Ordenación Litoral -POL) for the region of Galicia (Xunta de Galicia 2014). Currently, Monte Pindo’s biotic values are partially protected. It is designated as SCI (Site of Community Interest) 1110008 Carnota-Monte Pindo, and is included in the Natura 2000 network as an area of special protection of natural values related to both its vegetation and birdlife (ZEPA) (Figure 1). The abiotic values and geological heritage of this territory have been forgotten, and are, therefore, unprotected (Costa Casais et al. 2015). There is an urgent need to accentuate the principle that natural diversity is composed of both geodiversity and biodiversity, and that proficient conservation requires a holistic approach that views nature as a complex interaction of biodiversity and geodiversity patterns and processes. There are many elements of geodiversity which do not have a particular scientific value but which are still important resources for education, tourism, or the cultural identity of their communities (Brilha 2015).

The main objective of this work is to assess the geomorphological heritage of Monte Pindo. This study aims to demonstrate the importance and interest of its granite landscape in the hope that the area will be recognised as a Area, containing a high number of potential geosites. We will analyse and highlight its scientific, educational and geotouristic potential in order to promote its preservation as Geological Heritage.

2. Regional setting and geological context

The research focuses on the granite mountain known as Monte Pindo (627 m above sea level) in the Autonomous Community of Galicia (NW Spain). This territory is included in the area classified as “Costa da Morte” as established in the Politica de Ordenación Litoral (POL) (Coastal Planning Policy) for the region of Galicia. This space is located between the areas classified in the POL as “Rías Baixas’” and “Cape Fisterra” (figure 1).

The massif of Monte Pindo is made up of Late Hercynian calc-alkaline granitoids, with a predominance of biotite, within the group of the late granodiorites (IGME 1981). It belongs to the migmatitic domain of granitic rocks. The predominant type of rock is late granodiorite, which intruded after the late phases of folding. It is possible to differentiate two types in the massif: late granodiorite, with marginal facies occupying the northern half and late granodiorite, with central facies, occupying the southern part (GEODE 2015). They are biotitic granites, pink in colour, which have facies with medium to thick grain and are without orientation (Capdevila and Floor 1970). They are composed of: quartz, plagioclase, potassium feldspar and biotite. They also have apatite, zircon, clinozoisite, zoisite, fluorite and opaques as accessories. The phases of deformation which gave rise to the vertical structure of the area were fundamentally the Late Hercynian tectonics which determined their future evolution. The geomorphological features appear to show that Neogene tectonics caused a period of decompression leading to the creation of an intense set of blocks, which used the NE-SW fractures of the Late Hercynian period (Pérez-Alberti 1982). This activity produced an extensive network of vertical joints, determining the granitic modelling. The breakdown of the granite was produced by means of both physical and chemical weathering.

3. Results and discussion: The Heritage Values of Monte Pindo "vs." Vulnerability and Risk

Monte Pindo, demonstrates a wide variety of added values: intrinsic (representativity, a site of reference, of a scenic nature), intrinsic and relating to use (educational content), use heritage (association with other elements of natural, historical or ethnological-traditions), use and protection (fragility, accessibility, etc.) (figure 2). All of which contributes towards a site of exceptional natural and cultural value but at present the natural value is vulnerable and is at risk. In the following sections we analyze this topics.

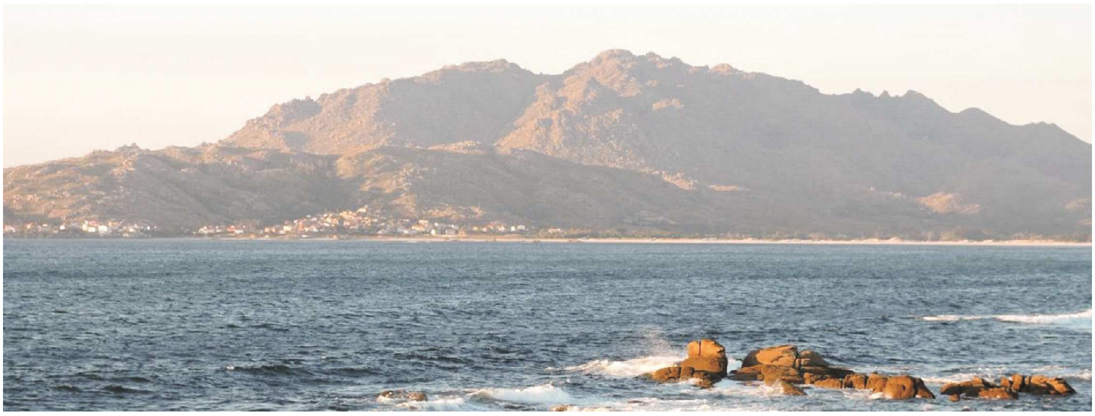


Figure 2 –View of the massif of Monte Pindo.

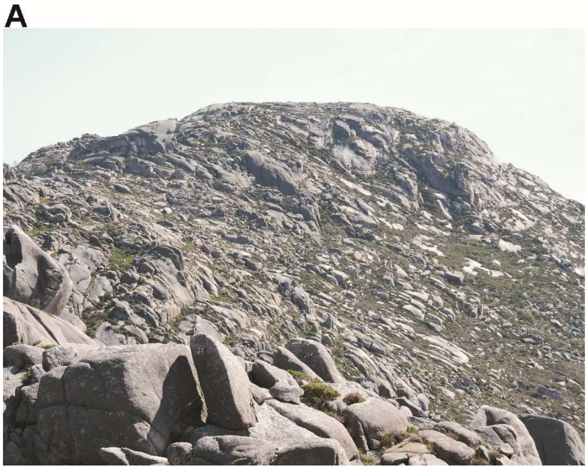
3.1. Heritage values

3.1.1. Geomorphological value

Monte Pindo has great potential for explaining geological processes. Its geomorphological heritage is characterised by a high degree of diversity of its granite landforms (Fernández-Mosquera 2002; Mayor-Rodríguez 2011; Twidale 1981, 1982; Vidal-Romaní 1989; Vidal-Romaní et al. 2014). The granite landforms are classified into two groups depending on their size: megaforms or large scale forms, and microforms or smaller forms (Godard 1977; Twidale 1986, 1989).

Megaforms are those with a minimum size of about 100 metres and can be up to 1 km in length. Some macroforms (tors, blocks) may have decametric size. There are convex megaforms (bornhardts or rock domes, nubbins, castle-kopjes, tors, blocks) and concave megaforms (alveoles). The most important are convex megaforms, represented by bornhardts or rock domes, nubbins or incipient rock domes and castle-kopje. *Bornhardts* present typical curved surfaces of bare rock, as result of sheet fractures. These landforms dominate the upper sections of the granite massif. The most representative example corresponds to the hill's highest point (A Moa, 627 m) (figure 3A). Its surface has been carved by numerous gnammas. The *castle-kopje* is defined by systems or orthogonal joints which give rise to castle shaped reliefs. They are numerous in the whole sector and are associated with *tors* (figure 3B). These are convex forms with vertical development. They have horizontal joints, creating parallelepiped blocks, on top of each other, resulting in chaotic forms. They can be identified by visitors because they have anthropomorphic, zoomorphic or other resemblances and they have particular names (e.g. "O Xigante - The giant", "O guerreiro - The Warrior"). The slopes are covered with abundant *blocks* (Figure 4A). *Alveoles* are also present in this sector. Due to their morphology, they have the capacity to retain and accumulate matter, favouring the formation of soil. Their profile is gentle, almost flat, soil can develop easily and small wetlands can form, which become spaces with a high degree of palaeoenvironmental value and biodiversity for the area. Chan das Lamas and Chan da Moa are good examples.

A



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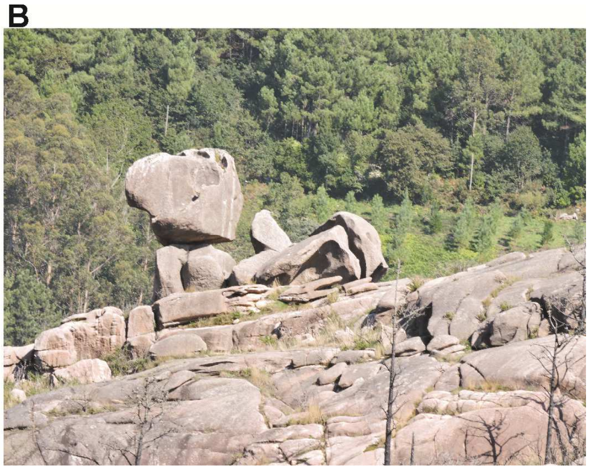

Figure 3 – (A) *Bornhardts* present typical curved surfaces of bare rock, as result of sheet fractures. These landforms dominate the upper sections of the granite massif. (B) *Tors,* are convex forms with vertical development. They have horizontal joints, creating parallelepiped blocks, on top of each other, resulting in chaotic forms.

Microforms are defined as having a maximum size of one metre, although they are frequently smaller and are associated with macroforms. Two groups can be distinguished: (a) forms without any evident relationship to the rock structure, and (b) forms with an evident relationship to the rock structure. The first group is represented by *linear forms* and point forms. The linear forms are: *runnels, gutters* (developed on a horizontal or very slightly sloped topography), or *grooves* and *flutings* (corresponding to similar features developed on inclined surfaces). The *point forms are concave*: gnammas, tafone, vasques. *Gnammas* are small circular depressions. They develop both on flat and sloped surfaces and can be enclosed or have a drainage channel (Figure 4B). Sometimes the concavities appear on the inner part of a wall. In this case the resulting landform is known as a *tafone*.

A B

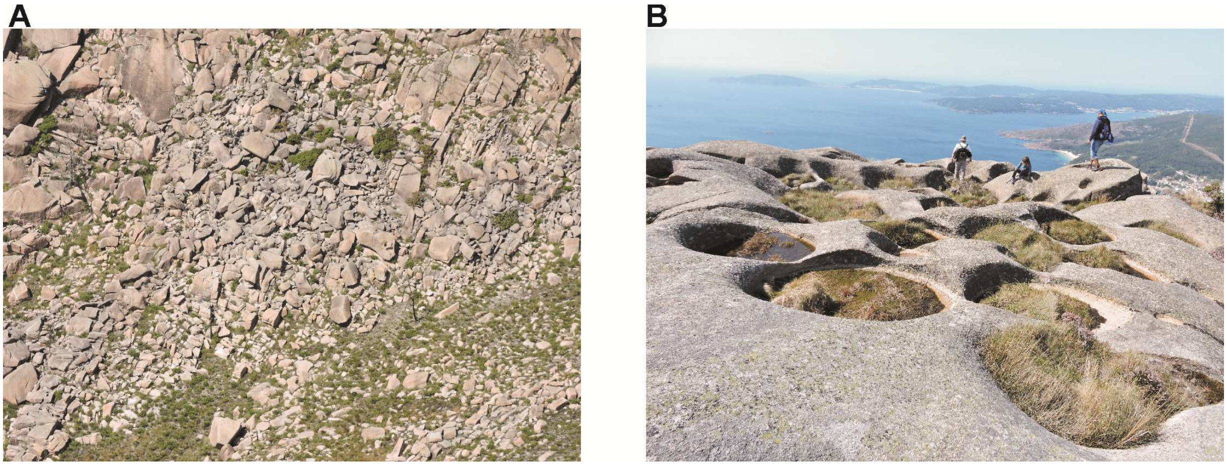

Figure 4 – (A) The slopes are covered with fallen blocks. (B) *Gnammas*, small circular depressions, on a *bornhardt*

Concavities can appear in connection with water courses. These can reach several metres in size, as is the case of the *vasques*, or *plunge pools* of larger dimensions, which are best shown at the base of the Xallas waterfall (figure 5A). The *microforms with an evident relationship to the rock structure,* can be divided into: *linear and planar forms*. In the first, *clefts* can be included and in the second*, pseudo bedding*, *structural caves* and *fractured slabs*. The presence of granitic slabs near the mouth of Xallas river must be highlighted. They are minor forms which are related to the structure of the rock – their joints are flat in shape and are tilted slightly down.

A B

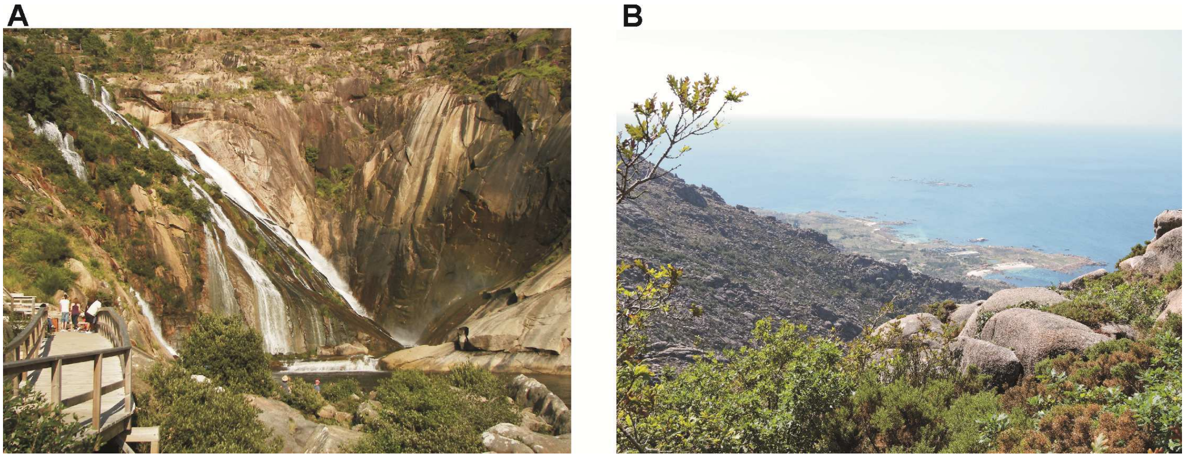

Figure 5 – (A) The Xallas River falls in waterfall, directly on the sea. (B) Quercus lusitanica, between granitic-rocks

3.1.2. Biodiversity value

The mountain has a protection category at Community level (SCI) due to its wealth of plant species. About 650 species have been catalogued, fifty of them protected and some in "critical" danger of extinction. It has five habitats protected by a European directive, eight plant species and twelve different species of wildlife also have regional protection. Monte Pindo is designated as SCI ES (Site of Community Interest) 1110008 Carnota-Monte Pindo, and is included in the Natura 2000 network as an area of special protection of natural values related to both its vegetation and birdlife (ZEPA). The *Quercus lusitanica*, a shrub existing only in Galicia, central Portugal, the southern provinces of Cádiz and Málaga and in the north of África, deserves special mention (figure 5B). Fauna and vegetation (mainly oaks, wetland vegetation and threatened species) suffer the directly from intentional fires. The effects are catastrophic for wildlife, vegetation and soil.

3.1.3. Geocultural value

On an archaeological level, Monte Pindo is rich in cultural heritage. Archaeological remains can be found dating from different historical periods. Rock art carved out of the pink granite, remains of Neolithic structures, forts (the castle of San Xurxo and castle of Peñafiel), hermitages, walls, paths, etc., all reflect the fact that this place has been occupied and used by different cultures throughout history (Barreiro 1970, 1986; Gago 2011, 2014; Galovart 2015) (figure 6A).

Monte Pindo is a symbol of identity with the landscape for both the local population and visitors from outside the area. This fact leads to the hill being valued in different ways. An association has been set up by some members of the local population with the aim of protecting the landscape. This association is supported by other groups, political parties and researchers, who argue that Monte Pindo should be proclaimed a "Natural Park" in order to protect the landscape with the aim of ensuring its preservation for future generations. On the other hand, another part of the local population is against this idea although the Monte is also a symbol of identity for them, an idea which is often reinforced by the assessment made of this landscape by visitors. The concern for the protection is not only a current matter. The first reference to the site's protection comes from a 1917 Royal Decree dated February 23rd, as is cited by the geographer (Mulero 2002). From ancient times, historians, geographers and writers have made reference to the greatness and the mystery surrounding Monte Pindo, one of the most mythical places in Galicia (Pensado 1975). Monte Pindo dominates a landscape of great beauty, rising to the Alto da Moa at 627 m above sea level. It is a spectacular viewpoint over the coastline extending from Fisterra Cape to beyond the Muros-Noia Ria. Monte Pindo has come to be known as the Celtic Olympus of Galicia and the hill came to be a reference point and a symbol of identity in the strengthening of Galician roots and was used by the intellectuals of the time belonging to the Xeración Nós (Otero Pedrayo 1926, 1991). According to oral tradition, the Monte Pindo is also, a place where the sun, the stars and the elements were worshipped. The particular shape of the hill has led to the creation of a multitude of legends. Furthermore, very real stories, close to the heart of the local population, have been forged, such as those in which the rocks of the hillside served as a refuge for those escaping the enemy during the Spanish Civil War.

3.2. Vulnerability and Risk

The construction of an electric power station, a reservoir, wind farms, quarries and a fish farm have had a great impact on the area, which is not reflected economically in the local population. Monte Pindo is severely threatened and extremely vulnerable. The *electric power station* located in the council of Ézaro, at the foot of Monte Pindo, has a great visual impact on the area, both due to the construction of the plant and to the pipelines which scar the hillside. The *reservoir*, built by the company Carburos Metálicos, was finished at the end of the 1980s. It was built at the mouth of the river without respecting its environmental flow. This has resulted in alterations to the minimum flow necessary for the preservation of the river's ecological, its environmental functions and the preservation of the landscape. This river, before it meets the sea, has formed three waterfalls over granitic material and wide pools with sculpted columns. The largest of the waterfalls lies at the river's mouth and is known as "A Fervenza do Xallas". The current lease-holder, "FerroAtlántica", has been obliged to maintain the river's minimum environmental flow in accordance with the law entitled "Resolución de Aguas de Galicia". Another threat to the site is the construction of *wind farms*, which surround the area (figure 6B). Also, Monte Pindo is under threat from open-cast *quarries*, attracted by its pink granite (figure 6C). The effects of quarrying are irreversible. The most direct impact is visual. The extraction of granite leads to the destruction of the most important value of the hill; its abiotic aspect, the rock with its granitic model, which sustains great biodiversity. The construction of *a fish farm*, at the foot of the hill, in the village of Quilmas-Carnota, has also had a significant effect on the coastline. The fish farm, lies within the SCI Carnota-Monte Pindo, an area of high ecological value which forms part of the Galician Red Natura. The immediate surroundings of the farm, which is coastline, is not looked after. The installations have a strong visual impact on the area. Tracks have been opened up over the dunes, waste is not disposed of correctly and the pipes of the fish farm are visible. All of this contributes towards a high level of vulnerability for such a fragile habitat as the coastline.

The hill is periodically burnt by deliberate *fires*, usually in the summer when the northwest wind blows more strongly (figure 6D). If there is extreme precipitation following the fires, this can lead to catastrophic events on the landscape. The intensity of the rain can have a great impact on the formation and development of the colluvial soil (Costa-Casais et al. 2009; Costa-Casais et al. 2015). The effects of the rain are added to those of the fires, thus causing the ground to be more sensitive to the effects of erosion (Costa-Casais et al. 2008; Costa-Casais and Martínez-Cortizas 2013). In this way, a section of land unprotected by vegetation becomes eroded and a significant amount is lost in the sea. These fires are started deliberately for no apparent reason. There is no policy for control and this does not appear to be of interest to the administration. The vegetation destroyed by the fires is mainly pine and eucalyptus, which are invasive species. Although *Quercus lusitanica* suffers damage, its greater resistance to fire means that it can hide in small valleys and rocky areas with little soil. Finally, the *high volume of visitors* must be mentioned. The number of people who climb Mount Pindo is very high. Tours are conducted without any control or planning, paths are made, the rocks are graffitied, people use motorbikes and quads and mass sporting events are organized (figure 6E).

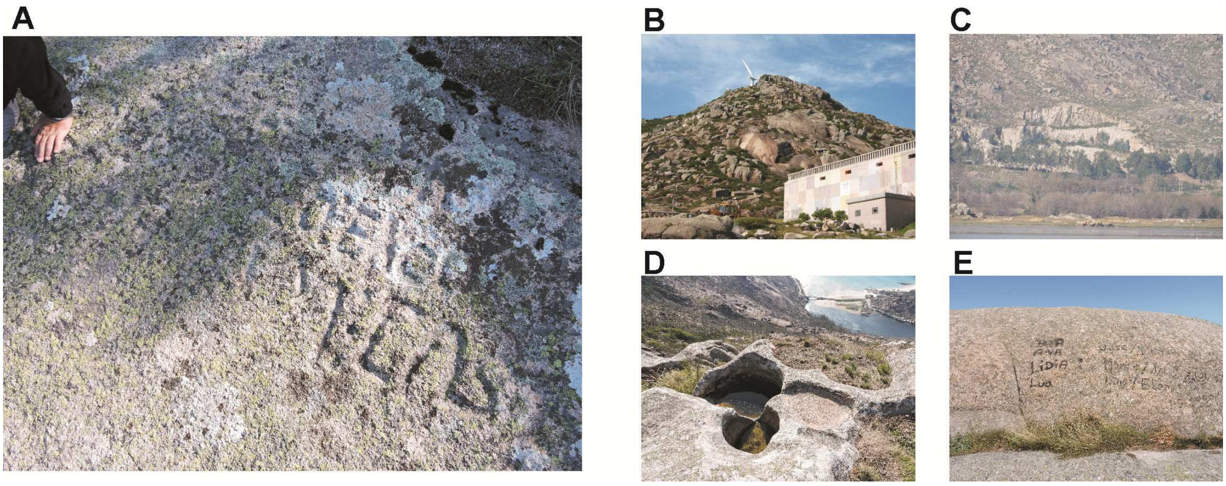

Figure 6 – (A) Petroglyphs carved out of the pink granite. (B) Wind farms surround the Monte Pindo, and have a great impact on the area. (C) Monte Pindo is under threat from open-cast *quarries*, attracted by its pink granite. (D) The reservoir built at the mouth of the Xallas river resulted in alterations to the river's ecological, its environmental functions and the preservation of the landscape. (E) The examples of rocks graffitied are numerous in the Monte Pindo

3.3. Proposal for the Assessment of Degradation Risk and Estimate of Protection Priority for Monte Pindo

Recent research on assessment and management of the geomorphological heritage of Monte Pindo (Costa-Casais et al. 2015) proposed and demonstrate the importance and interest of its granite landscape in the hope that the Monte Pindo will be recognised as a Geosite, with the dimension of Area, containing a high number of potential geosites (SGI). Its geomorphological heritage is characterised by a high degree of geodiversity of granite landforms. In order to carry out a methodological proposal, we followed the guidelines set out in the Methodological Document for the Drawing Up of the Spanish Inventory of Sites of Geological Interest of the Spanish Geological Survey (IGME) (García-Cortés et al. 2009, 2014). For the purposes of this study, Monte Pindo as a whole has been selected as representative of a granite massif to apply this methodology. However, we are aware that it is not a geosite but rather an area that contains many geosites. The most recent methodological document published regarding the Spanish Inventory of Sites of Geological Interest (García-Cortés et al. 2014) takes into account (Cendrero 1996) criteria according to which three types of value should be considered when a site is assessed: its intrinsic value, its value related to potential use and its value related to the necessity for protection (Costa-

Casais and Caetano Alves 2013). Following the collection of data and fieldwork, Monte Pindo was evaluated according to the above-listed parameters, which were given varying weight in order to analyze their scientific, educational and touristic interest. The values obtained for the Scientific, the Educational and the Touristic value are considered to be of very high value. With regard to the criteria for evaluating the susceptibility of degradation (fragility and vulnerability) of Monte Pindo, the susceptibility to natural degradation is considered low, while susceptibility to anthropic degradation is medium-high (Costa-Casais et al. 2015). The estimate of the protection priority of Monte Pindo was carried out based on the risk of degradation to anthropic threats. The score obtained for necessity / protection priority is 4.71, maximum value of degradation risk of SGI due to anthropic hazards (Costa-Casais et al. 2015). Geosites with degradation risk of SGI due to anthropic hazards values of between 3.33 and 6.66 are recommended for protection in the medium-short term (risk of medium degradation). This suggests that a specific protection status is necessary for Monte Pindo in the medium term (short-term measures of geoconservation) (Medus 1965; García-Cortés et al. 2009; Costa-Casais et al. 2015) (Table I).

Table I –Calculation of degradation risk and estimate of protection priority of Monte Pindo.

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INTEREST	**Symbol**
Scientific value of SGI	$\mathbf{V_C}$ = 8.75
Educational value of SGI	$\mathbf{V_D}$ = 7.75
Touristic value of SGI	$\mathbf{V_T}$ = 6.88
Susceptibility to natural degradation	$\mathbf{S_{DN}}$ = 1.25
Susceptibility to anthropogenic degradation	$\mathbf{S_{DA}}$ = 5.38
SGI Susceptibility to degradation	$\mathbf{S_D = ½ (S_{DN} + S_{DA})}$ = 3.32

	Symbol	**Formula**	**Result: MONTE PINDO**
Degradation risk of SGI due to natural hazards	$\mathbf{R_{DN}}$	$\mathbf{R_{DN} = MAX (R_{DNC}, R_{DND}, R_{DNT})}$	$\mathbf{R_{DN} = 1.09}$
Degradation risk of SGI due to anthropic hazards	$\mathbf{R_{DA}}$	$\mathbf{R_{DA} = MAX (R_{DAC}, R_{DAD}, R_{DAT})}$	$\mathbf{R_{DA} = 4.71}$
Degradation risk of SGI	**RD**	$\mathbf{R_D = MAX (R_{DC}, R_{DD}, R_{DT})}$	$\mathbf{R_D = 2.91}$

NECESSITY / PROTECTION PRIORITY	$\mathbf{R_{DA}}$	**MONTE PINDO**
High (urgent measures of geoconservation)	High. $\mathbf{R}_{DA} > 6.66$	
Medium (short-term measures of geoconservation)	Medium. $3.33 \leq \mathbf{R}_{DA} \leq 6.66$	$\mathbf{R}_{DA}$ **= 4.71**
Low (medium to long-term measures of geoconservation)	Low $1 \leq \mathbf{R}_{DA} < 3.33$	
No protection (measures of geoconservation unnecessary or in the long-term)	No significant $\mathbf{R}_{DA} < 1$	

Source: Manuela Costa-Casais et al. (2015)

Currently, the biotic value of this area is partially protected. However, it is necessary to find a solution not only for the protection of its biodiversity but also for its geodiversity and its cultural values. Due to the lack of understanding between local and regional governments regarding the protection status of Monte Pindo, as a Natural Park, for example, it would be necessary to obtain recognition of Monte Pindo's heritage interest on a geological-geomorphological level. From this starting point, the relevant local authorities should document this area of natural heritage. Based on this study, this knowledge/strategy should be implemented in stages, with the option of including the site in the list of Spain's geosites. It is necessary to put strategies into practice to enable the assessment of geological sites of interest with scientific, educational and didactic, cultural or touristic value; that is, those geomorphological geosites that form part of our Geological Heritage.

4. Final remarks: the heritage values of Monte Pindo

Monte Pindo, located on the coast, has great potential for explaining geological processes and its geomorphological heritage is characterised by the high degree of geodiversity of its granite landforms. The study of these granite forms provides valuable data with regard to the formation and evolution of granite massifs and their geomorphological aspects. Heritage values are represented by geomorphological, biotic, geocultural and educational and didactic features.

Currently, the biotic value of this area is partially protected. However, it is necessary to find a solution not only for the protection of its biodiversity but also for its geodiversity and its cultural values. Due to the lack of understanding between local and regional governments regarding the protection status of Monte Pindo, as a Natural Park, for example, it would be necessary to obtain recognition of Monte Pindo's heritage interest on a geological-geomorphological level. From this starting point, the relevant local authorities should document this area of natural heritage. Based on this study, this knowledge/strategy should be implemented in stages, with the option of including the site in the list of Spain's geosites. It is necessary to put strategies into practice to enable the assessment of geological sites of interest with scientific, educational and didactic, cultural or touristic value; that is, those geomorphological geosites that form part of our Geological Heritage.

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