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ORIGINAL ARTICLE

Designation of Natural Monuments by the Local Administration: the Example of Viana Do Castelo Municipality and its Engagement with Geoconservation (NW Portugal)

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Abstract A geosite inventory done in the coastal area of Viana do Castelo district (NW Portugal) revealed the occurrence of important geodiversity elements, mainly geomorphological features such as granite, tectonic, fluvial, aeolian, and cultural landforms. This geoforms record regional tectono-eustatic changes and the major paleoclimatic events from MIS11 to MIS1. The quantitative assessment showed that among 17 geosites, 6 of them have exceptional scientific value, high to very high potential for tourism and educational uses, and medium to high risk of degradation. Based on these results, the Viana do Castelo municipality has decided to designate these 6 geosites as 5 local natural monuments, according with the Portuguese legislation of nature conservation. This paper shows a good example of the importance of the involvement of local administration in the implementation of effective geoconservation strategies, once solid scientific studies reveal the real relevance of geodiversity.

Keywords Geosites · Geological heritage · Natural monument · Viana do Castelo Littoral Geopark

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Introduction

Geoconservation strategies should be defined and implemented by different levels of public administration. The engagement of local administration with geoconservation is of paramount importance because local land-use management policy is under their direct responsibility. The protection and management of geosites by municipalities can promote a sustainable use of the territory and the development of economical activities through the increase of geotourism. In Portugal, the national group of ProGEO (The European Association for the Conservation of the Geological Heritage) gives awards to municipalities with notable results in the implementation of geoconservation actions. The Geoconservation Award has been given yearly since 2004 through a national contest to which municipalities apply (Brilha 2008, 2009).

In order for municipalities to be directly involved with the protection of geosites, it is necessary that national legislation is properly adapted. The Portuguese legislation that governs nature conservation policies facilitates municipalities in the creation and management of local protected areas of different categories (natural parks, natural reserves, protected landscapes, and natural monuments). The decree 142/2008 of 24th July also allows for the creation of protected areas based on the need to protect geosites at a local, regional (in case of a protected area that extends over more than one municipality), and national levels.

This paper describes the process of creation of five local natural monuments in the municipality of Viana do Castelo (NW Portugal), based on a scientific study developed in the coastal area of Viana do Castelo district (Caminha and Viana do Castelo municipality) (Carvalhido 2012), between the Minho River mouth (N 41° 51′ 54.22″;W 8° 51′ 44.02″) and the mouth of the Neiva River (N 41° 36′ 045.77″;W 8° 48′ 37.72″) (Fig. 1).

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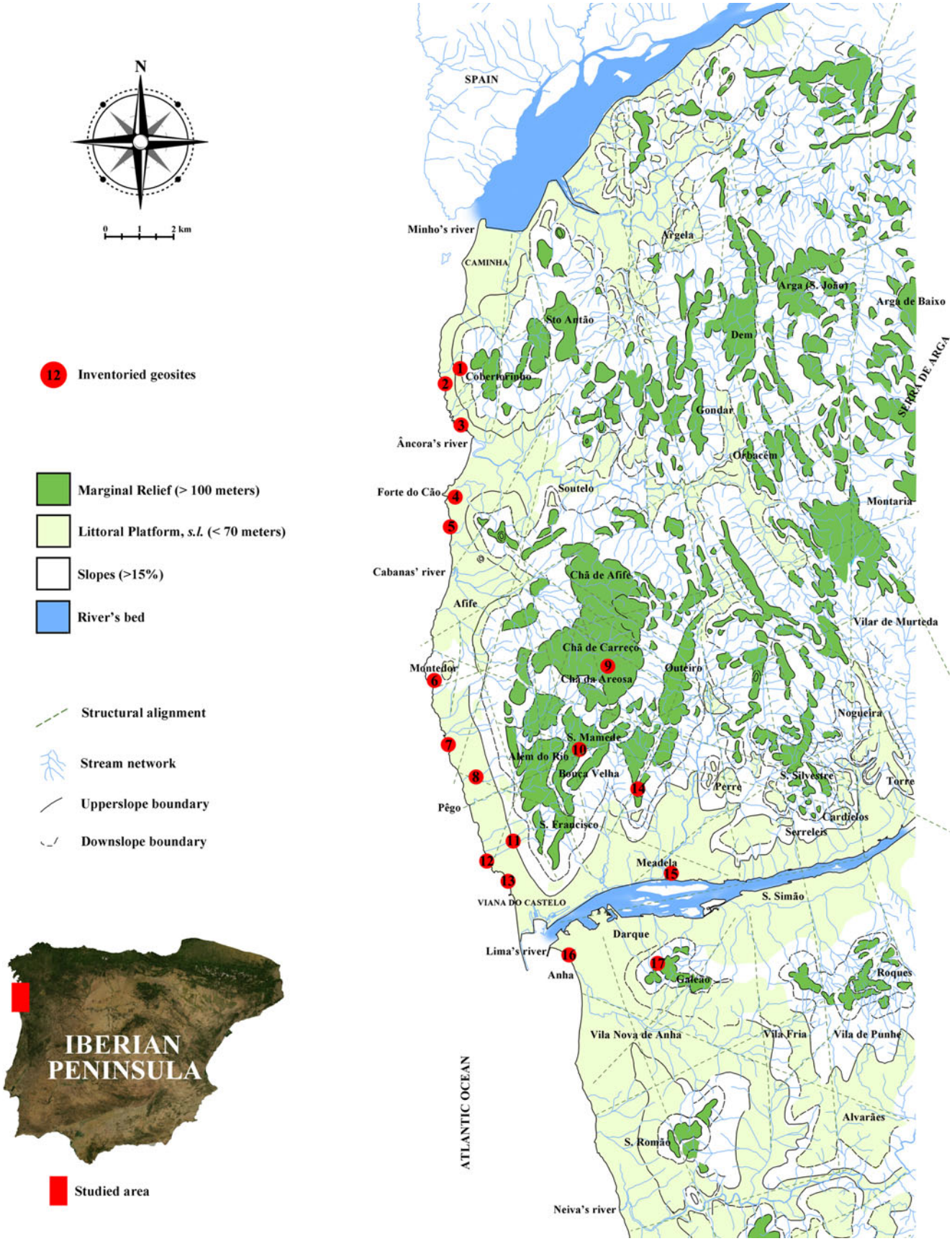
N
0 1 2 km
12 Inventoried geosites
Marginal Relief (> 100 meters)
Littoral Platform, s.l. (< 70 meters)
Slopes (>15%)
River's bed
Structural alignment
Stream network
Upperslope boundary
Downslope boundary
IBERIAN PENINSULA
Studied area
SPAIN
Minho's river
CAMINHA
Argela
Arga (S. João)
Arga de Baixo
Sto Antão
Dem
SERRA DE ARGA
Cobertoninho
Gondar
Âncora's river
Orbacém
Forte do Cão
Soutelo
Montaria
Cabanas' river
Chã de Afife
Afife
Vilar de Murteda
Chã de Carreço
Montedor
Chã da Areosa
Outeiro
Nogueira
S. Mamede
Além do Rio
Bouça Velha
S. Silvestre
Torre
Perre
Pêgo
Cardielos
S. Francisco
Serreleis
Meadela
VIANA DO CASTELO
S. Simão
Darque
Lima's river
Anha
Galeão
Roques
Vila Nova de Anha
Vila Fria
Vila de Punhe
ATLANTIC OCEAN
Alvarães
S. Romão
Neiva's river

◀ **Fig. 1** Geomorphological map of NW Portugal coast, with the location of the 17 geosites inventoried. Geosites: (*1*) Estrada Real; (*2*) St. Domingos; (*3*) St. Isidoro; (*4*) Forte do Cão; (*5*) Carrasqueira; (*6*) Alcantilado de Montedor; (*7*) Lumiar-Canto Marinho; (*8*) Poço Negro; (*9*) Chãs de St. Luzia; (*10*) St. Mamede; (*11*) St. Sebastião; (*12*) Rego de Fontes; (*13*) Praia Norte; (*14*) Penedo Furado; (*15*) Salinas da Meadela; (*16*) Ribeira de Anha and (*17*) Galeão

This study focused on the geomorphological and sedimentological characteristics of a Pleistocene coastal terrace staircase, covered by extensive late Pleistocene to Holocene sedimentary units and aimed to (1) obtain the first numerical ages for Pleistocene sequences of NW Portugal, (2) contribute to the understanding of the evolution of coastal processes and coeval sedimentary and geomorphological controls, (3) identify the main climatic stages, and (4) contribute for the understanding of the tectonic evolution of Minho region. The results of Carvalhido (2012) showed the scientific importance of some of these records and consequently the need to implement conservation measures in order to avoid their deterioration. Although this study presents the results of a geosite inventory in the Caminha and Viana do Castelo municipalities, the latter was the first one to start the designation process in January 2014. This paper is focused on the designation of 6 of those localities as local natural monuments in the Viana do Castelo municipality, as a guarantee for the inclusion of these geosites in municipal tools for land-use management.

Methods

The selection of geosites in the study area was based on the scientific value of landforms and geological occurrences through which is possible to recognise the various stages of geomorphological evolution of the coastline between Minho and Neiva river mouths. The qualitative assessment of the scientific value was made with criteria proposed by Lima (2008) and Brilha et al. (2010), namely representativeness, integrity, key-locality, geological diversity, and rarity.

Given the presence of several factors that may threaten the geosite's integrity, a quantitative assessment of the degradation risk of the geosites (DR) was carried out in order to facilitate the future management of these areas by the competent authorities through the definition of a municipal geoconservation strategy. Additionally, given the potential of some geosites for tourism and educational activities, a quantitative assessment of these potential uses was also carried out.

The quantitative assessment of degradation risk and potential for tourism and educational uses was adapted

Table 1 Criteria, indicators and parameters used for the assessment of the degradation risk (DR)

Criteria and indicators	Parameters
Accessibility (Ac)	30 (max.)
Very difficult access, just possible with special equipment	0
More than 500 m from an access only possible by all-terrain vehicle	5
More than 500 m from a road accessible by car	10
Less than 500 m from a road accessible by car	15
Less than 100 m from an access only possible by all-terrain vehicle	20
Less than 50 m from a road accessible by car	25
Less than 50 m from a road accessible by bus (>50 seats)	30
Intrinsic fragility (If)	25 (max.)
Only sensitive to large-scale anthropogenic changes	0
Sensitive to strong surface interventions	5
Sensitive to sampling or vandalism actions	10
Sensitive to frequent human trampling	20
Sensitive to occasional human trampling	25
Protection regime (Pr)	25 (max.)
Geosite located in an area with legal protection and access control	0
Geosite located in an area with legal protection but no access control	5
Geosite located in an area without legal protection but with access control	15
Geosite located in an area without legal protection and no access control	25
Proximity to areas/activities with potential to cause degradation (Pd)	20 (max.)
Site located more than 1 km of a potential degrading area/activity	0
Site located more than 500 m of a potential degrading area/activity	5
Site located more than 200 m of a potential degrading area/activity	15
Site located less than 50 m of a potential degrading area/activity	20

from Brilha (2005) and García-Cortéz and Carcavilla (2009) (Tables 1, 2 and 3). Although the described assessment was carried out before the publication of Brilha (2015), minor changes were introduced into the method in order to include some of the proposals of this new paper. The DR assessment used the following criteria: *Accessibility* (Ac), *Intrinsic fragility* (If), *Protection regime* (Pr) and *Proximity to areas/activities with potential to cause degradation* (Pd) (Table 1). The evaluation of the potential geotourism use (PGU) used six criteria: *Accessibility* (Ac), *Intrinsic fragility* (If), *Scenery* (Sn), *Facilities proximity* (Fp), *Proximity to other geosites or other cultural attractions* (Og), and *Interpretative potential* (Ip) (Table 2). Finally, the *potential educational use* (PEU) assessment was done with the following criteria: *Accessibility* (Ac), *Facilities proximity*

Table 2 Criteria, indicators and parameters used for the assessment of the potential geotourism use (PGU)

Criteria and indicators	Parameters
Accessibility (Ac)	10 (max.)
Very difficult access, just possible with special equipment	0
More than 500 m from an access only possible by all-terrain vehicle	1
More than 500 m from a road accessible by car	2
Less than 500 m from a road accessible by car	4
Less than 100 m from an access only possible by all-terrain vehicle	6
Less than 50 m from a road accessible by car	8
Less than 50 m from a road accessible by bus (>50 seats)	10
Intrinsic fragility (If)	20 (max.)
Sensitive to occasional human trampling	0
Sensitive to frequent human trampling	5
Sensitive to sampling or vandalism actions	10
Sensitive to strong surface interventions	15
Only sensitive to large-scale anthropogenic changes	20
Scenery (Sn)	20 (max.)
Site is not used as a tourism destination in local or national campaigns	0
Site occasionally used as a tourism destination in local campaigns	5
Site frequently used as a tourism destination in local campaigns	10
Site occasionally used as a tourism destination in national campaigns	15
Site frequently used as a tourism destination in national campaigns	20
Facilities proximity (Fp)	20 (max.)
Hotels and other tourist facilities located more than 10 km	0
Hotels and other tourist facilities located between 5 and 9 km	5
Hotels and other tourist facilities located between 1 and 4 km	10
Hotels and other tourist facilities less than 1 km	15
Hotels and other tourist facilities less than 300 m	20
Proximity to other geosites or other cultural attractions (Og)	10 (max.)
Geosites and/or cultural attractions located at more than 10 km	0
Geosites and/or cultural attractions located between 5 and 9 km	3
Geosites and/or cultural attractions located between 1 and 4 km	6
Geosites and/or cultural attractions located less than 1 km	8
Geosites and cultural attractions located less than 100 m	10
Interpretative potential (Ip)	20 (max.)
Illustrates products and geological processes in a clear and meaningful way only for experts in geology	0
Illustrates products and geological processes in a clear and meaningful way for people with advanced knowledge in geology	5
Illustrates products and geological processes in a clear and meaningful way for people with some knowledge in geology	15
Illustrates products and geological processes in a clear and meaningful way for people without any geological background	20

(Fp), *Proximity to other geosites or other cultural items* (Og), *Curricula* content (Cc), and *Geological diversity* (Gd) (Table 3). The criteria are self-explanatory when considering the indicators associated with each one (Tables 1, 2 and 3).

Each criterion is characterised by several indicators, each one scored with a numerical parameter. Numerical parameters are different for different criteria, reflecting diverse degrees of importance. The final value expresses a percentage score, which varies from *low* (<49 %) to *medium* (50–69 %), *high* (70–89 %), and *very high* (90–100 %).

Results

The geosite inventory allowed the initial identification of 17 sites with scientific value in the Viana do Castelo district (Fig. 1, Table 4). Only 15 geosites were assessed for their degradation risk and potential use for tourism and education, using the method previously explained. The geosites Estrada Real (no. 1) and S. Sebastião (no. 11) (Fig. 1) were not assessed as currently there are no outcrops available.

The results of this assessment are presented in Table 5. Almost half of the geosites (8) have a medium DR (50–65 %)—S. Domingos, Sto. Isidoro, Carrasqueira, Poço Nego, Praia Norte, Penedo Furado, and Salinas da Meadela e Ribeira de Anha. Five geosites have high DR (70–80 %)—Forte do Cão, Montedor, Lumiar-Canto Marinho, Rego de Fontes, and Galeão, and only four have low DR (35–45 %)—Estrada Real, Chãs de Sta. Luzia, and S. Mamede e S. Sebastião. The high DR of the most vulnerable geosites is due to a reduced geosite area and/or to rare landforms (e.g. litostratigraphic units, mineralogical and archaeological occurrences), which are susceptible to damage by human

Table 3 Parameters and respective criteria and points to assess the potential educational use (PEU)

Parameters and respective criteria	Points
Accessibility (Ac)	10 (max.)
Very difficult access, just possible with special equipment	0
More than 500 m from an access only possible by all-terrain vehicle	1
More than 500 m from a road accessible by car	2
Less than 500 m from a road accessible by car	4
Less than 100 m from an access only possible by all-terrain vehicle	6
Less than 50 m from a road accessible by car	8
Less than 50 m from a road accessible by bus (>50 seats)	10
Facilities proximity (Fp)	20 (max.)
Hotels and other tourist facilities located more than 10 km	0
Hotels and other tourist facilities located between 5 and 9 km	5
Hotels and other tourist facilities located between 1 and 4 km	10
Hotels and other tourist facilities less than 1 km	15
Hotels and other tourist facilities less than 300 m	20
Proximity to other geosites or other cultural items (Og)	10 (max.)
Geosites and/or cultural attractions located at more than 10 km	0
Geosites and/or cultural attractions located between 5 and 9 km	3
Geosites and/or cultural attractions located between 1 and 4 km	6
Geosites and/or cultural attractions located less than 1 km	8
Geosites and cultural attractions located less than 100 m	10
Curricula content (Cc)	30 (max.)
Illustrates products and geological processes only suitable for research level	0
Illustrates products and geological processes for one level of the education system	10
Illustrates products and geological processes for two levels of the education system	20
Illustrates products and geological processes for all levels of the education system	30
Geological diversity (Gd)	30 (max.)
Illustrates only one type of geological product or process	0
Illustrates two types of products or geological processes	10
Illustrates three types of products or geological processes	20
Illustrates four or more types of products or geological processes	30

Table 4 Results of the geosites inventory (*CM* Caminha municipality, *VM* Viana do Castelo municipality). The geosite numbers refer to Fig. 1

Geosite	Area (Ha)	Location	Geographic coordinates (WGS84)
Estrada Real (1)	–	Moledo (CM)	41° 50.513′ N/ 8° 52.248′ W
St. Domingos (2)	0.9	Moledo (CM)	41° 50.022′ N/8° 52.508′ W
St. Isidoro (3)	0.6	V.P. Âncora (CM)	41° 49.734′ N/8° 52.508′ W
Forte do Cão (4)	2.1	Gelfa (CM)	41° 47.877′ N/8° 52.416′ W
Carrasqueira (5)	1.4	Afife (VM)	41° 47.696′ N/8° 52.418′ W
Montedor (6)	34	Carreço (VM)	41° 44.964′ N/8° 52.774′ W
Lumiar–Canto Marinho (7)	24	Carreço (VM)	41° 43.693′ N/8°52.308′ W
Poço Negro (8)	3.1	Lugar do Pêgo (VM)	41° 43.369′ N/8° 50.879′ W
Chãs de Sta Luzia (9)	353	Chã de Sta Luzia (VM)	41° 45.339′ N/8° 49.009′ W
S. Mamede (10)	22.8	S. Mamede (VM)	41° 43.794′ N/8° 49.716′ W
S. Sebastião (11)	–	Areosa (VM)	41° 42.618′ N/8° 51.138′ W
Rego de Fontes (12)	6.12	Areosa (VM)	41° 42.055′ N/8° 51.432′ W
Praia Norte (13)	28.8	Monserrate (VM)	41° 41.889′ N/8° 51.189′ W
Penedo Furado (14)	0.1	Meadela (VM)	41° 43.237′ N/8° 48.356′ W
Salinas da Meadela (15)	422	Meadela (VM)	41° 42.087′ N/8° 47.993′ W
Ribeira de Anha (16)	41	Darque (VM)	41° 40.271′ N/8° 49.476′ W
Galeão (17)	37	Darque (VM)	41° 40.459′ N/8° 48.116′ W

trampling or sampling. In addition, these geosites are easily accessible and require immediate action to reduce the risk of being damaged or destroyed. Geosites with a medium DR are occurrences with more difficult access and are landforms with a greater resilience to erosion or vandalism, either because of a greater strength of materials or by its magnitude. These geosites need periodic conservation actions in order to maintain the integrity of relevant sedimentological/stratigraphic features. Finally, low DR geosites—Chãs de Sta Luzia and S. Mamede—do not require any particular protection action because they are extensive occurrences of erosion surfaces in areas with very limited urban development.

Concerning the assessment of the potential use of the geosites (Table 5), almost half of them (8) have high to very high PGU (71 to 95 %): S. Domingos and Forte do Cão (Caminha municipality), and Montedor, Poço Negro, Rego de Fontes, Praia Norte, Salinas da Meadela and Ribeira de Anha (Viana municipality). These geosites achieved high scores in the criteria *Scenery* (Sn), *Facilities proximity* (Fp,) and *Interpretative potential* (Ip), but only 44 % of them offer some level of

Table 5 Results of geosites assessment: degradation risk (DR), potential geotourism use (PGU) and potential educational use (PEU). The geosites Estrada Real (no. 1) and S. Sebastião (no. 11) were not assessed because currently there are no outcrops available

Geosite name and number (cf. to Fig. 1)	DR score (%)	PGU score (%)	PEU score (%)
Estrada Real, 1	–	–	–
St. Domingos, 2	60	77	83
St. Isidoro, 3	65	61	53
Forte do Cão, 4	75	83	93
Carrasqueira, 5	50	56	79
Montedor, 6	70	81	91
Lumiar-Canto Marinho, 7	70	66	79
Poço Negro, 8	60	71	51
Chãs de Sta Luzia, 9	45	50	50
S. Mamede, 10	35	43	36
S. Sebastião, 11	–	–	–
Rego de Fontes, 12	70	83	98
Praia Norte, 13	65	95	100
Penedo Furado, 14	55	36	59
Salinas da Meadela, 15	50	74	69
Ribeira de Anha, 16	50	73	75
Galeão, 17	80	49	54

resistance to being visited without being damaged. St. Isidoro, Carrasqueira, Lumiar-Canto Marinho, and Chãs de Sta. Luzia are geosites with a medium PGU (50–69 %). These geosites have very good *Accessibility* (*Ac*) and are close to other geosites or other cultural attractions (*Og*), and most of them have good nearby facilities (*Fp*) and a good score in *Interpretative potential* (*Ip*). The assessment showed that these geosites have medium to low scores concerning *Scenery* (Sn) and medium to high degradation risk (DR), which are evidence of a low landform variety but more vulnerable. If no protection measures are taken to save the few preserved elements, there is a strong possibility for the total loss of these geosite. There are 3 geosites assessed as low PGU (36 to 49 %)—Galeão, Penedo Furado and S. Mamede, despite having medium scores in *Accessibility* (Ac), *Intrinsic fragility* (If), *Scenery* (Sn), and *Interpretative potential* (Ip). The low PGU is justified by the absence of nearby facilities or other geosites and/or cultural attractions.

Regarding the potential of educational use (PEU), the overall results show a similar behavior as observed for PGU (Table 5): 48 % of geosites have high to very high score of PEU, namely Forte do Cão, Montedor, Rego de Fontes, Praia Norte (PEU 91–100 %) and S. Domingos, Carrasqueira, Lumiar-Canto Marinho, Ribeira de Anha (PEU 75–83 %). In general, geosites with a high to very high PGU were also ranked with a high to very high PEU. With a medium PEU, Poço Negro and Salinas da Meadela geosites are the only exceptions. S. Mamede geosite is the only one with a low PEU. However, this geosite maintains a high relevance for scientific research.

The degradation risk and potential of use of the inventoried geosites is synthetised in the following map (Fig. 2).

Local Natural Monuments

The geological and geomorphological elements that occur in the coastal area of Viana do Castelo municipality are included in the Natura 2000 Network (Littoral Norte—PTCON0017, Rio Lima—PTCON0020). However, the Natura 2000 network was created under two European Directives (Birds and Habitat), which have no explicit role in geodiversity protection. Therefore, the abiotic features of the Viana do Castelo

Fig. 2 Map of the inventoried geosites and graphical representation of the results obtained with the numerical assessment for the degradation risk and potential educational and touristic use

coast have only an indirect legal protection as part of the ecosystem.

Twelve of the seventeen inventoried geosites are located in the municipality of Viana do Castelo. The evaluation procedures showed that 6 geosites concentrate the highest values of PGU, PEU, and DR: Montedor, Rego de Fontes, Praia Norte and Ribeira de Anha with high to very high PGU and PEU, and Lumiar-Canto Marinho and Salinas da Meadela with high PGU and PEU. All these 6 geosites have a medium to high DR. Given these characteristics, as well as the intrinsic scientific value recognised for the 6 geosites, the Earth Sciences Centre of the University of Minho has proposed their legal designation as natural monuments to the Viana do Castelo Municipality. Since 2008, Portuguese legislation for nature conservation allows municipalities to implement four categories of protected areas, namely natural parks, natural reserves, protected landscapes and natural monuments.

The project for the designation of the 6 geosites as 5 local natural monuments was ratified unanimously at the municipal council meeting of March 20, 2014, initiating a process of consultation with other local, regional and national institutions. All these institutions have pronounced favourably on the designation as local natural monuments. A public hearing was opened from September 1 to October 3, 2014, and the process was legally completed in April 6, 2016 with the publication of the legal statutes - Diário da República, 2.ª série — N.º 67, Aviso n.º 4658/2016. As the result of this initiative, five local natural monuments—Alcantilado de Montedor, Pedras Ruivas, Ínsuas do Lima, Canto Marinho, and Ribeira de Anha—have been created by the Viana do Castelo municipality with the aim of protection the 6 geosites (Fig. 3).

The limits of these protected areas were defined, taking into consideration the geosite areas and the limits of the Natura 2000 network. A buffer of 200 m towards the infratidal zone in the sites on the coast was also applied, ensuring the protection of geological elements offshore.

Alcantilado de Montedor Natural Monument

This natural monument has an area of approximately 55 ha, bordered north by Paçô Fortress (N 41° 44′ 44.95″/W 8° 52′ 41.16″) and south by Cambôa do Marinheiro Beach (N 41° 44′ 42.58″/W 8° 52′ 38.33″) (Fig. 1).

Corresponding to Montedor geosite (no. 6), this is the most diverse natural monument in terms of geomorphological characteristics, including residual, tectonic and coastal features (Fig. 4a–d). Fluvial, aeolian, periglacial and cultural aspects are also present. The geological values identified in the area allow the understanding of various scientific aspects related to geological, palaeoenvironmental and cultural developments in the region over the last 400,000 years (MIS11 the MIS1) (Carvalhido 2012; Carvalhido et al. 2014a; Carvalhido et al. 2014b; Carvalhido et al. 2014c).

a) Main geomorphological features:

- Residual: granite boulders, weathering pans, tafoni, contact alveoli and undulating granite surfaces (phase III);

Fig. 3 Location of the five Local Natural Monuments of Viana do Castelo. Google Earth image. Scale varies accordingly to the perspective

- Tectonic: late to post-variscan structures of Montedor massif (e.g. Santa Justa Fm.—Bouça of Frades Plutonite thrust) (Fig. 4a);
- Coastal: coastal platforms modeled at 18 m, 13 m, 8 m and 3 m (asl) with littoral landforms preserved (e.g. beach deposits, notches, potholes and *Paracentrotus lividus* alveoli) (Fig. 4b).

b) Other features:

- Fluvial: *Sto Isidoro Sands* (MIS4);
- Aeolian: *Ronca de Montedor Sands* (MIS4) (Fig. 4c) and *S. Domingos Sands and Silts* (MIS3);
- Periglacial: *S. Domingos Sands and Silts* (MIS3), *Cambôa do Marinheiro Silts* (MIS2) and *Rego de Fontes Conglomerates and sands* (MIS2-MIS1);
- Cultural: saltpans and rock carvings from the Iron Age; Middle Age fishing grounds—Cambôa do Marinheiro and Cambôa de Morgado (Fornelos beach) (Fig. 4d).

Assessment results: DR—70 % (high); PGU—81 % (high); PEU—91 % (very high).

Canto Marinho Natural Monument

This natural monument has an area of about 24 ha where around 713 saltpans of pre-Roman age are exposed in the intertidal zone (Fig. 1, Fig. 4e) (Costa et al. 2012). This area is also the most important in the preservation of several ancient fishing grounds (cambôas), a rare cultural heritage that has no parallel

Fig. 4 Some of the geomorphological features preserved on the proposed local natural monuments of Viana do Castelo: (*a*) *Santa Justa* Fm.—*Bouça of Frades* Plutonite thrust; (*b*) Eemian notch and pothole; (*c*) MIS4 aeolianite—*Ronca de Montedor Sands*; (*d*) Medieval fishing ground wall (Cambôa do Morgado); (*e*) Pre-Roman saltpans preserved at Canto Marinho beach; (*f*) *Bouça de Frades* rounded granite boulders outcropping *Sta Justa* Fm. and *Valongo* Fm.; (*g*) Tight to isoclinal folding cleavage on *Santa Justa* Fm. quartzites; (*h*) Large-scale folds comprising the main outcrop of *Santa Justa* Fm.; (*i*) Domino faulting on the residual relief of *Sta Justa* Fm.; (*j*) *Paracentrotus lividus* alveoli—sea urchin trace fossil; (*k*) *Scolithus* preserved on *Sta Justa* Fm.; (*l*) Pegmatite with spodumene megacrysts; (*m*); Ripplemarks preserved at *Sta Justa* Fm.; (*n*) Wetland at the right margin of Lima river, where are preserved ancient (medieval?) saltpans; (*o*) Large-scale pothole identified at the coast of Viana do Castelo (MIS7?) and (*p*) Eemian conglomerate outcrop—*Forte do Cão Conglomerates and Sands*

on the Portuguese NW coast. There are also other features preserved such as residual, tectonic, stratigraphical and mineralogical.

a) Main geomorphological features:

Residual: *Bouça de Frades* granite outcropping as rounded granite boulders (Fig. 4f);

Tectonic: presence of abundant folds, tight to isoclinal (only recognised at this monument), with some axial planes moderately inclined (dip <30°) (Fig. 4g)—testifies accordingly to Pamplona et al. (2006) the tangential deformation regime towards west (D2) responsible for laminar extrusion of *Bouça de Frade Plutonite*;

b) Other features:

Stratigraphical: D2-thrust contact between *Bouça de Frades Plutonite*, *Sta. Justa Fm*. (Armorican quartzite) and *Valongo Fm*. (garnet andalusite nodular schistes);

Mineralogical: occurrence of some rare minerals on Viana do Castelo's coastal area such as garnet and staurolite;

Cultural: the pre-Roman age saltpans (Fig. 4e) could be used as marks to the lower position of sea level during the Iron Age and medieval period, as they were used not by direct sea flooding but by filling with a pitcher, away from the direct influence of the sea (Almeida 2005).

Assessment results: DR—70 % (high); PGU—66 % (medium); PEU—79 % (high).

Pedras Ruivas Natural Monument

The Pedras Ruivas Natural Monument corresponds to an area of approximately 58 ha, between Rego de Fontes Fortress (N 41° 42′ 6.24″/W 8° 51′ 29.38″) and Norte Beach (N 41° 41′ 37.21″/W 8° 50′ 59.67″), with an approximate length of 1500 m and encompassing 2 geosites: Rego de Fontes and Praia Norte (Fig. 1).

a) Main geomorphological features:

- Residual: coastal platforms preserved at *Valongo* Fm. (MIS5e—2 levels) with trace fossils of *P. lividus* (alveoli) in the lower level; residual relief of *Sta. Justa* Fm. (Fig. 4h);
- Tectonic: left-lateral strike-slip variscan fault resulting in *domino* faulting (Fig. 4i), sigmoidal shapes and positive flower structures on *Sta. Justa* Fm.; observed several generations of folds (Fig. 4h) and boudinage; *Kink-band* folding on *Valongo* Fm.

b) Other features:

Periglacial: *Rego de Fontes Conglomerates and Sands* and *Cambôa do Marinheiro Silts* are lacustrine bodies formed during the glacial maximum (MIS2) evolving to alluvial fans (proximal facies) and solifluction (lobes) with origin on the hillside of Santa Luzia Mt. due to the process of deglaciation (MIS2 to MIS1).

Paleontological: *P. lividus* alveoli (MIS5) (Fig. 4j), *Cruziana rugosa* and *Scolithus* (Fig. 4 k) (Sta. Justa Fm.);

Mineralogical: pegmatite and aplite-pegmatites with spodumene megacrysts (Fig. 4l);

Stratigraphical: ripple marks and sub-horizontal laminations (*Sta. Justa* Fm.) (Fig. 4m);

Ecological: *Cambôa do Marinheiro Silts* allows the maintenance of coastal plains wetlands of Carreço, Areosa and Afife due to the clay and organic materials.

Cultural: the well-known murder, locally known as *The Crime of the Redheads Stones* (Carvalho 2007) occurred in 1904 near the outcrop of the *Sta. Justa* Fm. (Armorican quartzites with iron patine). The name of the murder is directly linked with the dominant color of these rocks.

Assessment results: DR—65 to 70 % (medium to high); PGU—83 to 91 % (high to very high); PEU—98 to 100 % (very high).

Ínsuas do Lima Natural Monument

The monument has an area of 422 ha, comprising the Lima riverbed, the fluvial longitudinal bars and the wetland at the right margin (Fig. 1 and Fig. 4n). According to Almeida (2005), this area was the largest and most important salt pan centre in NW Portugal and was established at both margins at Lima low estuary.

Geologically, this is a depressed area, slightly above sea level, with evidences of the ENE-WSW Lima reverse fault activity because the left margin's altitude (1.9 and 2.4 m, asl) is lower than the right (between 2.6 and 3 m, asl). Consequently, the higher salt productivity on the right margin is due to less frequent flooding. The tectonic relevance is also associated with the activity of another reverse fault (NNW-SSE), which controls the broad depression of the vestibular section of Lima river (channel width ≈ 1200 m), the longitudinal river bars and the contrasting channel width with an incised course upstream (channel width ≈ 300 m).

This is an important area for the study of erosion surfaces and has also high ecological importance.

Assessment results: DR—50 % (medium); PGU—74 % (high); PEU—69 % (medium).

Ribeira de Anha Natural Monument

The monument corresponds to the area surrounding the mouth of Anha stream with about 41 ha (Fig. 1, Fig. 4o, p).

a) Main geomorphological features:

- Residual: partially eroded pothole with circular cross-section and 140 cm deep (Fig. 4o). Corresponds to the biggest pothole identified on the coast of Viana do Castelo probably from MIS7.;
- Stratigraphical: *Forte do Cão Conglomerates and Sands* (MIS5) (Fig. 4p) preserved approximately 100 cm below the same terrace level identified in Gelfa (+2.00 m) (municipality of Caminha) testifies the coastal compartmentalization in sectors differently affected by vertical deformation triggered by ENE-WSW reverse faults.

Assessment results: DR—50 % (medium); PGU—73 % (high); PEU—75 % (high).

Viana do Castelo Littoral Geopark

The exceptional geological values of the coast of Viana do Castelo, together with the significant biodiversity and archaeological heritage, may justify the implementation of the Viana do Castelo Littoral Geopark. In spite of this, the designation has no legal support and is a label that could provide a strong identity to the coastal area of Viana do Castelo, boosting the tourism activity and enabling the effective management of funding opportunities for the promotion and strengthening of territorial development. The geopark area should include the five local natural monuments but also other geosites, areas of relevant biodiversity and archaeological heritage and areas where an 'immaterial heritage' has a connection with local geodiversity.

There are several arguments in favour of the creation of such a label in the proposed area:

- The recently created natural monuments are close to each other, not more than 20 km away from the county schools, and with good accessibility conditions;
- It is possible to identify an area of 600 ha with key elements for the understanding of the geological evolution of the region from the Lower Cambrian, and in particular with great detail from the Upper Pleistocene;
- The natural monuments have high potential for educational use applied to all school levels and have high to very high potential for tourism use;
- All natural monuments have geocultural relevance showing that geodiversity imprints a profound influence on ecology, archeology and on the history of Viana do Castelo;
- The area is included in the North Coast Great Route (pedestrian route);
- The climate of the region is suitable to promote an all-year use;
- Natura 2000 network is continuous and has an equal interest and value;
- Teachers need to have educational resources in order to provide local examples to their students helping to promote in them healthy sense of pride;
- Today, tourists demand good infrastructures and alternative programmes that could fulfill their desire to enjoy the area;
- The offshore area may also constitute a good attraction to the area; its potential is currently being inventoried under the scope of another project;

Final Considerations

The inventory, characterisation and assessment of geoheritage are very important steps for the success of nature conservation policies. However, quite often these studies have no continuity and end with no major consequences. This work stresses the importance of an inventory strongly supported by scientific knowledge and on the awareness of politicians concerning local resources, as the key to the success of the nature conservation process.

Viana do Castelo municipality has concluded the administrative process for the protection of 6 geosites. The development of actions for an effective educational and touristic uses is the following step in this municipal geoconservation strategy.

The research carried out has showed that there are four other significant geosites in the territory of Caminha, the neighbouring municipality. The expansion to this municipality of similar geoconservation actions is being promoted.

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References

Almeida CB (2005) – A exploração do sal na costa portuguesa a Norte do Rio Ave. In: Da Antiguidade Clássica à Baixa Idade Média. Actas do I Seminário Internacional sobre o sal português. Instituto de História Moderna da Universidade do Porto, Porto, pp. 137–170

Brilha J (2005) – Património geológico e geoconservação: a conservação da natureza na sua vertente geológica. Palimage Editores, Viseu, p 190

Brilha J. (2008) – Geoconservation Awards: a way to promote geological heritage in Portugal. Proc. 5th International Symposium ProGEO on the Conservation of the Geological Heritage, Rab, Croatia, 13–14.

Brilha J. (2009) – Geological Heritage and Geoconservation in Portugal. Proc. 8th European Geoparks Conference, New Challenges with Geotourism, C. Neto de Carvalho & J. Rodrigues (Eds.), Idanha-a-Nova Municipality/Naturtejo Geopark, Portugal, 31–35.

Brilha J (2015) inventory and quantitative assessment of geosites and geodiversity sites: a review. Geoheritage. doi:10.1007/s12371-014-0139-3.

Brilha, J., Alcala, L., Almeida, A., Araújo, A., Azeredo, A., Azevedo, M., Barriga, F., DA Brum, Silveira, A., Cabral, J., Cachão, M., Caetano, P., Cobos, A., Coke, C., Couto, H., Crispim, J., Cunha, P., Dias, R., Duarte, L., Dória, A., Falé, P., Ferreira, N., Soares, A., Fonseca, P., Galopim De Carvalho, A., Gonçalves, R., Granja, H., Henriques, M., Kullberg, J. C., Kullberg, M. C., Legoinha, P., Lima, A., Lima, E., Lopes, L., Madeira, J., Marques, J., Martins, A., Martins, R., Matos, J., Medina, J., Miranda, R., Monteiro, C., Moreira, M., Moura, D., Neto Carvalho, C., Noronha, F., Nunes, J.C., Oliveira, J.T., Pais, J., Pena Dos Reis, R., Pereira, D., Pereira, P., Pereira, Z., Piçarra, J., Pimentel, N., Pinto De Jesus, A., Prada, S., Prego, A., Ramalho, L., Ramalho, M., Ramalho, R., Relvas, J., Ribeiro, A., Ribeiro, M., Rocha, R., SÁ, A., Santos, V., Sant'ovaia, H., Sequeira, A., Sousa, M., Terrinha, P., Valle Aguado, B., Vaz, N. (2010) – The national inventory of geosites in Portugal. Abstracts Book of the International Conference on Geoevents, Geological Heritage and the Role of IGCP (First Meeting of ProGEO Regional Working Group SW Europe), Ayuntamiento de Caravaca de la Cruz, Spain, 18–24.

Carvalhido, R. (2012) – O Litoral Norte de Portugal: evolução paleoambiental quaternária e proposta de conservação do património geomorfológico. Tese de Doutoramento em Ciências, Universidade do Minho.

Carvalhido, R.; Pereira, D. & Cunha, P. (2014a) – Depósitos costeiros quaternários do noroeste de Portugal (Minho - Neiva): caracterização datação e interpretação paleoambiental. Comunicações Geológicas (2014) 101, Especial II, 605–609.

Carvalhido, R.; Brilha, J. & Pereira, D. (2014b) – Monumentos Naturais Locais de Viana do Castelo: processo de classificação e estratégias de valorização. Comunicações Geológicas (*2014*) 101, Especial III, 1219–1223.

Carvalhido, R.; Pereira, D; Cunha, P.; Buylaert, J. & Murray, A. (2014c) Characterization and dating of coastal deposits of NW Portugal (Minho-Neiva area): a record of climate, eustasy and crustal uplift during the Quaternary. Quat Int, 328-329: 94–106

Carvalho A (2007) – O Crime das Pedras Ruivas. Cadernos Vianenses, 39:257–274

Costa M, Machado J, Lopes H, Almeida T (2012) Pias salineiras do Canto Marinho: inventário aqueológico. Cadernos Vianenses, Tomo 46:95–111

García-Cortéz A, Carcavilla L (2009) Documento metodológico para la elaboración del inventario español de lugares de interés geológico (IELIG). Instituto Geológico y Minero de España, Madrid version 12, 61 pp

Lima, F. (2008) *Proposta Metodológica para a Inventariação do Património Geológico Brasileiro*. Tese de Mestrado, Universidade do Minho, Braga, 94 pp.

Pamplona J, Gutiérrez-Alonso G, Ribeiro A (2006) Superposition of shear zones during orogenic development: an example from the NW Variscan Belt. Viana do Castelo, NW Portugal