TOWARDS A EUROPEAN HERITAGE DIVERSITY: GEOSITES ON THE GALICIAN COAST (NW SPAIN) / HACIA UNA DIVERSIDAD PATRIMONIAL EUROPEA: GEOSITIOS EN LA COSTA GALLEGA (NW ESPAÑA)

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Abstract

The pervasive lack of awareness in today's society regarding geological processes and their effects on the landscape is of such magnitude that their relationship to biodiversity and their value as part of the natural heritage is almost completely ignored. In this situation are the Quaternary deposits located on the Galician coast (NW Spain). The lack of awareness of these deposits, or the mere fact that they have either been omitted, or included as other coastal formations in the POL (The Planning Programme for Coastal areas of Galicia), makes their recognition and promotion unfeasible. Taking into account the scientific works and considering the current administrative context, the aim of this study is to demonstrate the importance and scientific and educational interest of the Quaternary sedimentary deposits as palaeoenvironmental records in the hope that this will be recognised as a Geosites by administration, in order to promote their geoconservation as a meaningful and diverse Geological Heritage in European Coastal context.

Keywords: Geosites, Quaternary deposits, Geological heritage, Galician Atlantic coast–NW Spain.

Resumen

La falta generalizada de conciencia en la sociedad actual en relación con los procesos geológicos y sus efectos sobre el paisaje es de tal magnitud que su relación con la biodiversidad y su valor como parte del Patrimonio Natural casi está completamente ignorado. En esta situación se encuentran los Depósitos Cuaternarios situados en la Costa de Galicia (NW de España). Su falta de conocimiento, o el mero hecho de que, se han omitido o incluido como otras formaciones costeras en la POL (Plan de Ordenación del Litoral de Galicia) hace que su reconocimiento y su difusión sea inviable. Teniendo en cuenta los trabajos científicos y el contexto administrativo actual, el objetivo de este estudio es mostrar su importancia e interés científico y educativo como registros paleoambientales con la esperanza de que alcancen su reconocimiento por parte de la administración como Geositios, con el fin de promover su geoconservación como un Patrimonio Geológico significativo y diverso en el contexto Costero Europeo.

Palabras clave: Geositios, Depósitos Cuaternarios, Patrimonio Geológico, Costa Atlántica Gallega–NW España.

1. Introduction

In 2007, for the first time in 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). Law 42/2007 elaborates on the conservation and

management of geological heritage and geodiversity and incorporates the list of geological frameworks as identified for Spain under the UNESCO-IUGS Global Geosites Project. The law includes the concepts of geodiversity and geological heritage and prescribes geoconservation as one of the main bases for nature management and conservation in Spain (Costa-Casais and Caetano Alves 2013). This Law identifies the public administrations of Spain's autonomous regions (communities) as entities responsible for the preservation of natural heritage and hints that geoheritage must be inventoried by geosites. The Spanish Geological Survey (IGME) has launched a project to inventory National Geosites in Spain. It was carried out collaboratively between Spanish research institutes and scientific societies related to Earth Sciences. The new legislative framework on nature conservation implies that inventories and studies of the state of conservation of geodiversity and geological heritage should be carried out. The methodological steps required to advance the characterisation and protection of geological heritage have already been defined (García-Cortés and Carcavilla 2009, García-Cortés et al. 2014). This inventory is not a closed list and may be subject to modification due to new incorporations. The lack of knowledge on a scientific level on the part of the administration regarding national, regional or local "sites of geological interest" makes it complicated to create appropriate legislation, as something which has not been contemplated cannot be protected (Costa-Casais and Caetano Alves 2012, 2013). The pervasive lack of awareness in today's society regarding geological processes and their effects on the landscape is of such magnitude that their relationship to biodiversity and their value as part of the natural heritage is almost completely ignored (Guillén-Mondéjar and Del Ramo 2004; Guillén-Mondéjar 2007). In this situation are the Quaternary sedimentary deposits located on the Galician coast and particularly those located along the Atlantic coast. A review of the literature on the sedimentary deposits of the Galician coast shows that there is a significant number of scientific publications: (a) studies on the classification of ancient sedimentary deposits and their relation with morphogenetical processes (Costa-Casais et al. 1996a; Pérez-Alberti et al. 1999); (b) physicochemical characterisations of the deposits (Costa-Casais et al. 1996a; Martínez-Cortizas et al. 1996, 1997; Martínez-Cortizas and Costa-Casais 1997); (c) studies on colluvial deposits of nival origin (Costa-Casais et al. 2002, 2005; Pérez-Alberti et al. 1998a); (d) the retreat of sedimentary cliffs (Blanco-Chao et al. 2006, 2009); (e) palaeoenvironmental interpretation and reconstruction (Cano et al. 1997; Threnhaile et al. 1999; Costa-Casais 2001; Blanco-Chao et al. 2002, 2003; Costa-Casais 2002); (f) relationship to Pleistocene climate, as in Heinrich events (Costa-Casais et al. 2007a, 2007b); (g) geological heritage and Quaternary deposits (Costa-Casais and Caetano Alves 2012, 2013, 2015).

The Planning Programme for Coastal areas of Galicia — POL -*Plan de Ordenación del Litoral de Galicia* Xunta de Galicia (2010) (Decree Law 20/2011, passed on 23 February 2011) is in accordance with what is established in the Law 6/2007, to take urgent steps regarding the planning of the territory and the coastal areas in particular "to establish the principles and general rules for a territorial planning strategy of the coastal area based on criteria of durability

and sustainability, in addition to establish the necessary regulations in order to guarantee the conservation, protection and assessment of the coastal regions. Among its functions is that of highlighting those coastal ecosystems and geomorphological and scenic sites which, due to their natural, current or potential characteristics, deserve conservation and protection". The ancient sedimentary deposits located along the coast are not specifically mentioned in its many pages. It is not clear whether they are considered to be cliffs, which would mean that they are likened to rocky formations (which is not correct); or perhaps they are not included in any category of the named coastal formations, which would imply that they are not protected. The lack of awareness of these deposits, or the mere fact that they have either been omitted, or included as other coastal formations, makes their recognition and promotion unfeasible.

This study concentrates on the coast of Galicia, mainly on the Atlantic coast, to analyse Quaternary deposits. Taking into account the scientific works and considering the current administrative context, the aim of this study is to demonstrate the importance and scientific and educational interest of the Quaternary sedimentary deposits as palaeoenvironmental records in the hope that this will be recognised as a Geosites by administration, in order to promote their geoconservation (Brilha 2005, 2015; Carcavilla et al. 2007; Henriques et al. 2011) as a meaningful geological heritage in European coastal context.

2. Regional setting

The study area is located in the Atlantic coast of Galicia in the northwestern Iberian Peninsula. Galicia occupies the northwestern section of the Hercynian Hesperic or Iberian Massif (Figure 1). An extensive network of northwest–southeast and northeast–southwest trending faults was produced in the latter phases of the Hercynian orogeny (Parga Peinador 1969). A group of north–south running fractures developed later in the early Mesozoic as a result of rifting in the Atlantic. Then, from the Eocene until at least the early Quaternary, intense tectonic movements along the unstable Atlantic margin formed a series of uplifted blocks and basins (Pérez- Alberti, 1991); many of these uplifted blocks have created coastal mountains with elevations of between 300 and 600 m. Hercynian or late Hercynian granitic rocks, Precambrian schists and basic rocks dominate in western Galicia (Blanco-Chao et al. 2003) (Figure 1).

The irregular outline of the Galician coast and the presence of coastal mountain ranges favoured the development, during the Late Pleistocene, of a morphogenetic environment dominated by cold processes. The mountains constitute orographic barriers which provided suitable conditions for fluvio-nival and periglacial slope processes when the sea level was lower than today in the isotopic stages 3 and 2 (Costa-Casais 2001). The end result was the accumulation of sedimentary material of continental origin in areas prone to sedimentation and cut into sea cliffs during the post-glacial transgression. Coastal formations carved out in transgressive episodes, such as shore platforms, pebbles and boulder beaches were fossilised

by these continental deposits during the regressive episodes. These deposits were subsequently covered by Holocene sediments.

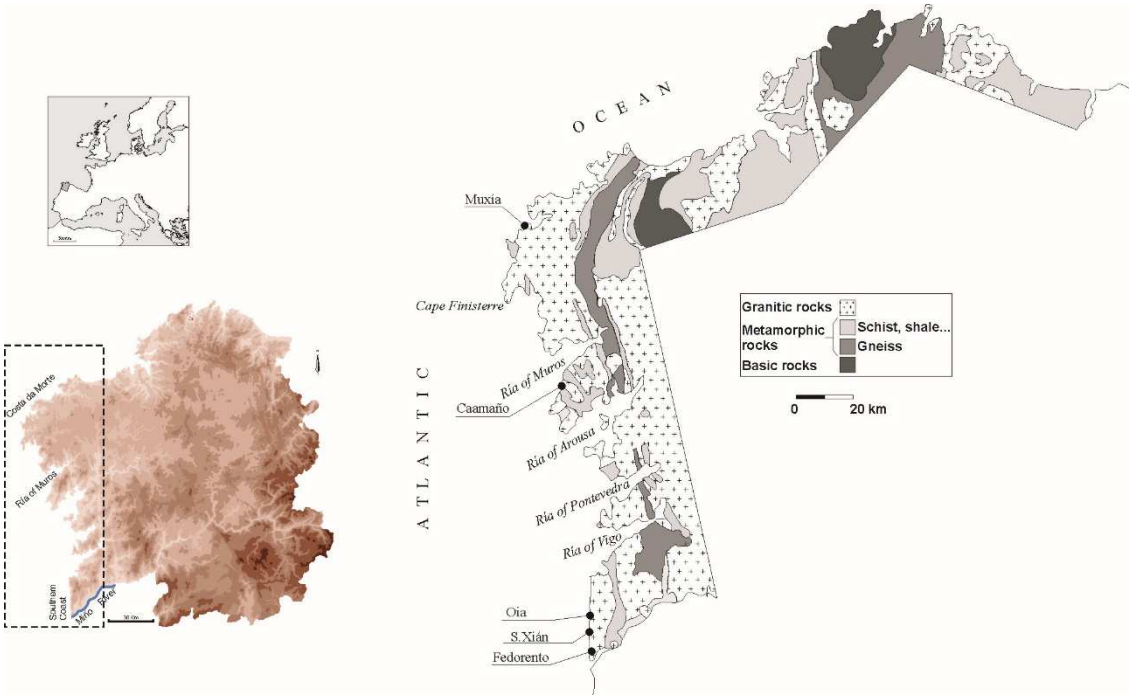

Figure 1 – Location of the study area: selected geosites and rocks along the coast of Galicia (modified of Blanco Chao et al. 2003) / Figura 1 – Localización del área de estudio: geositios seleccionados y litología a lo largo de la costa de Galicia (modificado de Blanco Chao et al. 2003)

The tidal environment is semidiurnal with a mean tidal range of 2·5 m, and a spring tidal range of between 3·75 and 4 m (Instituto Oceanográfico de la Marina, Ministerio de Defensa). The Atlantic coast of Galicia has a high wave energy environment with marked seasonal behaviour. The highest waves usually occur in autumn and winter. Waves off the coast are most frequently generated by storms associated with westerly, northwesterly and southwesterly cyclonic activity. They are between 1 and 2·5 m in height for about 80 per cent of the year. Most waves higher than 3 m are generated by Atlantic low pressure centres in winter, and they approach the coast from the west and northwest (Dirección General de Puertos del Estado) (Blanco-Chao et al. 2003).

3. Results and discussion: Geosites in Atlantic Coast of Galicia

3.1. Factors that control the formation of the Quaternary deposits

The genesis of the deposits was controlled by oceanic moisture, the existence of coastal mountains, the gradient of slopes and their distance from the source area (Figure 2). Today, they function as active cliffs of unconsolidated sedimentary material of which only the part closest to the source is preserved. The deposits are not only fossilizing the coast, but they can be extend up the slopes, their thickness decreasing on the hillsides but maintained as a

sedimentary cover on the floor of the valleys (Costa-Casais 2001; Costa-Casais et al. 2002, 2005).

Figure 2 – Deposit of Arnela de Lourido (Muxía): The specific factors which controlled the formation and the type of deposit were: humidity coming off the ocean, height of the coastal mountains, gradient of the slopes and distance from the source area / Figura 2 – Depósito de Arnela de Lourido (Muxía): Los factores específicos que controlaron la formación y el tipo de depósito fueron: humedad proveniente del océano, altura de las montañas costeras, gradiente de las laderas y distancia al área fuente

The sedimentary processes, thicknesses and facies of the terrestrial sediments that were deposited over abandoned Eemian coastlines during the middle and late Weichselian, were determined by four main factors (Blanco Chao and Costa-Casais 2001; Pérez-Alberti et al. 1998b; Costa-Casais 2001, Costa-Casais et al. 2002, 2005, 2007b; Costa-Casais and Caetano Alves 2013):

Humidity coming off the ocean. Air masses from the ocean make the sea-facing slopes of the mountains the most humid, and slope orientation played an important role in determining the thickness and extent of the deposits. Along the Atlantic coast of Galicia, slopes facing the sea were covered by sediments, while those on the opposite side have fewer or thinner deposits with a smaller variety of facies that are restricted to very favourable locations.

Height of the coastal mountains. Snow and ice accumulated on mountains close to the present coastline, providing favourable conditions for cold region processes during the last glacial stage. Most of the sediments deposited on the slopes and on the coast are therefore the result of snowmelt, frost action, gelifluction and other periglacial processes.

Slope gradient influenced the type and efficacy of the erosive and depositional processes. Mountains close to the present coastline have moderate to high gradients, and in many places, there is an abrupt transition from the mountains to the coast. High gradients generated fast-flowing streams fed by melting snow and cut-and-fill processes, as well as gelifluction and laminar flows that deposited interbedded coarse and fine sediments.

Distance from the source area. Deposits are thicker, coarser and more extensive in areas close to the sources than in areas further away and their finer grained distal ends were in areas that are now under the sea.

3.2. Colluvial Layers of Coarse material

Two types of deposits can be distinguished: (a) where the mountains are distant from the coast, the intervening topography is not usually dissected by valleys and the sediments are predominantly fine-grained and less than 2–3 m in thickness (Figure 3A); (b) deposits infilling valleys located close to the mountains, with their central portions filled with alternating coarse debris and sandy, organic-rich sediment layers (Costa-Casais 2001; Costa- Casais et al. 2005) (Figure 3B).

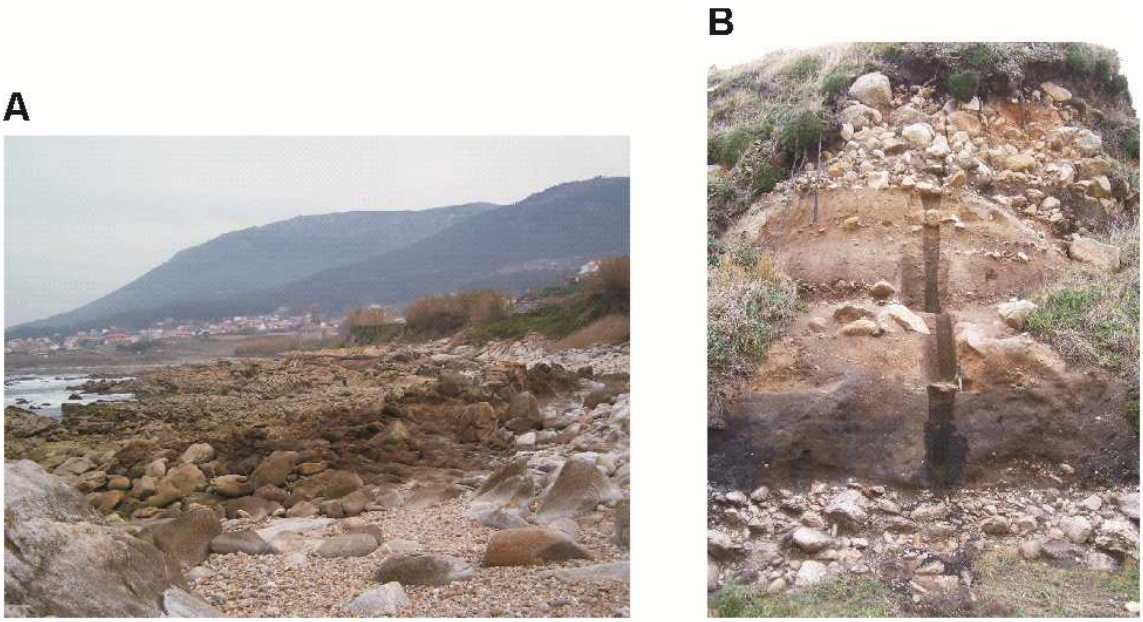

Figure 3 – Deposits infilling valleys located close to the mountains in the “Southern Coast” (photo A) with their central portions filled with alternating coarse debris and sandy and organic-rich sediment layers (photo B). Figura 3 – Depósito que colmata los valles situados cerca de las montañas en la "Costa Sur" (foto A) con su parte central formada por la alternancia de material grueso y arenoso y niveles sedimentarios ricos en materia orgánica (foto B)

Nival and periglacial activity. Coarse grain-sized colluvial layers are interspersed with palaeosols of finer material. Nival and periglacial activity were responsible for the formation of most of the colluvial layers, which tend to overlap producing a great complexity of facies. The most important formations, linked to processes of fusion and cryogenesis, are simple and complex palaeochannels and wide cross-bed structures of coarse rounded or subrounded, oriented, overlapping material with different degrees of weathering (Figure 4). The size of the palaeochannels is variable, reaching up to 1– 2 m in both width and height. They also show cut

and fill structures that were generated by rapid, non-turbulent flows of snow fusion. Other formations related to fusion processes include debris flow (gelifluction and laminar solifluction), which are characterised by the alternation of fine and coarse material (Figure 4A). At times of greater stability, fine material with a variable content of organic material was deposited on the hill slopes, whilst, when fusion processes were active, rapid flows of water were generated which carried away vast quantities of material. The fine material was more easily eroded, but the coarse material stayed close to the slope resulting in the genesis of stratified, granoclassified, oriented and overlapping layers (Figure 4B) (Costa-Casais 2001; Blanco-Chao and Costa-Casais 2001; Costa-Casais and Caetano Alves 2013).

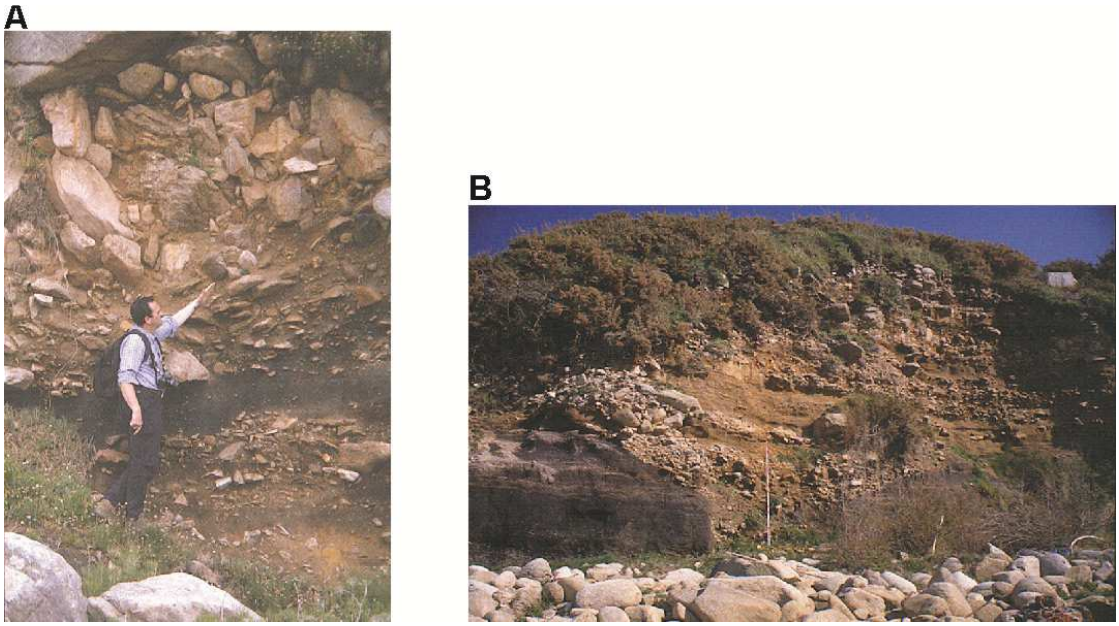

Figure 4 – The most important formations linked to processes of fusion and cryogenesis are debris flow (gelifluction and laminar solifluction) (photo A) and complex palaeochannels (photo B) / Figura 4 – Las formaciones más importantes ligadas a los procesos de fusión y criogénicos son los debris flow (gelifluxión y solifluxión laminar) (foto A) y paleoannales complejos (photo B)

Periglacial processes are the *gelifluidal* and *solifluidal* facies. The most representative formations and periglacial processes are the gelifluidal and solifluidal facies of the head type, composed of pebbles and sands, tightly packed into a silty clay matrix (Figure 5A). The material is well ordered and, in many cases, lies parallel to the slope (Figure 5B). According to Van Vliet-Lanöe and Valadas (1983), these formations can be used as palaeoclimatic indicators, as the sands reveal the existence of deep seasonal ice with a high degree of humidity and the coarse material proves the presence of permafrost under cold and dry climatic conditions.

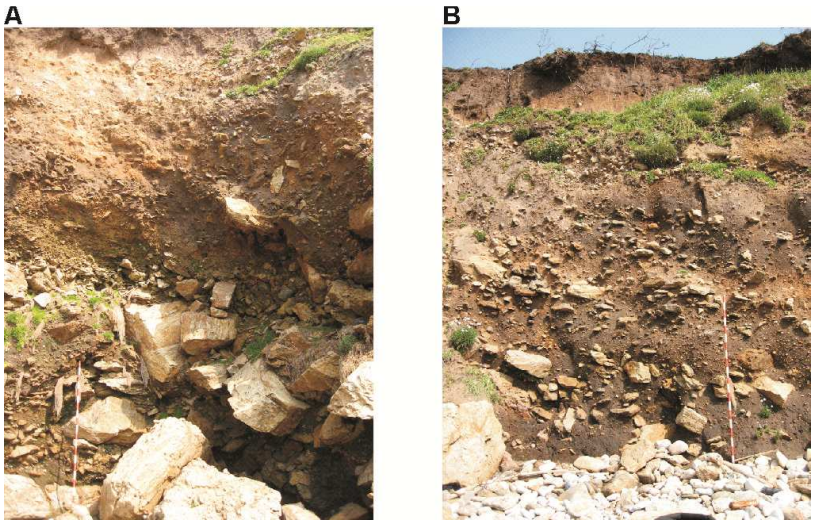

Figure 5 – Representative formations and periglacial processes are the gelifluidal and solifluidal facies of the head type, composed of pebbles and sands, tightly packed into a silty clay matrix. Photo A and B: deposit of Caamaño (Ría de Muros-Noia) / Figura 5 – Formaciones y procesos periglaciales representados por facies gelifluidas y solifluidales del tipo head, compuestas por gravas y arenas, embutidas en una matriz arcillo- limosa. Foto A y B: depósito de Caamaño (Ría Muros-Noia)

3.3. Soil Dynamics

The palaeosols are rich in organic matter and also contain thin gravel and charcoal layers (Figure 6A). These soils reflect periods of slope stability at a time of widespread cold conditions. They are only absent in places where erosion preceded the formation of the colluvial layers (palaeochannels, cross-bed structures and debris flow or lines of gravel). Van Vliet-Lanöe (1988, 1990a, b) interprets their presence, such as those located in Britanny (France), as reflecting wetter periods. The fossilisation of the palaeosols in colluvial material either slowed down or stopped their pedogenetical evolution.

Therefore, their properties reflect the dominant environmental conditions when they were at the surface (Martínez-Cortizas and Moares 1995). Soil formation may have occurred in periods of climate amelioration, which would favour pedogenesis, under overall cold conditions (Costa-Casais et al. 1996b; Costa-Casais 2001; Pérez-Alberti et al. 1998b, 1999; Blanco-Chao et al. 2002, 2003). During periods of climatic deterioration, they were partially eroded, and the resulting material was transported and deposited in lower topographical regions by short, repetitive laminar flows, which also generated stone, gravel and charcoal lines and iron mottling (Figure 6B). The radiocarbon dates we obtained indicate that the oldest sediments were deposited around 40 Ka BP (Costa-Casais 2001; Costa-Casais and Caetano Alves 2013). The physico-chemical properties of the sediments are suggestive of intense chemical/mineral alteration in periods of paleosol formation (Costa-Casais et al. 1994; Costa-Casais et al. 2007b).

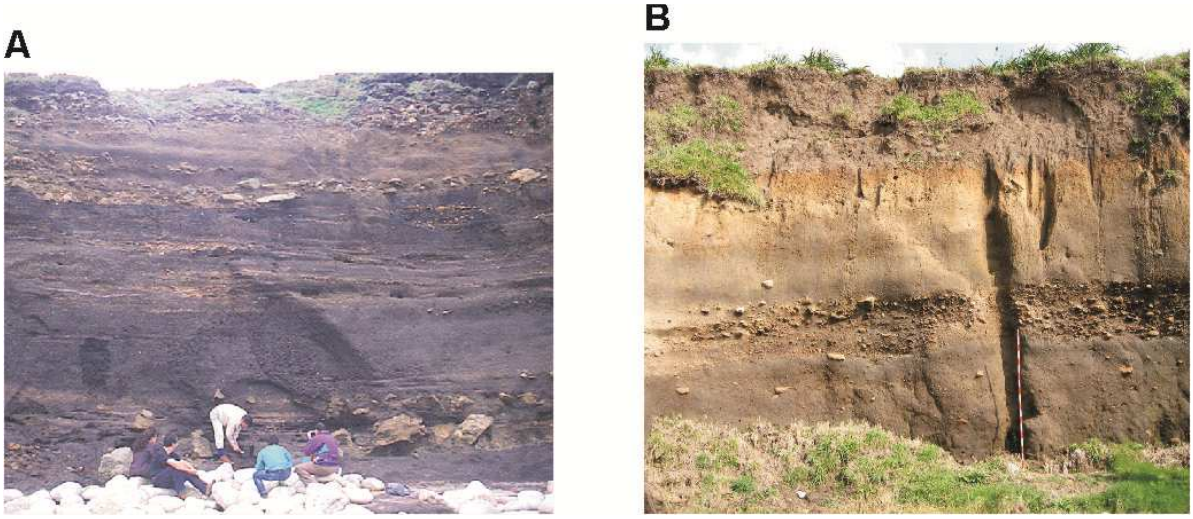

Figure 6 – Soil formation may have occurred in periods of climate amelioration, which would favour pedogenesis, under overall cold conditions. Photo A: Central facies of deposit of Arnela de Lourido (Muxia). Photo B: Central facies of deposit of Caamaño (Ría de Muros-Noia) / Figura 6 – La formación del suelo puede haber ocurrido en períodos de mejora climática, lo que favorece la pedogénesis, en condiciones de frío general. Foto A: Facies central del depósito de Arnela de Lourido (Muxia). Foto B: Facies central del depósito de Caamaño (Ría de Muros-Noia)

3.4. Paleoenvironmental archives: Chronological context and Heinrich Events

The Quaternary deposits, today active cliffs, are a highly valuable palaeoenvironmental record that contains a number of erosive-cumulative processes, represented by colluvial layers, which can be correlated with a number of Heinrich Events (HE) identified in marine sediment cores from the North Atlantic. The deposits have an accumulation of material since at least 40,000 BP. Its formation, which is related to preferential area for accumulation, has allowed a detailed continental sedimentary record to be preserved (Costa-Casais and Caetano Alves 2013). The inventory and analysis of the variability of the colluvial sedimentary facies of the deposits, which were generated by cold processes, enable them to be correlated with HE (Duplessy et al. 1981; Heinrich 1988) (Figure 7). Radiocarbon dating has allowed them to be placed within the chronological framework of the Late Pleistocene and with the HE in particular (Costa-Casais et al. 2007b; Valcárcel and Costa-Casais 2011). In a literature review, we have found datings for the Atlantic coast of Galicia, most of them from soil organic matter of paleosols underlying and overlying the coarse colluvial layers, although some were carried out on charcoal (Costa-Casais et al 2007b; Costa-Casais and Caetano Alves 2013). The oldest ages (43–38 Ka BP) were obtained at the base of the deposits located on the sector of “Southern Coast" of Galicia (Oia, San Xián, Fedorento); Deposit of Caamaño (Ría de Muros-Noia), Deposit of Arnela-Muxia (Costa da Morte) (Costa-Casais 2001; Costa Casais et al. 1994, 1996a, 1996b) (Figure 1). Taking into account the documented ages, it can be stated that there is a fairly continuous chronological record for the Late Pleistocene. Chronological gaps correspond with HE that are represented by coarse grained colluvial layers, for which radiocarbon dating was not possible (Bard et al. 2004; Costa-Casais et al. 2009). The obtained

dates also show a good record for the Holocene in most deposits. For these Holocene aged sandy, acidic, organic matter-rich colluvial soils, both climatic changes and human activities have been proposed as drivers of their formation (Costa-Casais et al. 2008; 2009; Martínez-Cortizas et al. 2009). The information accompanying each radiocarbon dating differs between authors, as does the type of material that has been dated and the depth at which the sample was collected, amongst other things. There are a number of uncertainties which necessitates much care in the interpretation of these ages.

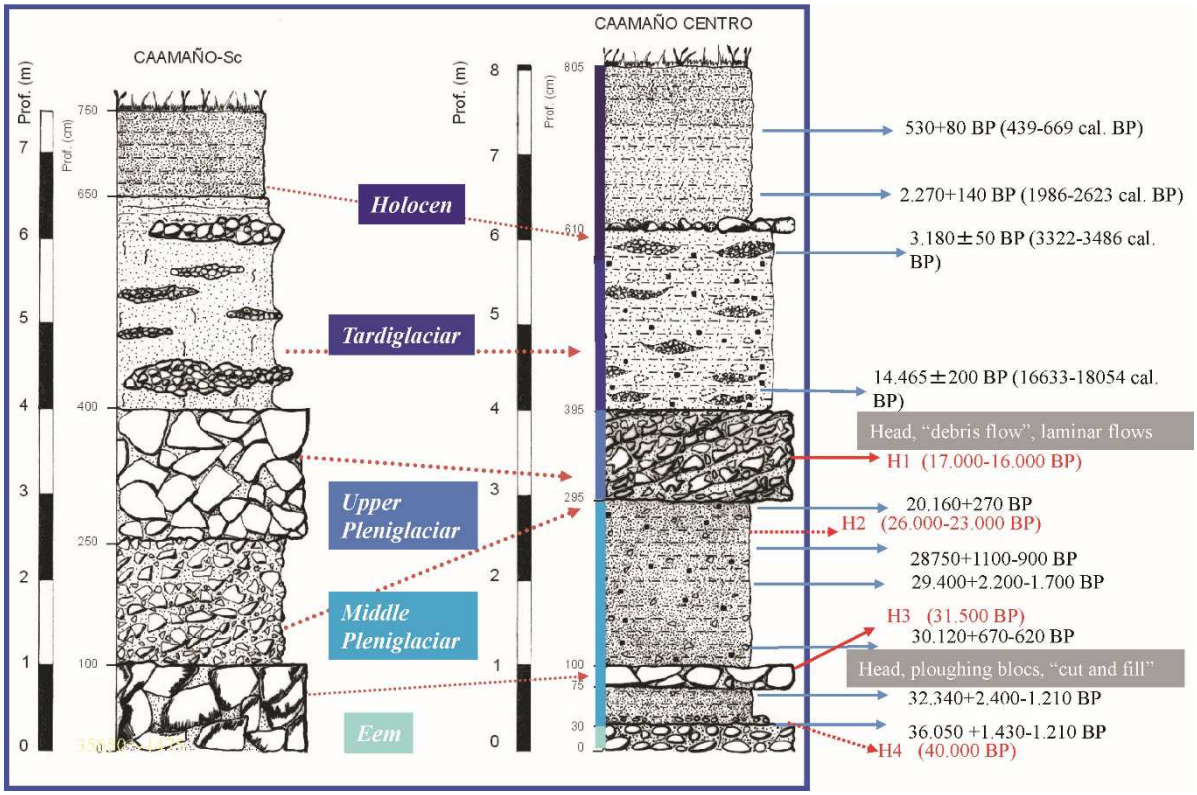

Figure 7 – The deposits, nowadays littoral, are among the best palaeo-environmental archives of continental origin. They reflect environmental change in the Late-Pleistocene on both a local and a regional scale. Chronological context and Heinrich events in the deposit of Caamaño (Ría de Muros-Noia) (Modified of Costa-Casais 2001) / Figura 7 – Los depósitos, hoy litorales, se encuentran entre los mejores archivos paleoambientales de origen continental. Reflejan el cambio ambiental en el Pleistoceno Tardío tanto a nivel local como regional. Contexto cronológico y Eventos Heinrich en el depósito de Caamaño (Ría de Muros-Noia) (Modificado de Costa-Casais 2001)

The colluvial layers would be the best example of paleoenvironmental archives of continental origin, at least those who have an increased diversity of facies. These archived environmental changes of the Late Pleistocene and geochemical signals that can translate into local and regional climate changes. Comparing with other terrestrial cores located in ocean margins, near the coast of Galicia - Iberian Margin (Thouveny et al. 2000; Zaragosi et al. 2001; De Abreu et al. 2003) - allows a more precise interpretation of the implications of climate

change on the continent and the oceans, and to assess the movement of continent-ocean materials flows.

3.5. Proposal for the assessment of degradation risk and estimate of protection priority for the Quaternary Deposits

The Quaternary deposits should be considered as geosites, in terms of their scientific value as based on geomorphological, stratigraphical, sedimentological, pedological and other criteria. Recent research on Quaternary deposits proposed the "Southern Coast of Galicia" and specifically San Xián and Oia Sur deposits as Geosites (Costa-Casais and Caetano Alves 2012, 2013, 2015). The results obtained in applying the criteria to assess the degree of importance of the sites of geological interest. A specific protection status is necessary for each geosite interest (scientific, educational and touristic) in the medium term and both geosites show a high degree of vulnerability. One of the main objectives, in terms of a mapping programme for the POL, should be to recognise the vulnerability of the Quaternary deposits. From this starting point, the relevant local authorities should document this natural heritage in the Galician Atlantic coast. Based on that study, this knowledge/strategy should be implemented in stages, with the option of including the two sites listed in the list of Spain's geosites. In order to do this, it is necessary to put strategies into practice to enable the assessment of geological sites of interest with scientific, pedagogical and cultural value; that is, those geomorphological, stratigraphical and sedimentological geosites that form part of our Geological Heritage. It's necessary inventoried, characterised their degree of interest, relevance and vulnerability quantified, the next step is to work towards their geoconservation (Brilha 2005; Carcavilla et al. 2007; Henriques et al. 2011). The identification and characterization of sites are decisive steps in any geoconservation strategy (Brilha 2015) (Figure 8).

Figure 8 – The identification and characterization of sites in the coast of Galicia are decisive steps in any geoconservation strategy / Figura 8 – La identificación y caracterización de los geositios en la costa de Galicia son pasos decisivos en las estrategias de geoconservación

4. Final remarks: The heritage values of the Quaternary Deposits

The Quaternary deposits which fossilise a large part of the Galician Atlantic Coast should be recognized as geosites stand out in terms of their geological value for geomorphological, stratigraphical, sedimentological, pedological and other reasons. They are environmental archives of the past and therefore contain scientific information that is of great assistance in attempting to understand the evolution of the coast. It should be emphasised that Galician Atlantic coast is unique on a national level due to the scientific and educational value offered by these landforms. Our proposal study highlights the need to promote the conservation and appropriate management of these "geosites" as an important part of Geological Heritage on the European coast, with their documented values, taking into account the philosophy and practices of geoconservation. It is insufficient to only identify the Geological Heritage of the coast; its conservation and management must also be promoted. Once the Quateranry deposits have been inventoried and characterised and its degree of interest, relevance and vulnerability have been quantified, the next step should be to take measures towards its geoconservation. Informative and educational programmes should be carried out and supported, with the aim of promoting the actions necessary in the area of scientific dissemination and conservation. It is essential that the conservation and management of our Geological Heritage to be integrated in the objectives and programmes (development and planning policies) of our governments so that areas possessing geological interest are not harmed or completely lost. Emphasize that the Council of Europe for the Conservation of Geological Heritage and Areas of Special Geological Interest (Recommendation Rec (2004) 3), stated that Geological Heritage constitutes a natural heritage of intrinsic scientific, cultural, aesthetic, scenic and economic interest, which must be preserved for future generations. The Quaternary deposits are an important Geological and Geomorphological Heritage, as are environmental records of the past and, therefore, its scientific knowledge is helpful for understanding the evolution of the Galician coast, contextualize the paleoenvironmental processes and compare the scale of local, regional and extra-regional paleoclimatic impacts.

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5. Bibliography

BARD, E., ROSTEK, F. & MÉNOT-COMBES, G. (2004). Radiocarbon calibration beyond 20000 14C yr BP by means of planktonic foraminifera of the Iberian Margin. *Quat Res,* 61(2):204–214. doi:10.1016/ j.yqres.2003.11.006

BLANCO-CHAO, R. & COSTA-CASAIS, M. (2001). Influencia de formas y depósitos antiguos en la dinámica litoral: un ejemplo de la costa sur de Pontevedra (Galicia). *Actas del XVI Congreso de Geógrafos Españoles*. (pp. 137–140). Universidad de Oviedo: CeCodet, AGE, GEA.

BLANCO-CHAO, R., COSTA-CASAIS, M., MARTÍNEZ-CORTIZAS, A., PÉREZ-ALBERTI, A. & VÁZQUEZ, M. (2002). Holocene evolution in Galician coast (NW Spain): an example of paraglacial dynamics. *Quat Int,* 93–94:149–159. doi:10.1016/S1040-6182(02)00013-7

BLANCO-CHAO, R., COSTA-CASAIS, M., MARTÍNEZ-CORTIZAS, A., PÉREZ-ALBERTI, A. & TRENHAILE A.S. (2003). Evolution and inheritance of a rock coast: western Galicia, Northwestern Spain. *Earth Surf Process Landforms* 28:757–775. doi:10.1002/esp.496

BLANCO-CHAO, R., PÉREZ-ALBERTI, A., COSTA-CASAIS, M. & VALCÁRCEL, M. (2006). Abrasion processes in coarse-clastic beaches linked to rocky shore platforms. *J Coast Res*, 48:21–18

BLANCO-CHAO, R., FEAL, A., VALCÁRCEL, M., COSTA-CASAIS, M & PÉREZ-ALBERTI, A. (2009). Retrocesos en acantilados sedimentarios de la costa atlántica gallega durante los últimos 3500 años. In J.A. Morales, M. Cantano, A. Rodríguez, I. Delgado (Eds.), *Nuevas contribuciones sobre geomorfología litoral*. (pp. 55–58). Huelva. Univ. De Huelva, SGE, SEG55.

BRILHA, J. (2005). *Património geológico e geoconservação: a conservação da natureza na sua vertente geológic*a. Palimage, Viseu.

BRILHA, J. (2015). Inventory and Quantitative Assessment of Geosites and Geodiversity Sites: *A Review. Geoheritage*, doi:10.1007/12371-014-0139-3.

CANO, J., FUMANAL, M.P., FERRER, C., USERA, J., BLÁZQUEZ, A.M. & OLMO, J. (1997). Evolución de la costa meridional de Galicia durante el Cuaternario superior. *Cuaternario Ibérico*, (pp. 33–46). Huelva.

CARCAVILLA, L., LÓPEZ, J. & DURÁN, J.J. (2007). Patrimonio geológico y geodiversidad: investigación, conservación, gestión y relación con los espacios naturales protegidos. *Serie Cuadernos del Museo GEOMINERO*, 7. INSTITUTO GEOLÓGICO Y MINERO DE ESPAÑA, Madrid.

COSTA-CASAIS, M. (2001). *Análise sedimentaria e reconstrución paleoambiental da Costa Atlántica de Galicia*. PhD Dissertation. Universidade de Santiago de Compostela, Servizo de Publicacións e Intercambio Científico. Santiago de Compostela.

COSTA-CASAIS, M. (2002). Análise sedimentaria e reconstrución paleoambiental da Costa Atlántica de Galicia. Xeográfica. *Revista de Xeografía, Territorio e Medio Ambiente. Riscos Territoriais* 2:191–194.

COSTA-CASAIS, M. & CAETANO ALVES, M.I. (2012). Geological heritage and geodiversity: Quaternary Deposits as palaenvironmental records in the “Southern Coast” (Galicia, NW Spain). In A. Gonzalez (Coordinador), *Avances de la Geomorfología en España 2010-2012*. Actas de la XII Reunión Nacional de Geomorfología. (pp. 27-30). Santander: Publican Ediciones, Universidad de Cantabria.

COSTA-CASAIS, M. & CAETANO ALVES, M.I. (2013). Geological heritage at risk in NW Spain. Quaternary deposits and landforms of “Southern Coast” (Baiona-A Garda). *Geoheritage*, 5, 227–248.

COSTA-CASAIS, M. & CAETANO ALVES, M.I. (2015). Otra visión del patrimonio geológico: la puesta en valor de los depósitos cuaternarios de la costa gallega (NW España). In A. Hilario, M. Mendia, M. Monge-Ganuzas, E. Fernández, J. Vegas, A. Belmonte (Eds.), *Patrimonio geológico y geoparques, avances de un camino para todos*. Publicaciones del Instituto Geológico y Minero de España. Serie: Cuadernos del Museo Geominero nº 18. (pp 125-130). Madrid: Ministerio de Ecomomía y Competitividad.

COSTA-CASAIS, M., MARTÍNEZ-CORTIZAS, A. & PÉREZ-ALBERTI, A. (1994). Caracterización de un depósito costero de la Ría de Muros-Noia (La Coruña, Galicia). In J. Arnáez-Vadillo, J.M. García-Ruiz & A. Gómez-Villar (Eds.), *Geomorfología en España*. (pp. 357–368). Logroño: Sociedad Española de Geomorfología.

COSTA-CASAIS, M., MARTÍNEZ-CORTIZAS, A. & PÉREZ-ALBERTI, A. (1996a). Tipos de depósitos costeiros antiguos entre o Cabo de Fisterra e o de Corrubedo. In A. Pérez-Alberti, P.

Martini & W.Chesworth & A. Martínez-Cortizas (Eds.), *Dinámica y Evolución de Medio Cuaternarios* (pp. 417–430). Santiago de Compostela: Xunta de Galicia.

COSTA-CASAIS, M., MOARES, C. & MARTÍNEZ-CORTIZAS, A. (1996b). Caracterización físico-química do depósito litoral de Mougás (Pontevedra): implicacións morfoxenéticas. In A. Pérez-Alberti, P. Martini, W. Chesworth & A. Martínez-Cortizas (Eds.), *Dinámica y Evolución de Medio Cuaternarios*. (pp. 430–440). Santiago de Compostela: Xunta de Galicia.

COSTA-CASAIS, M., PÉREZ-ALBERTI, A. & BLANCO-CHAO, R. (2002). Depósitos coluviales de origen nival en la costa sur de Pontevedra (Galicia): facies y procesos deposicionales. In E. Serrano, A. García de Celis, J.C. Guerra, CG Morales, M.T. Ortega (Eds.) *Estudios recientes (2000–2002) en Geomorfología: Patrimonio, Montaña y Dinámica Territorial*. (pp. 539–546). Valladolid: Sociedad Española de Geomorfología.

COSTA-CASAIS, M., BLANCO-CHAO, R., MARTÍNEZ-CORTIZAS, A. & PÉREZ-ALBERTI, A. (2005). Factores determinantes en la sedimentación de los depósitos antiguos en la costa occidental de Galicia. In R. Blanco Chao, J. López Bedoya, A. Pérez-Alberti (Eds.), *Procesos geomorfologógicos y evolución costera*. (pp. 295–305). Santiago de Compostela: Servizo de Publicacións da Universidade de Santiago de Compostela.

COSTA-CASAIS, M., BLANCO CHAO, R., MARTÍNEZ CORTIZAS, A. & PÉREZ-ALBERTI, A. (2007a). Evidencias de eventos Heinrich en sedimentos continentales de la costa Atlántica de Galicia (NW de la Península Ibérica). In L. Pujol, J.J.Fornós (Eds.), *Investigaciones recientes (2005–2007) en Geomorfología Litoral*. Universitat de les Illes Balears, Institut Mediterrani d'Estudis Avançats, IMEDEA (CSIC-UIB), Societat d'Història Natural de les Balears. (pp. 167–173). Palma de Mallorca: Sociedad Española de Geomorfología.

COSTA-CASAIS, M., BLANCO-CHAO R., MARTÍNEZ-CORTIZAS A. & PÉREZ-ALBERTI, A. (2007b). Los episodios Heinrich en la costa de Galicia (NW de la Península Ibérica). Un análisis a través de los sedimentos continentales. Servicio de Publicaciones, Universitat de les Illes Balears, *Revista Territoris*, 7:39–53.

COSTA-CASAIS, M., MARTÍNEZ-CORTIZAS, A., KAAL, J., FERRO-VÁZQUEZ, C. & CRIADO-BOADO, C. (2008). Depósitos coluviales holocenos del NO peninsular: geoarchivos para la reconstrucción de la dinámica geomorfológica. In J. Benavente, F.J.Gracia (Eds.), *Trabajos de Geomorfología en España 2006–2008*. (pp 83–86**)**. Cádiz: Sociedad Española de Geomorfología.

COSTA-CASAIS, M., MARTÍNEZ-CORTIZAS, A., PONTEVEDRA-POMBAL, X. & CRIADO-BOADO, F. (2009). Analysis of landforms in geoarchaeology: Campo Lameiro, NW Iberian Peninsula. *Mem Descr Carta Geol d'It* 87:39–51.

DE ABREU, L., SHAKLETON, N. J., SCHÖNFELD, J., HALL, M. & CHAPMAN, M. (2003). Millennial-scale oceanic climate variability off the Westernn Iberian margin during the last two glacial periods. *Marine Geology*, 196: 1-20.

DUPLESSY, J.C., DELIBIRIAS, G., TURON, J.L., PUJOL, C. & DUPRAT, J. (1981). Deglacial warming of the northeastern Atlantic Ocean: correlation with the paleoclimatic evolution of the European continent. *Palaeogeogr Palaeoclimatol Palaeoecol* 35:121–144. doi:10.1016/0031-0182(81)90096-1

GARCÍA-CORTÉS, A. & CARCAVILLA, L. (2009). (Coords.) *Documento metodológico para la elaboración del inventario español de lugares de interés geológico (IELIG)*. IGME. [Avaliable Online] http://www.igme.es/internet/patrimonio/novedades/METODOLOGIA/IELIG/V12.pdf. [Accessed 1 February 2010].

GARCÍA-CORTÉS, A., CARCAVILLA, L., DÍAZ-MARTÍNEZ, E. & VEGAS, J. (2014). (Coords.) *Documento Metodológico Para la Elaboración del Inventario Español de Lugares de Interés Geológico (IELIG).* Instituto Geológico y Minero de España (IGME). [Available Online] http://www.igme.es/internet/ patrimonio/novedades/METODOLOGIA/IELIG/V16 web.pdf [accessed on 13 January 2015]**.**

GUILLÉN-MONDÉJAR, F, & DEL RAMO, A. (2004). Patrimonio geológico y geodiversidad de la Molata de Charán (Moratalla, Murcia) *Geo-Temas 6*(4):103–106.

GUILLÉN-MONDÉJAR, F. (2007). La ciencia de la geología y el Patrimonio geológico en España: cultura social y ordenación del territorio. In C. Restrepo, J.M. Mata (Eds.) *Actas del I Congreso Internacional sobre Geología y Minería en la Ordenación del Territorio y en el Desarrollo*. (pp. 15–37). Utrillas (Teruel): Universidad Politécnica de Cataluña, Dpto. de Ingeniería Minera y Recursos Naturales.

HEINRICH, H. (1988). Origin and consequences of cyclic ice rafting in the northeast Atlantic Ocean during the past 130000 years. *Quat Res*, 29:142–152. doi:10.1016/0033-5894(88)90057-9

HENRIQUES, M.H., PENA DOS REIS, R., BRILHA, J. & MOTA, T. (2011). Geoconservation as an Emerging Geoscience. *Geoheritage*, 3:117–128. doi:10.1007/s12371-011-0039-8

MARTÍNEZ-CORTIZAS, A. & MOARES, C. (1995). *Edafología y arqueología. Estudio de yacimientos arqueológicos al aire libre en Galicia*. Xunta de Galicia, Santiago de Compostela.

MARTÍNEZ-CORTIZAS A. & COSTA-CASAIS, M. (1997). Indicios de variacionesdel nivel del mar en la ría de Vigo durante los últimos 3000 años. Gallaecia, 16:23–47.

MARTÍNEZ-CORTIZAS, A., COSTA-CASAIS, M. & MOARES, C. (1996). Niveles dunares pleistocenos y holocenos en la costa de Galicia: hipótesis cronológica en base a su grado de edafización. In A. Pérez-Alberti, P. Martini, W. Chesworth & Martínez-Cortizas, A. (Eds.) *Dinámica y Evolución de Medio Cuaternarios*. (pp. 391–404). Santiago de Compostela: Xunta de Galicia.

MARTÍNEZ-CORTIZAS, A., COSTA-CASAIS, M. & LÓPEZ-SÁEZ, J.A. (2009). Environmental change in NW Iberia between 7000 and 500 cal BC. *Quat Int,* 200:77–89. doi:10.1016/j.quaint.2008.07.012

PARGA PEINADOR, J.R. (1969). Sistemas de fracturas tardihercinicas del Macizo Hespérico. *Tabajos del Laboratorio Geológico de Laxe*. Monograph, 37. Sada, A Coruña.

PÉREZ-ALBERTI, A. (1991). *La geomorfología de la Galicia sudoriental (problemas geomorfológicos de un Macizo antiguo de la fachada Atlántica Ibérica: centro-sudeste de Galicia)*. PhD thesis, Universidade de Santiago, Spain.

PÉREZ-ALBERTI, A., BLANCO CHAO, R., COSTA CASAIS, M. & VÁZQUEZ PAZ, M. (1998a). Formas litorales heredades en costas rocosas de Galicia. In A. Gómez Ortiz, F. Salvador Franch (Eds.). *Investigaciones Recientes de la Geomorfologia Española*. Servei de Gestió i Evolució del Paisatge. (pp. 333–340). Granada: Vicerectorat de Recerca/Geoforma Ediciones.

PÉREZ-ALBERTI, A., COSTA-CASAIS, M. & BLANCO-CHAO, R. (1998b). L'importance des processus d'origine froide sur la cote atlantique de la Galic (Nord-Ouest de la Peninsule Iberique). Environnements periglaciaires. Association Francaise du Periglaciaire, *Notes et Comptes-Rendus du Groupe Régionalisation du Périglaciaire*, Université de Paris 5–XXIII: 21–32.

PÉREZ-ALBERTI, A., COSTA-CASAIS, M. & MARTÍNEZ-CORTIZAS, A. (1999). Nuevas aportaciones al conocimiento del cuaternario reciente en la costa atlántica de Galicia. In Universitat de València, Departament de Geografia (Ed.), *Geoarqueologia i Quaternari litoral*. Memorial Maria Pilar Fumanal (pp. 381–390). València: Universitat de València.

THRENHAILE, A.S., PÉREZ-ALBERTI, A., MARTÍNEZ-CORTIZAS, A., COSTA-CASAIS, M. & BLANCO-CHAO, R. (1999). Rock coast inheritance: an example from Galicia, Northwestern Spain. *Earth Surf Process Landf*, 24:605–621. doi:10.1002/(SICI)1096 9837(199907)24:7<605::AIDESP977>3.0.CO;2-1

THOUVENYN, N., MORENO, E., DELANGHE, D., CANDON, L., LANCELOT, Y. & SHAKLETON, N. Y. (2000). Rock magnetic detection of distal ice-rafted debries: clue for the identificatio of Heinrich layers on the Portuguese margin. *Earth and Planetary Science Letters* 180: 61–75.

VALCÁRCEL, M. & COSTA-CASAIS, M. (2011). Modelos paleocriológicos confrontados con depósitos costeros en el NW de la Península Ibérica. In V. Turu, A. Constante (Eds.),

Cuaternario en España y áreas afines, Avances en 2011. Resúmenes XIII Reunión Nacional de Cuaternario (pp. 31–35). Andorra.

VAN VLIET-LANOË, B. (1988). *Le rôle de la glace de ségrégation dans les formations superficielles de L'Europe de L'Ouest. Processus et héritages*. Thèse d'Etat. Paris I,-Sorbonne. Publication Editec.

VAN VLIET-LANOË, B. (1990a). Le pédocomplexe de Warneton: où en eston? Bilan paléopédologique et micromorphologique Bulletin de L'Association Française por l' Étude du Quaternaire. *Quaternaire* 1:65–76.

VAN VLIET-LANOË B (1990b). The genesis of the argillic horizon in Weichselan loess of Northwestern Europe. *Quat Int* 5:49–56. doi:10.1016/1040-6182(90)90024-X

VAN VLIET-LANOË, B. & VALADAS, B. (1983). A propos des formations déplacées des versants cristallins des massifs anciens: Le rôle de la glace de ségregation dans la dynamique. *Bulletin de L'Association Française por l' Étude du Quaternaire. Quaternaire* 4:53–160.

XUNTA DE GALICIA (2010). Plan de Ordenación do Litoral de Galicia (POL). Información mantida pola Xunta de Galicia. Servizo prestado pola Conselleria de Medio Ambiente, Territorio e Infraestruturas. [Online] http:// www.xunta.es/litoral/. [Accessed 13 December 2010]

ZARAGOSI, S., EYNAUD, F., PUJOL, C., AUFFRET, G. A., TURON, J. L. & GARLAN, T. (2001). Initiation of European deglaciation as recorded in the northwestern Bay of Biscay slope environments (Meriadzek Terrace and Trevelyan Escarpament): a multi proxy approach. *Earth Planet. Sci. Lett*, 188: 493–507.

Legislative documentation

(2007) LAW 5/2007, de 3 de abril, de Red de Parques Nacionales (National Parks Network). *Boletín Oficial del Estado (BOE)* 81, 4/4/2007.

(2007) LAW 6/2007 del 11 de maio, de medidas urgentes en materia de ordenación del territorio y del litoral de Galicia. *Boletín Oficial del Estado (BOE)* 137, 08/06/2007.

(2007) LAW 42/2007, de 13 de diciembre, del Patrimonio Natural y de la Biodiversidad (Natural Heritage and Biodiversity) LPNB, *Boletín Oficial del Estado (BOE)* 299, 14/12/2007.

(2007) LAW 45/2007, de 13 de diciembre, de Desarrollo Sostenible del Medio Rural (LDSMR) (Sustainable development of Rural Environment). Boletín Oficial del Estado (BOE) 299, 14/12/2007.

(2011) DECREE LAW 20/2011, de 10 de febrero, por el que se aprueba definitivamente el Plan de Ordenación del Litoral de Galicia. *Diario Oficial de Galicia (DOGA)*, 23/02/2011.

(2004) 3 RECOMMENDATION REC on conservation of the geological and areas of special geological interest. (Adopted by the Committee of Ministers on 5 May 2004 at the 883rd meeting of the Ministers' Deputies). *Council of Europe*, Committee of Ministers.