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Analysis of landforms in geoarchaeology: Campo Lameiro, NW Iberian Peninsula

Analisi delle forme del rilievo in geoarcheologia: Campo Lameiro, Penisola Iberica nord-occidentale

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ABSTRACT – The present work is part of an interdisciplinary project on the future Rock Art Park of Campo Lameiro (Galicia, NW Spain), in which Earth Science disciplines played a fundamental role in the development of the archaeological project. Our investigation focused on the evolution of landforms as a key factor in geoarchaeological analysis. The aim was to determine the influence and control of relief structure on the formation, distribution and genesis of soils and sediments in Campo Lameiro –which may be considered as the environmental archives. This approach is particularly important in this area, due to the scarcity of archaeological remains other than the rock art itself. Soils and sediments are unique archives that have recorded landscape transformations linked to cultural evolution. In the studied area the oldest sedimentary facies date back to the late Pleistocene – early Holocene. From the mid Holocene onwards the dominant processes are erosion and colluviation, in high and low potential energy areas respectively; which implied an intense redistribution of the soil resource through time. During the Bronze Age, when most rock art panels appear to have been made, these processes intensified and the rock surfaces were largely exposed. The environmental dynamics in the area follows a pattern already described for other sectors of NW Spain, and is therefore consistent with the regional evolution. Our results demonstrate the usefulness of paleoenvironmental analyses in building a framework for the comprehension of Galician rock art.

KEY WORDS: Geoarchaeology, Landforms, Environmental archives, Late Pleistocene, Holocene.

RIASSUNTO – Il presente lavoro è parte di un progetto interdisciplinare sul futuro Parco dell'arte rupestre di Campo Lameiro (Galizia, nord-ovest della Spagna), dove le discipline delle Scienze della Terra giocano un ruolo fondamentale nello sviluppo del progetto archeologico. Le ricerche sviluppate si sono concentrate sull'evoluzione delle forme del rilievo come fattore chiave nelle analisi geoarcheologiche. Lo scopo è stato quello di determinare l'influenza e il controllo dei fattori strutturali del rilievo nella formazione, distribuzione e genesi dei suoli e dei sedimenti in Campo Lameiro, che può essere considerato un archivio ambientale. Questo approccio di lavoro è particolarmente efficace ed importante in quest'area, a causa della scarsità di ritrovamenti archeologici diversi da quelli legati all'arte rupestre. Suoli e sedimenti sono archivi unici in cui sono registrate le trasformazioni del paesaggio collegate all'evoluzione culturale. Nell'area di studio la più antica facies sedimentaria risale al tardo Pleistocene – inizio Eocene. Dal medio Olocene in avanti i processi dominanti sono l'erosione e la produzione di colluvio, rispettivamente in aree ad alta e bassa energia potenziale. Questo implica un'intensa ridistribuzione della risorsa suolo nel tempo. Durante l'Età del Bronzo, quando la maggior parte delle pitture rupestri sembra siano state fatte, questi processi si intensificarono e le superfici rocciose furono ampiamente esposte. Le dinamiche ambientali nell'area seguono uno schema già descritto per altri settori della Spagna nord-occidentale e quindi conforme con l'evoluzione regionale. I risultati qui illustrati dimostrano l'utilità delle analisi paleoambientali per la comprensione dell'arte rupestre della Galizia.

PAROLE CHIAVE: Geoarcheologia, Forme del rilievo, Archivi ambientali, Tardo Pleistocene, Olocene.

1. - INTRODUCTION

Geoarchaeology is both an interdisciplinary and specialized discipline. This dichotomy does not weaken the discipline, although it does lead to de-

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bates over its boundaries and definitions (Huckleberry, 2000). Butzer (1971, 1981, 1982) was among the first to stress the application of a geoscientific perspective in the study of human prehistory, a field that he defined at the time as prehistoric geography. In his view, humans are best understood with respect to their ecology, and Geoarchaeology could play an important role in defining the environmental context of past societies. He also alluded to the significance of such research to modern environmental issues. Huckleberry (2000) defined Geoarchaeology, slightly modifying the perspective offered by Gifford & Rapp (1985), as "the application of Earth Science method and theory to understanding the human past." This definition is broad enough to include experts from a range of scientific backgrounds to contribute towards the understanding of human prehistory. The archaeological record is a complex system affected by a variety of chemical, physical and biological processes, that have to be defined prior to deciphering behaviour through induction. All of these theoretical considerations, and a growing recognition of the value of interdisciplinary study, have made it possible for Geoarchaeology to become an essential component in archaeological projects (Martínez Cortizas, 2000).

Regardless of the nature and rate of human disturbance on the landscape, considerable debate has surrounded the identification of climate changes and human impacts (whether direct or indirect) as driving forces of landscape change. Assessments of the geomorphic impacts of human modification to landscapes must be framed within the context of the natural range of variation, requiring solid baseline information on the long-term character and behaviour of the system in question (Brierley & Stankoviansky, 2002). Relief structure and its evolution govern the formation, erosion and distribution of soil and sediments. Due to the difficulties in direct dating of the panels, in rock art sites it is necessary to unveil the chronology of the processes of weathering, erosion and sedimentation to know when the exhumation of the rock outcrops occurred, and thus rock art could have been produced.

On the other hand, the distribution of archaeological sites is a function of several factors: cultural activities, taphonomic processes, geomorphic changes, and the nature and extent of the archaeological surveys themselves (Schiffer, 1987; Stein, 2001). The distribution of archaeological sites detected using GIS reflects patterns of discovery and documentation, which in turn are influenced by survey strategies such as the distribution of rock art, and geomorphic processes -erosion and deposition of sediments (Bauer *et alii*, 2004; Guccione *et alii*, 1998). Also, the concept of landscape sensitivity is fundamental to the relationship between climate and erosion in shaping the landscape. According to Knox (2001) "Agricultural landscapes are more sensitive to climatic variability than natural ones because tillage and grazing typically reduce water infiltration and increase rates and magnitudes of surface runoff." The effect of erosive rainfall can be amplified because bare soil accelerates surface runoff and soil erosion. Studies developed in NW Spain support the interpretation that human activities in the past led to a rapid decrease of forest cover and accelerated soil erosion, challenging the ability of cultures to adapt to new circumstances (González Díez *et alii*, 1996; Martínez Cortizas *et alii*, 2005).

The work presented here is part of an interdisciplinary study on the area where the future Rock Art Park of Campo Lameiro (Galicia, NW Spain) will be located. In this project Earth Sciences disciplines played a major role in complementing the archaeological research. Our paper focuses on the evolution of landforms -rocky substrate, sediments and soils - as a key factor for geoarchaeological analysis, with the objective of defining the relief units –location and timing of formation- and to relate them to the spatial distribution of the rock carvings. We aim to determine the influence and control of relief structure on the formation, distribution and evolution of soils and sediments.

This approach is particularly important in the studied area since there are few archaeological remains other than the rock art itself. Granite landforms, soils and sediments are unique archives that have recorded transformations in the landscape linked to cultural evolution.

2. – STUDY AREA AND METHODOLOGY

The future Campo Lameiro Rock Art Park is being built in southwestern Galicia (NW Spain) at an elevation of 330 m a.s.l. and 25 km from the coast (fig. 1). The area is an almost isolated hill, isolated by a series of fractures with preferential directions (N-S, E-W), which the fluvial network uses to flow through the territory. The general rolling topography, with a series of tops and troughs, is the result of a combination of granitic macro and microforms. It is an area of transition between the coast and mountain range with humid, temperate climate. Present mean annual temperature is 14.5 °C, and mean annual precipitation is 1500 mm (Martínez Cortizas & Pérez Alberti, 1999).

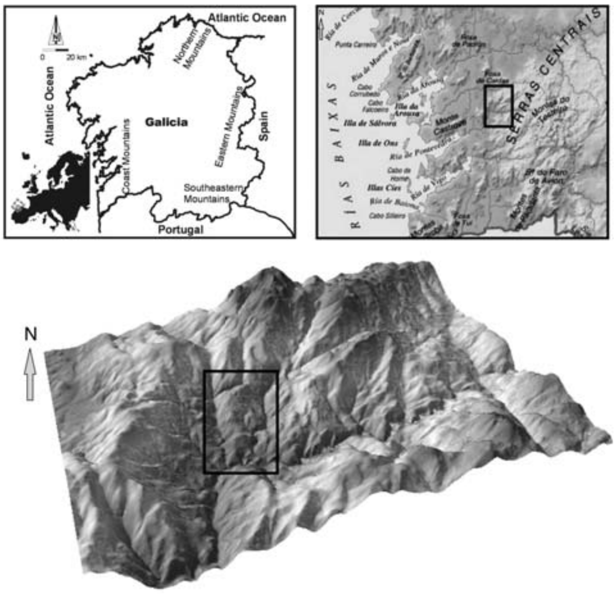

Fig. 1 – The future Campo Lameiro Rock Art Park will be located in South-Western Galicia (NW Spain) at an elevation of 330 m a.s.l. and 25 km from the Atlantic coast.
– Il futuro Parco dell'arte rupestre di Campo Lameriro sarà ubicato nel settore sud-occidentale della Galizia (Spagna NW) a 330 m s.l.m di quota e a 25 km dalla costa atlantica.

The methodology used to relate the geoarchaeological analyses and the geomorphologic context started with the interpretation of aerial photographs, in order to define the relief units and how they link to the regional geomorphologic context. In a second stage, fieldwork was carried out in order to differentiate landforms. All this information was used as a basis in order to designing and subsequent opening of 43 ditches in ten sectors, with a total length of 2.5 km (fig. 2). We followed two main criteria for its design: the variety of morphological units, their location in sectors prone for accumulation, in erosive/accumulative or erosive areas; and their proximity to the rock carvings. The aim was to obtain as extensive and varied a representation as possible of the superficial formations that fossilize the substrate, their facies and morpho-sedimentary features, and to obtain as full a stratigraphic sequence as possible.

The groups of ditches correspond to different microtopographies, each associated to rock carvings. Systematic descriptions of the sedimentary facies were made in order to define the vertical and lateral stratigraphic changes. More detailed descriptions were made for a small number of profiles in each ditch, which generally coincided with the deepest ones and showing the greatest variation of sedimentary facies.

Eleven deep soil profiles (with depths between 1,5 and 3 m) were also selected for more complete geochemical soil analyses -such as the concentration of trace elements- and pollen analyses: five representative of different sectors of the area, five in a transept perpendicular to one of the most important rock art panels, and one outside of the Park area. The locations of the trenches, the soil profiles and the rock art panels were incorporated into a digital terrain model, then combined with the information obtained from the other disciplines involved –Geomorphology, Archaeology and Pedology– to conform a GIS database (fig. 2).

3. – RESULTS

3.1. – GEOLOGICAL STRUCTURE AND BEDROCK LITHOLOGY

The sector of Campo Lameiro was subjected to the lithostructural evolution of the northwestern Iberian Peninsula. The tectonic movements that occurred throughout the geological history of Galicia acted differentially on its lithology, and defined the main lines of the relief at regional and local scales (PARGA PONDAL, 1969; PÉREZ ALBERTI, 1986; 1990; 1993). The result was the for-

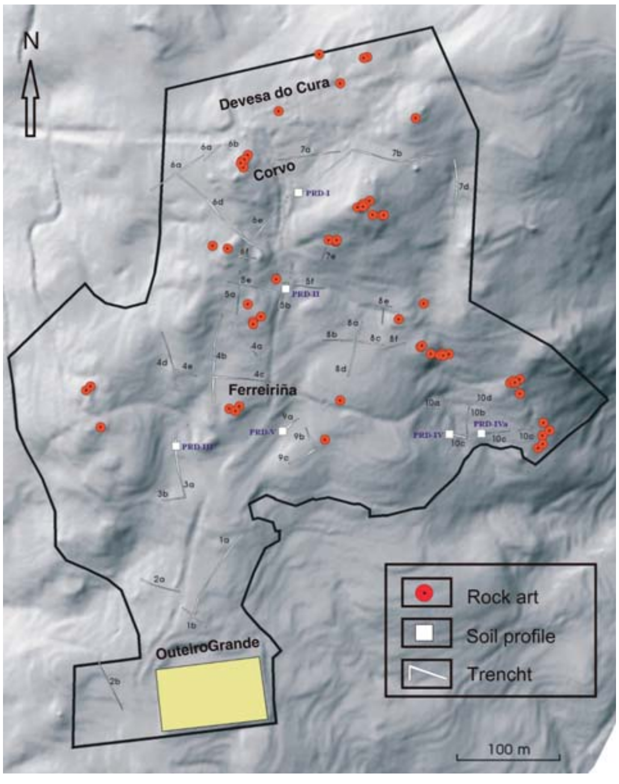

Fig. 2 – The georeferenced trenches, soil profiles and rock art panels georeferenced, were incorporated into a digital terrain model, then combined with the information obtained from the other disciplines involved – geomorphology, archaeology and pedology– to conform a GIS database.
– Le trincee georeferenziate, i profili pedologici e le pitture rupestri georeferenziate sono state aggiunti in un modello digitale del terreno e successivamente implementati con le informazioni geomorfologiche, archeologiche e pedologiche per costruire un database cartografico.

mation of a series of fractures running from NW-SE, NE-SW and N-S, which generated a relief marked by the dichotomy between the vertical shapes of the hills and mountains, and the horizontal shapes of the valleys, cut through by the fluvial network (fig. 3). Within this structural context the studied area appears as an almost isolated hill at the centre of the watershed, defined by the river network, and surrounded by the main fractures running from N-S and E-W as well as by numerous joints that break the substrate running N-S, E-W, NW-SE and NE-SW (fig. 3, fig. 4a).

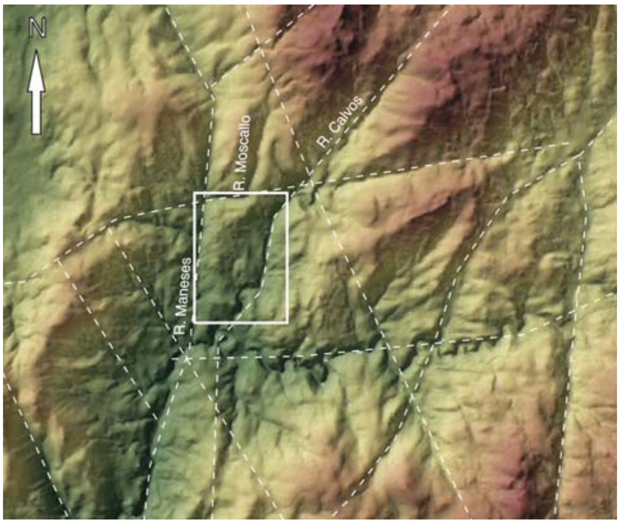

Fig. 3 – Joint system in the surrounding area to the future Campo Lameiro Park. The white box indicates the sector of study, shown with detail in figure 4. – *Sistema di fratture nell'area circostante il futuro Parco di Campo Lameiro. Il quadrato bianco indicata l'area di studio, mostrata in dettaglio in figura 4.*

The lithology is homogenous throughout the whole of the Park. It is comprised of two mica granitic rocks with megacrystals of K-feldspars; with minerals showing a certain degree of orientation towards the north of the area (IGME, 1982 a, 1982 b). Outside the area of the Park, a small band of schists and paragneiss is found running from northwest to southeast.

3.2. – Landforms

3.2.1. – *Granite landscape*

Granitic modelling dominates the slopes of the area and the differences in altitude makes it possible to divide it into three sectors, with granitic outcrops separated by small talwegs. The tops are organized following a polygonal pattern resulting from long-term granite alteration that is controlled by a joint system running from N-S and E-W (fig. 4a). This tectonic pattern defines an alignment with a series of tops and granitic slabs interspersed

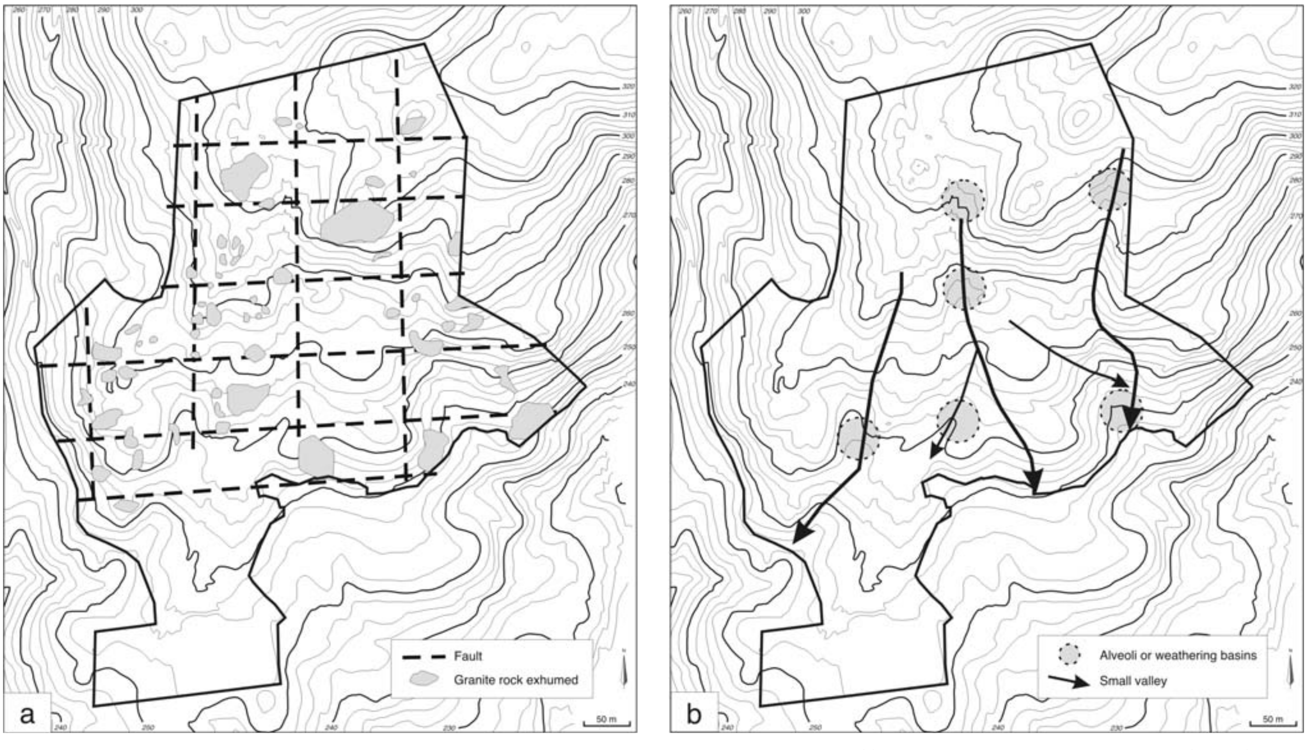

Fig. 4 – a) Organization of tops following a polygonal pattern resulting from granite alteration, controlled by a joint system running from N-S and E-W. b) Tectonic pattern defines an alignment with tops and granitic slabs interspersed with low-lying areas, which correspond to alveolar depressions. The location of the granite outcrops and the alveolar depressions defines three main flow paths within the area, that channelized the transport of water and sediments to the valleys. – *a) Oraganizzazione delle cime secondo uno schema poligonale, risultato dell'alterazione granitica e controllato da un sistema di* joint *con direzione N-S ed E-O. b) La struttura tettonica definisce un allineamento con cime e lastre granitiche inframezzate con aree depresse, che corrispondono a depressioni alveolari. L'ubicazione dell'affioramento granitico e le depressioni alveolari definiscono tre canali di flusso principali nell'area, che trasportano acqua e sedimenti a valle.*

Tab. 1 – *The lithological, structural and geomorphological variely of granite landscape. Types of megaforms and microforms in Campo Lameiro, modified from* TWIDALE *(1992).*
- La varietà litologica, strutturale e geomorfologica del paesaggio granitico. Tipi di megaforme e microforme in Campo Lameiro, modificato da TWIDALE (1992).

GRANITE LANDSCAPE IN CAMPO LAMEIRO

MEGAFORMS

CONVEX FORMS	**CONCAVE FORMS**
Mountain ridges Castle-kopje Tor Block	Alveoli or weathering basins

MICROFORMS

MICROFORMS without any evident relationship to the rock structure

Linear forms	**Pointed forms**
Gutters	Gnammas Tafone

MICROFORMS without any evident relationship to the rock structure

Linear forms	**Flat forms**
Polygonal craking Nerviate forms	Brocken blocks

with small low-lying areas, which correspond to alveolar depressions (fig. 4b).

The central sector of the area has a maximum elevation of 330 m a.s.l. and minimum one of 259 m a.s.l. Altitude decreases from north to south in a series of steps, with *Devesa do Cura* and *Corvo* tops to the north, at a elevations over 300 m a.s.l., to a central peak, *Ferreiriña*, at 289 m a.s.l., and to the south, *Outeiro Grande*, at 250 m a.s.l. (fig. 2).

The upper and lower sectors are connected through steep, deeply eroded slopes, where the rock substratum is visible at the surface -as it happens in the slopes facing towards the east of the Park. This sector is contrasting with the central and western ones, where the main shape is articulated into three levels with different altitudes and gentler slopes, dominated by alveolar depressions surrounded by crests and granitic slabs.

The lithological, structural and geomorphological variety found corresponds to that of granitic landforms (tab. 1). The latter are classified into two groups, depending on their size: megaforms or large scale forms, and microforms or smaller forms (GODARD, 1977; TWIDALE, 1986; 1989). The most important within the first group are convex megaforms, mostly granitic crests, represented by c*astle kopjes* (fig. 5) in which vertical joints predominate over horizontal joints, such as those were the petroglyphs of *As Ventaniñas* and *As Forneiriñas are located;* or *tors*, in which the main joints run horizontally, such as *Pena Furada* (fig. 6).

Recent stone quarrying works on the crests has considerably modified their initial structure, making it difficult to find them with their natural shape. As a whole they are combined with concave megaforms – *depressions or alteration alveoli* – which occupy a lower topographic position, and are surrounded by granitic tops (fig. 7).

At an intermediate topographic position are the granitic *slabs*, minor forms that are related to the structure of the rock - joints direction mainly -, flat in shape and slightly tilt down. They are associated with other smaller linear forms not related to the rock structure and usually located on vertical surfaces as *grooves* and *channels*, with small depressions as *gnamas* –found both on horizontal and vertical walls. But also to other small linear microforms related to rock structure, as narrow chan-

Fig. 5 – Dismantled castle kopje in the upper part of Campo Lameiro. In some cases fallen blocks contain rock carving.
– *Kopje smantellata nella parte superiore di Campo Lameiro. In alcuni casi i blocchi caduti contengono delle incisioni rupestri.*

Fig. 6 – Tor of Pena Furada. The main joints run horizontally. There are rock carvings on the horizontal surfaces both on the basal rock and higher surfaces.
– *Tor della Pena Furada. I* joints *principali si sviluppano orizzontalmente. Vi sono incisioni rupestri sulle superfici orizzonatli sia nella parte basale che in quella superiore.*

Fig. 7 – Dismantled castle kopjes between alveoli or weathering depression. In the front there are rock carvings represented by cup marks and rings.
– *Kopje smantellata tra alveoli o depressioni legate all'alterazione meteorica. Di fronte vi sono incisioni rappresentate da coppelle ed anelli.*

nels and *cracks*, which follow the direction of joints or the areas between the planes of a joint. The rock art panels of *Os Carballos* and *Os Cogoludos* are good examples, carved on slabs, in which the joints, narrow channels and other linear features are the result differential erosion (fig. 8).

Within the smaller forms are specific shapes that are not related to rock structure: as *gnamas* and *taffonis*. They are associated with megaforms and mainly found on tops and slabs. The first are concave in shape, and appear both on horizontal and vertical surfaces, whereas the second appear in the inner part of a wall producing a hollow structure -as in the tor of *Pena Furada* (fig. 9). In other cases gnamas at both sides of a rock connect to create a hole, as seen at the top of *Ventaniñas* (fig. 10).

Fig. 8 – Slab with joints, splits and linear branches. The rock surface is covered by rock carvings - cup marks and rings.
– *Lastra con fratture, fessure e ramificazioni lineari. La superifcie della roccia è ricoperta da incisioni, coppelle ed anelli.*

3.2.2. – *Sedimentary deposits*

The thickest sedimentary deposits with the greatest variety of stratigraphic layers are preferentially found in the alveolar depressions, where sedimentation was favoured, and their paleoform has conditioned the evolution of these surface formations over time. Nevertheless, depending on where they are located surperficial formations can be classified into four main groups: those situated in high potential energy areas prone both to erosion and sedimentation, such as the one represented by the sequence of PRD-I (fig. 2, fig. 11a); those in low energy areas where accumulation dominated, such as the channelled depressions where PRD-III (fig. 11a) and PRD-V (fig. 11b) are found; formations that fossilize alveoli found at intermediate posi-

Fig. 9 – Tafoni of Pena Furada. It appears in the inner part of a wall producing a hollow structure.
– *Tafoni a Pena Furada, presenti nella parte superiore di un muro, producono una struttura con caratteristiche conche.*

Fig. 10 – Gnamma located in Ventaniñas. Gnammas are concave in shape, and appear both in horizontal and vertical surfaces.
– *Depressioni a conca (gnammas) ubicate in Ventaniñas. I gnammas hanno forma concava e compaiono sia nelle superfici verticali che orizzontali.*

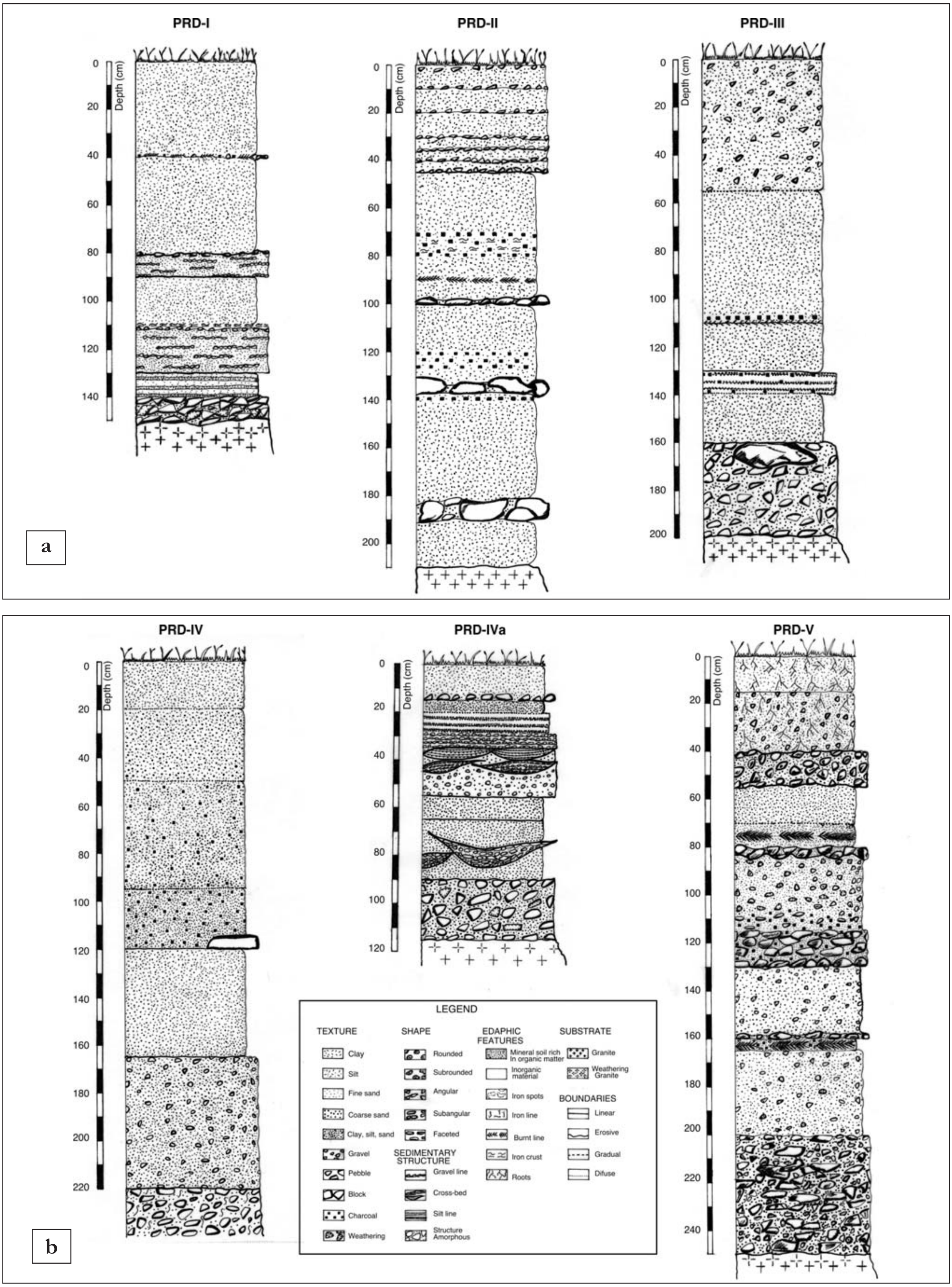

Fig. 11 – Sedimentological and stratigraphic columns: a) profiles PRD-I, II, III; b) profiles PRD-IV, IVa, V and a legend.
– Colonne sedimentologiche e stratigrafiche: a) profili PRD-I, II, III; b) profili PRD-IV, IVa, V e la legenda.

tions, located next to the base of a granite slab and with their external border eroded, as is the case of PRD-II; and those that fossilize alveoli floors, as is the case of PRD-IV, PRD-IVa (fig. 11b).

We do not make here a detailed description of each deposit, but provide a general summary of the most important morphosedimentary features (fig. 11a,b). Two types of stratigraphic units have been found: a basal inorganic sedimentary layer that covers the granitic substrate with varying thickness (50 to 100 cm); and a younger, thicker layer (up to 250 cm) represented by colluvial, polycyclic soils, rich in organic matter.

The basal unit appears over the rock or a deeply weathered saprolite, and is compossed of gravel and faceted stones with rounded edges, mostly quartz with some granite, embeded in a matrix of medium to coarse sands with abundant muscovite and usually without a clear sedimentary structure. This unit is well represented in the PRD-IVa deposit (fig. 11b), which has one of the most complete stratigraphic sequences due to its topographic position. It contains layers of gravels and faceted stones interspersed with a sandy matrix without any structure, accumulations of faceted gravels in cross beds and layers of subrounded quartz sands alternating with silt layers, in a lenticular shape. Iron coatings and discrete iron layers are also frequent.

The second unit is represented by colluvial soils that show an apparent homogeneous morphology resembling deep, black to dark brown A horizons (mineral soil rich in organic matter). They have a loamy sand to sandy loam texture, with abundant quartz and muscovite, are acidic and have high C/N ratios. Despite the apparent homogeneity in the morphology, they contain gravel and stone lines at different depths, charcoal layers and layers of burnt soil of typical red to orange colour, as it can be observed in figure 11 a, b.

4. – DISCUSSION

4.1. – Granite landscape

Granite modelling is the result of the interaction of a number of factors: rock type, tectonic, climatic changes, human activities and the associated morphogenetic systems, which either directly or indirectly have acted over time, and led to the present shapes seen in Campo Lameiro (fig. 12).

The dense joint system helped to weaken the granite and allowed alteration and weathering to proceed deeply into the rock. These processes were enhanced during periods of favourable climatic conditions, such as the tropical climate that prevailed in NW Spain during the Tertiary (Pérez Alberti, 1986). Under these wet and warm climate conditions the weathering of the granite progressed faster generating a deep mantle of saprolite. At the same time the granitic macro and microforms were predefined and later exhumated by the removal of the saprolite mantle through erosion and transport.

Alveolar depressions are the most representative major forms found in Campo Lameiro. Their formation was also controlled by the joint system that channelled both the upwards and downwards alteration processes (hydrothermal/thermal) and the downwards weathering processes (illuviation and other pedogenetic processes) (Vidal Romaní, 1989). Their final shape is also linked to fluvial and alluvial processes that gradually uncovered the megaform.

The genesis of the more localized, small scale granite forms occurred in many different ways through time. But most of them are the result of the presence discontinuity planes that favoured uneven advances of the chemical and physical alteration/weathering processes (dissolution, exfoliation, humectation-dessication and haloclastism) as well as formative features caused by concentrated loads in particular sectors of the granite body that would predetermine the existence of weak areas well before exhumantion (Twidale, 1989).

4.2. – Sedimentary deposits

Present landscape in Campo Lameiro integrates and reflects the interactions of environmental factors and human activity over time. This dynamic

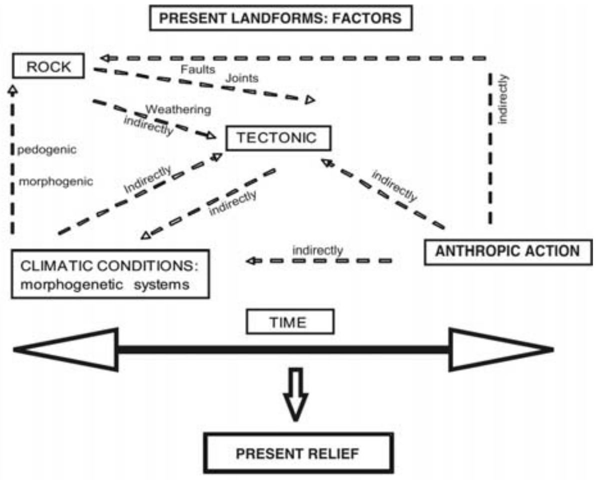

Fig. 12 – The present landforms of relief are the result of different parameters: rock, tectonic, climatic conditions, time and anthropic action. – *Le forme del rilievo attualmente presenti sono funzione di differenti parametri: litologia, tettonica, condizioni climatiche, tempo e attività antropica.*

Tab. 2 - *Bulk radiocarbon (14 C yr BP) and calibrated ages (1σ and 2σ) for different depths in two colluvial soils (PRD-I and PRD-II).*
- Datazioni al radiocarbonio (14 C yr BP) ed età calibrate (1σ e 2σ) per differenti profondità in due depositi colluviali (PRD-I e PRD-II).

Sample code	**Depth (cm)**	**Convetional age BP**	**Calibrate age 1σ BP**	**Calibrate age 2σ BP**	**Laboratory**
PRD-I-11	50-55	2300±40	2350-2310 BP	2360-2300 BP	Ua-21845
PRD-I-15	70-75	3055±40	3340-3280 BP	3360-3160 BP	Ua-21846
PRD-I-19	90-95	5300±50	6065-5995 BP	6200-5935 BP	Ua-21847
PRD-I-25	120-125	7610±55	8430-8355 BP	8485-8330 BP	Ua-21848
PRD-II-18	85-90	1835±40	1720-1820 BP	1695-1870 BP	Ua-22555
PRD-II-25	120-125	3055±40	3240-3340 BP	3160-3360BP	Ua-22556
PRD-II-35	170-175	3770±40	4090-4160 BP	4060-4255 BP	Ua-22557
PRD-II-39	190-195	5350±40	6020-6080 BP	5995-6155 BP	Ua-22558

evolution has been constant from the Late Pleistocene until today, as has been revealed by the palaeoenvironmental records analyzed and the chronology supported by radiocarbon datings (tab. 2). Microtopography controlled erosion and sedimentation, the first being most acute in the steepest slopes and at the foot of the tops, while the redistributed soils and sediments accumulated in the talwegs and the alveolar depressions. The shape of the studied area, a small isolated mountain with heights decreasing north to south, ensures that all sediments have an internal source and there was not significant contributions from the outside. The location of the granite outcrops and the alveolar depressions defines the existence of three main flow paths (fig. 4b) within the area, which served to channel the transport of water and sediments to Praderrei and Paredes valleys. Part of it was not carried away, but was instead captured and accumulated in the alveolar depressions.

The influence and control of the relief structure is a determining factor in the formation, distribution and evolution of the soils and sediments. Due to the lack of significant archaeological remains apart from the rock carvings, colluvial soils are the only environmental archives that preserved the record of the past changes. Colluvial soils are stratigraphically complex, differ in maximum age and phases represented, and have signficant time hiatuses (as for example PRD-I, see table 2).

Radiocarbon dating and stratigraphic correlation helped to put into context the natural and human induced changes that took place in Campo Lameiro since the late Pleistocene/beginning of Holocene. These are comparable to those occurred in other areas of the northwest of the Iberian Peninsula and the Atlantic coast of Europe during the same period, although some specific morpho-sedimentary features are related to local evolution. One of the most outstanding features provided by the morphology of the sediments is the sequence of colluvial levels, with charcoal, stone and gravel layers as well evidence of soil burning. This burnt soils would be a consequence of both natural and human provoked fires. All these features point to intense soil erosion, either as a result of environmental factors, human activity or a combination of both, as has been described for other parts of Europe (Sarmaja-Korjonen, 1992). Geomorphology, stratigraphy and chronology provided the basis to reconstruct landscape evolution in the area, which can be described in four main phases.

- Phase 1:11.000-8000 BP

The inorganic facies that evenly cover part of the rock substrate and that preserved the sedimentary structure in some places (such as PRD-IVa, figure 11b), is the result of the erosion and transport of the strongly weathered saprolite mantle, which generated a large amount of material. The mineralogical composition, shape of the clasts, degree of weathering and the type of fine matrix refers to a morphogenetic system controlled by water. This colluvio-alluvial formation is probably the result of the erosion of more ancient deposits. Its sedimentary facies are quite varied. There are heterogeneous and chaotic layers, resulting form soil flow processes; cross-bed, linear structures and lenticular sand layers, related with alluvial transport, which are only preserved in alveoli bottoms. They were formed under an alluvial morphogenetic system, probably as small alluvial fans, with three main channels following the natural talwegs.

The deepest deposit is associated with the ancient trough that runs through the eastern sector of the area from north to south.

Fans are dynamic systems that can temporarily storage sediments (Gómez Villar, 1996) as a result of a sporadic yet continuous supply, in geological terms, in a highly energetic environment. Slope angle, the ability to concentrate runnoff, the heterometry of the sediments and a low vegetation cover are all factors that help to explain the presence of this kind of formations. A decreasing slope angle and the widening of the valley decreases the energy of the runoff waters and favours the dispersion of sediments in an orderly manner. Alluvial fans depend equally on rainfall torrentiality and the ability to produce large amounts of sediments. At PRD-I (fig. 11a) this basal unit is fossilized by a paleosol that provided a radiocarbon age dating of 8,480-8,320 cal. BP, indicating that the fans are at least late Pleistocene or early Holocene in origin. Their formation in the studied area may be associated to the Younger Dryas (11.000-10.000 BP) which was characterized by a severe cooling and rainy environment, as is represented at sedimentary level by important alluvial-colluvial accumulations that are well defined in the northwestern Iberian Peninsula (Martínez Cortizas & Moares Domínguez, 1995; Valcárcel Díaz, 1998). This is consistent with recent research on fluvial activity in Spain that suggests increase activity by 11.170-10.230 and 9.630-8.785 BP (Thorndycraft & Benito, 2006).

⇨ Phase 2: 8000-6000 BP

From 8,480-8,320 cal. BP to 6,200-5,930 cal. BP (age obtained at the top of second paleosol of PRD-I), sedimentation must have slowed and pedogenesis progressed due to landscape stability and large vegetation cover. Although not detected in Campo Lameiro, the earliest evidence of significant transformations by humans in NW Iberia date back to this period, around 7500-7000 BP (during the Epipaleolithic), and seem to have been the result of small scale impacts in the forest by means of fires (Martínez Cortizas, 2000; Martínez Cortizas *et alii*, 1999 a,b, 2000).

⇨ Phase 3: 6000-3500 BP

The second paleosol of PRD-I shows an abrupt discontinuity with the overlying layer –a stone line-suggesting the onset of intense soil erosion. Considering the available radiocarbon dating this may have happen after 6200-5930 cal BP, an age correlated to the initiation of sedimentation in PRD-II with a basal radiocarbon dating of 6155-5990 cal BP. As a result of increased erosion the transport of soil and sediments caused a progressive accretion and infilling of the alveolar depressions and the valleys of Praderrei and Paredes. It was possibly at this time, around 6000 BP (the Mid Neolithic), when the granite outcrops started to be exhumed together with the upper part of the slabs. Studies on landscape evolution in northwestern Spain indicate that soil erosion began to be a widespread phenomenon at least from 6,000-5,500 BP (Costa *et alii*, 1996; Martínez Cortizas, 2000; Martínez Cortizas *et alii*, 2000). A decline in forest cover and the first appearance of cereal polen indicated by palynological studies (Ramil, 1993; Martínez Cortizas *et alii*, 2005), the erosive discontinuities, stone and charcoal lines in colluvial soils, as well as the start of a progressive soil acidification point to human activities as the main trigger. But this is also coincident with a climatic abrupt change in Spain and other parts of Europe (Martínez Cortizas *et alii*, 1999 b,c; Magny *et alii*, 2006) to wetter and cooler conditions, which probabily resulted in a higher landscape sensitivity to human activities.

⇨ Phase 4. 3500- 500 BP

A relative stability of the slopes seems to have occurred at the beginning of this period, shown by the development of a new paleosol cycle which is represented in PRD-I and PRD-II (fig. 11a), and in both cases with the same age (3360-3160 cal. BP). Soil data obtained shows an increase in organic matter, which may also support a certain degree of stability in this paleosurface.

After 2000 BP a new erosive phase occurred, represented in the soils by gravel and stone lines, charcoal layers and burnt soil layers, which again seems to be the consequence of forest fires. In a study on the evolution of climate and landforms during the Upper Holocene in the Iberian Range and the Ebro and Pre-Pyrenean basins, Gutiérrez Elorza & Peña Monné (1992), focused on the role played by human activities, distinguished two periods of sediment accumulation linked to erosive processes: a generalized one that corresponds to the cold phase of the Iron Age (2900-2300 BP) and another, less significant during the Post-Medieval period corresponding to the Little Ice Age (500 BP). The dating of 2360-2300 cal BP at a depth of 50 cm in PRD-I, just above the charcoal, may be assimilated to the moment indicated for the Upper Holocene in the Iberian Range and which is also indicated by Martínez Cortizas *et alii* (2000) for the Atlantic ranker of *Coto da Fenteira* in NW Spain. Whereas the age of 1690-1870 cal. BP at 90 cm in PRD-II, over a burnt soil layers, marks an erosive episode that may be local, and perhaps related to activity that took place at the foot of the rock carving of *Os Carballos*.

By 3000 BP a critical threshold must have been crossed in NW Spain because many indicators show an acceleration of environmental degradation. A significant forest decline coincides with an increase in soil acidification and the first detection of atmospheric and soil metal pollution (MARTÍNEZ CORTIZAS *et alii*, 1997, 2002; KYLANDER *et alii*, 2005). In fact, forest evolution and atmospheric metal pollution (a proxy of mining and smelting activities) have been coupled since 3000 BP until the beginning of the industrial revolution (MARTÍNEZ CORTIZAS *et alii*, 2005).

4.3. – ARCHAEOLOGICAL IMPLICATIONS

In order to relate present landforms and rock art in the studied area, it is necessary to understand the processes of alteration/weathering of the granite and the structural control exerted by granite landforms on landscape evolution (i.e. erosion and sedimentation). The timing of exhumation of the rock surfaces is key in providing a useful surface for rock art expressions. The erosive processes involved in rock surfaces exhumation were driven both by natural factors –as climate changes– and human activities –mainly through impacts on the vegetation cover (WILKINSON, 2005). Apart from the direct changes on vegetation communities, human activities intensified soil erosion and led to a dramatic redistribution of the soil resource as well as to the exposure of the raw material that was used to make the carvings: the granite rock. The outcrops and the upper part of the slabs probably began to be exposed by 6000 BP (Mid Neolithic), as this was the time when soil erosion started to be widespread. At the end of the Neolithic/beginning of the Bronze age erosion accelerated, with most outcrops and the lower part of the slabs being exhumed. This may have been the time when the first carvings were made.

An iconographic study of the rock carving panels of the area represented by cup and rings and its comparison with other found in Atlantic areas ascribed them to the Late Neolithic (4800 – 4500 BP) or Early Bronze Age (4500 – 3000 BP) -such as the panel of *Os Cogoludos*, located at the foot of the highest and steepest granite outcrop in the area (SANTOS ESTÉVEZ, 2005). According to this author, most of the carvings in the studied area -such as scenes of deer hunting or equestrian- may have been made between 3000 and 2400 BP and were therefore in use from the Late Bronze Age until the Iron Age. This provides a minimum age of some 3,000 years and a long period of time for rock exposure. Obviously, the steepest areas and those at higher elevations would have been the first to be affected by erosion, whereas those in the middle section -such as the slab of *Os Carballos*- would have been exposed later depending on the balance between erosion and accumulation in the local basin.

A dating of 960-790 cal. BP just at the base of the colluvium that covered much of the carving of O*s Carballos* prior to archaeological excavation, indicates that at that time the panel was buried. The burial of the rock slabs at the middle and lower sectors of the area may well have occurred quite quickly. For example, the top 60 cm of the PRD-II colluvium are comprised of interspersed coarse sands and gravels with indications of fast laminar transport. This structure may be indicative of the basin having been partially filled, with the material flowing over its lower edge towards one of the main basins of the area (where PRD-V is located). At the same time the slabs at higher elevation and on gentler slopes started to be buried by a shallow soil layer, depending on the evolution of the surrounding outcrops. The other sectors would have been subjected to preferential accumulation as it is the case of PRD-IV, PRD-III and PRD-V.

Although the upper layers of the last two deposits possibly show a more local evolution. Both sectors, situated in troughs, are currently enclosed by stonewalls. This was possibly done in order to protect them from erosion, and to use these wet areas for pasture. Both the slopes in the eastern and western sector are predominately erosive, with the only exception of few locations with small alveolar depressions.

Although human activities seem to have been involved in the landscape evolution of the area since at least 6000 years ago, enviromental changes (natural and human induced) have also challenged human societies which responded to perceived changes adapting to the new conditions in a feedback loop so that landscape and human groups coevolved interacting in a complex way.

The result of this interaction expressed as modifications in the vegetation cover, the elimination of the soil resources in many areas and its concentration in more localized, control-demanding sectors, and a progressive acidification and contamination. These transformations may have affected ecological diversity in ways we still have to uncover, that subtetly modified the services offered by biodiversity to human societies. To a great extent, present landscape is the product of these interactions.

5. – CONCLUSIONS

This study demonstrates the usefulness of interdisciplinary palaeoenvironmental analysis in building up an integrated framework for the understanding of rock art in NW Spain. The distribution of archaeological sites in the studied area is a function of various factors including cultural activities, geomorphic changes, taphonomic processes, and the nature and extent of the archaeological surveys themselves. The chronology of environmental changes is consistent with studies developed in other areas of NW Spain but also in other parts of Spain and Europe. Both climate changes and human activities were the driving forces of an evolution that is strongly conditioned by the local lithology.

The onset of widespread erosion occurred at the Mid Holocene under increasing human pressure and climate deterioration. As a result many areas were denudated and the soil resource redistributed into more localized sectors. These processes accelerated during the Bronze Age, when most of the rock art panels seem to have been made, as the rock was exposed due to the exhumation of granite landforms. The combined effect of climatic changes and disturbances from human activity had a major impact on local vegetation communities and soil cover, thereby increasing soil erosion and contributing to a more degraded environment. The sensitivity of landscape to human pressures seems to have changed coupled to climate deterioration.

A proper understanding of landscape evolution, and particularly of present cultural landscape, needs the integration of cultural and environmental records in order to obtain a more in depth view of human eco-dynamics than by simply analyzing environmental variables alone.

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