PROTECTION AND CONSERVATION OF SAMPAIO AREA (LABRUGE, VILA DO CONDE, NORTH OF PORTUGAL)

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ABSTRACT

Sampaio's beach, located 15 km North of Porto, has many points of interest. There is a fossil wave cut notch and a marine deposit, hanging at 9 meters high. Nearby we can see a deposit of the same age (probably last interglacial), lying at 5 meters. The difference in the altitudes of the two deposits could be explained by a neotectonic effect, as all the cliffs that enclose Sampaio's beach are structurally controlled.

Over the 5 meters marine deposit we find a complex würmian sequence, with two solifluxive deposits and an aeolian deposit between them.

The association of this geomorphological features with a very rare archaeological site makes us emphasise the need of protecting this place.

It is a very demanded beach, so, its protection must be done with the help of the concerned people. We are co-operating with Vila do Conde City Council for the preservation of this area and for environmental education of their students.

KEYWORDS

Littoral platform; marginal relief; wave cut notch; wave cut platform; neotectonics, marine deposits; aeolian deposits; solifluxive deposits; "*castro*"; environmental education.

INTRODUCTION

The littoral strip of Portugal is generally made up of a platform, going from the sea level till about 200 meters high. This platform is bordered from the inland by a relief, which was formerly described as a fossil cliff. Nowadays, however, this relief is supposed to be a fault scarp, which has functioned, probably after the deposition of the oldest deposits of this platform (O. Ribeiro; H. Lautensach; S. Daveau, 1987).

Between Rio (= river) Minho, at the Spanish border, and Espinho (15km South of Porto) the portuguese coastline is carved into a granite-metamorphic basement, the Iberian Hercinyan massif. To the South of Espinho this basement is buried under Pleistocene and Holocene deposits that announces the portuguese Meso-Cenozoic western border (Lusitanian basin).

Inside this northern coast of Portugal there is a prevalence of sandy beaches overlaying the Hercynian bedrock. Sometimes these sands are eroded and bedrock appears. Other times there are some rock outcrops advancing onto the sea and forming low cliffs, never higher than 20 meters. These low cliffs are relatively frequent near Porto. North of Rio Ave they disappear and reappear to the North of Rio Lima (Montedor).

Characterisation of littoral platform from Porto region

The most outstanding aspect of the littoral platform from Porto region, in the geomorphological point of view, is the opposition between the littoral platform, where there are many outcrops of cenozoic deposits, and the "marginal relief" (figure 1) which is bordering it from inland.

The main difficulty to establish the correlation of littoral platform deposits lies in the lack of chronological data from the sediments. This is particularly annoying in an area that is undergoing recent tectonic movements. To solve this difficulty, we made a sedimentological approach mainly based on grain size, morphoscopy, clay mineral and bedrock weathering.

There are three main kinds of cenozoic sediments in this area.

1 - Fluvial deposits (higher than 40 meters)

Almost all the deposits of this littoral platform were described as "raised beaches". However, we find out that the older and higher deposits have a fluvial nature. In some places we find rather angular pebble deposits. In other places we can find very poorly calibrated alluvial fans. These deposits are similar to the *rañas* of the interior of the Iberian Peninsula.

Besides its stratification, calibration and pebble shape, the mean roundness of sand grains and its surface analysis has been an important distinctive criterion between fluvial and marine deposits. The mean roundness was established according to Shepard and Powers (see G. S. Carvalho, 1966). We analysed at a binocular microscope about 50 grains for each sample. Each grain was compared with Powers chart (1966) and its apparent roundness and surface texture was registered. Surface texture was very helpful in the deposit's diagnosis. We found out that marine grains were sometimes brilliant or pitted-brilliant. Fluvial ones were mainly dull or splintery.

Theoretically the value of mean roundness can vary between 0,1 (very angular) and 0,85 (very well rounded).

As the knowledge of about 300 samples was improving morphoscopic analysis proved to be one of the best ways to understand the nature of the different sediments and to classify them.

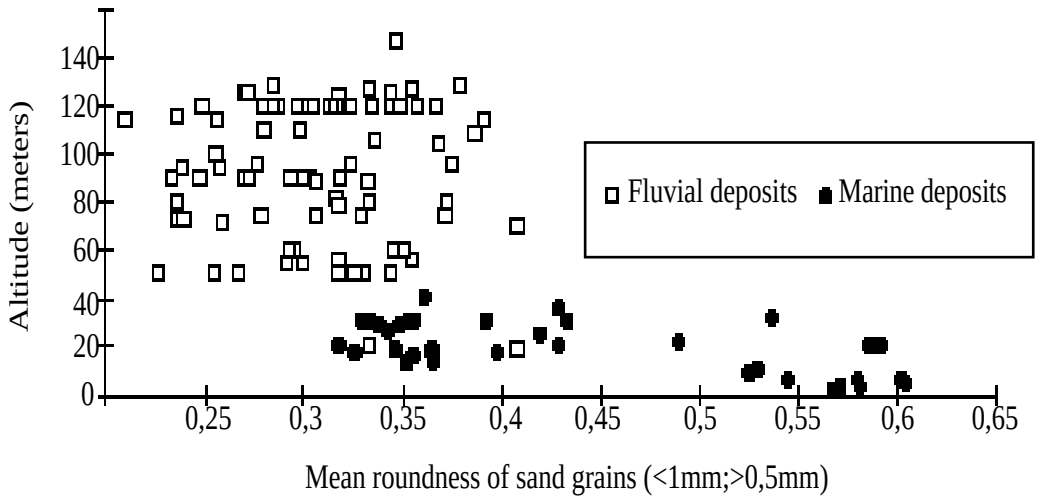

Figure 2: Relationships between altitude and mean roundness of sand grains.

At figure 2 we can see a sharp difference between mean roundness of the higher, fluvial deposits and the lower marine ones. This evidences lead us to think that there was a real opposition of processes between the higher deposits and the lower ones.

The older, fluvial deposits lay in a complex sequence, which is rather difficult to identify and correlate, because they appear in many small patches, and they are recent tectonics affected.
The older ones are fine, micaceous sands, with more than 90% of well-crystallised caulinite in the matrix. Probably, these deposits were created in a low energy (littoral?) plain, certainly before the tectonic uplift of the marginal relief. Lying over these micaceous sands there are very coarse deposits, probably to be correlated with the *rañas*[1]. So, conditions must have radically changed.

None of these deposits has been dated yet, however, some of them are probably older than Vilafranquian (Miocene? Pliocene?), because of their relationship with those coarse or badly calibrated deposits that could be related to Vilafranquian *rañas*.

2 - Marine deposits (below 40 meters)

We have recognised three marine levels, lying beneath 40 meters. The distinction between them lies in their sedimentological nature, mainly in colour, bedrock weathering, clay mineral analysis and degree of consolidation. We called them as level I, the higher and older one (between 40 and 30 meters high), level II (from 35 to 15meters), and level III (from 16 meters to 0 meters or even below mean sea level). Within a certain area these three levels are staggered. However, the altitude of each one can vary from one place to another. The altitudes we referred show that altimetry was not the only criterion we used.

At figure 3, we find a sharp difference between them on fine (< 62µ) fraction mineralogy. Kaolinite is dominant in level I, but its frequency goes down very rapidly. At level III, kaolinite is almost residual. Illite becomes dominant at level II. At level III quartz is clearly dominant.

So, mineral composition of fine fraction seems to give some verisimilitude to our classification of marine deposits.

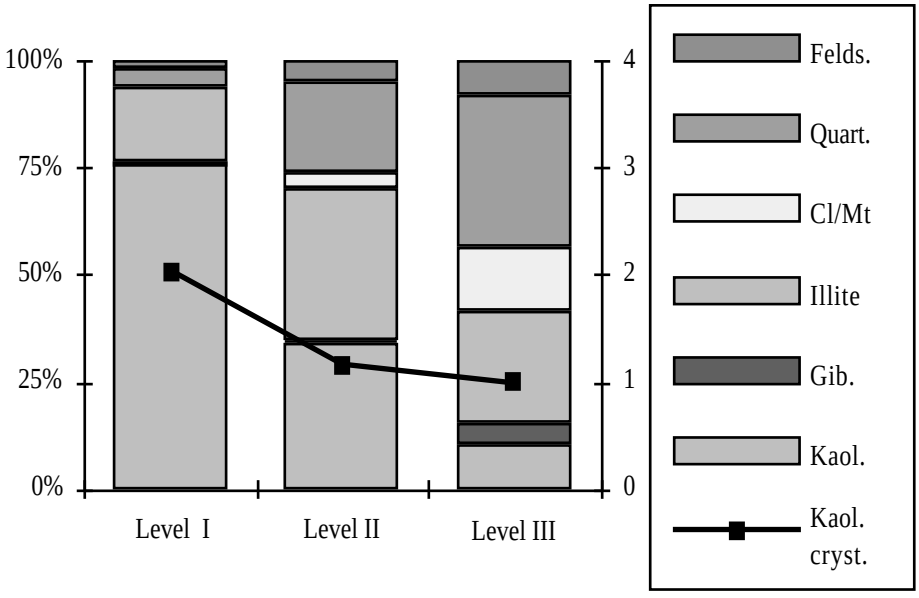

Figure 3: Mineralogy of fine fraction (mean values for each marine level) and kaolinite crystalinity (4=very good crystalinity; 3=good cryst.; 2=mean cryst.; 1=bad cryst.)

This is confirmed by morphoscopic analysis results (figure 4). Average mean roundness (MR) increases rapidly from the higher levels to the lower and newer ones. Besides that, there is a clear difference between

surface texture of level I and level II deposits. These deposits are rather different from level III deposits that contain a great frequency of pitted-brilliant grains.

As we wrote before, the altitudes of different levels of marine deposits vary from place to place. At figure 5 we have plotted each level altitude against its distance from Rio Ave's mouth. We find out that there is a general trend of sinking to the South. However, it is not a regular one. It seems that the interference of different tectonic orientations produced an irregular pattern, going up and down.

At the North of Espinho, in the area of Iberian Hercynian massif, we found several bedrock outcrops within the coastal zone, emerging from beach sands. These bedrock outcrops are generally remains of ancient marine platforms bearing disappeared fossil marine deposits, belonging, mainly to level III.

We have plotted their altitudes against distance from Rio Ave's mouth (figure 6). At this figure we got the same idea of a general tilting to the South, with many irregularities that we interpreted as the interferences of several tectonic orientations (parallel and oblique or perpendicular to coast-line, figure 7).

We can correlate the higher position of last interglacial sea level with the rare cliffs that exist in this generally low coast. We believe that this correlation proves the importance of neotectonics in relief configuration.

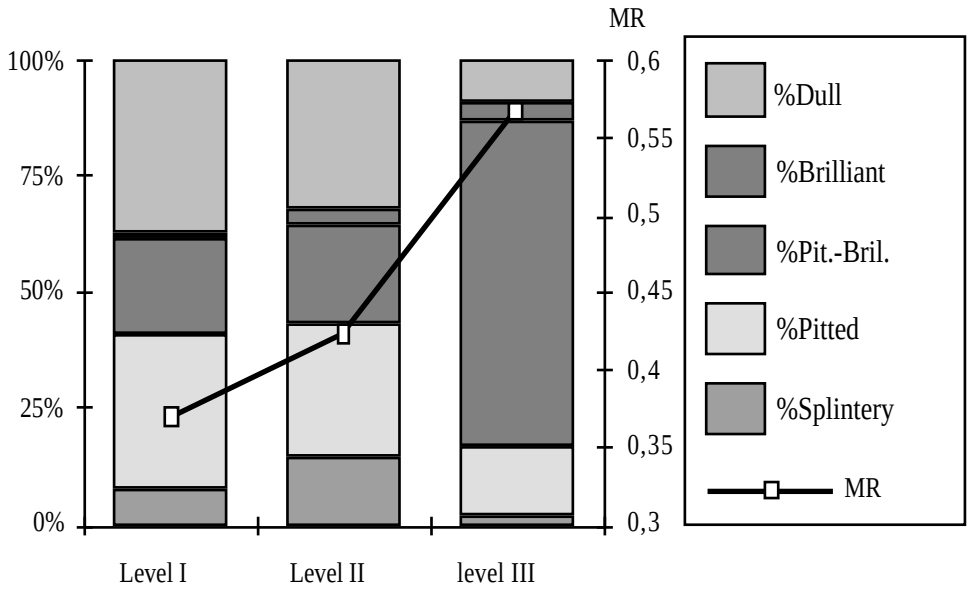

Figure 4: Surface textures and mean roundness of sand grains (=MR) for each marine level
(average values)

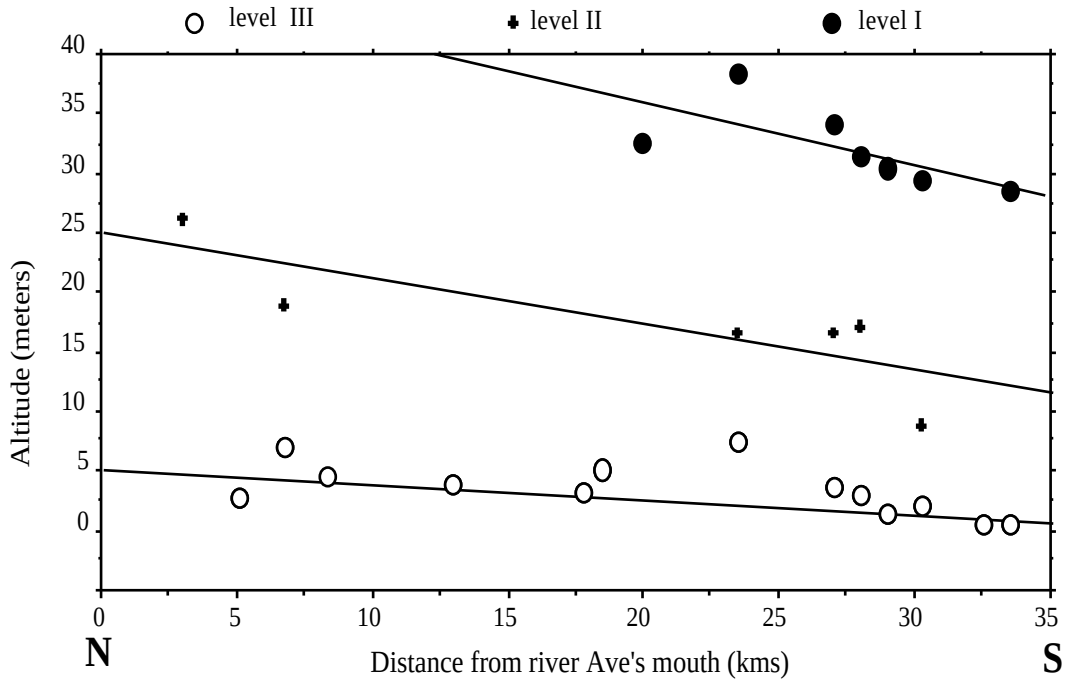

Figure 5: Mean altitudes of ancient marine levels between Rio Ave's mouth and Espinho

Besides the sharp contrast between fluvial and marine deposits there is a step between them that must have a tectonic origin. It means that, during Quaternary the western part of littoral platform must have subsided along a NNW/SSE fault (parallel to Porto-Tomar fault), which allowed marine erosion and sedimentation to take place in the depressed block.

3 - Solifluxive, aeolian and lagoon deposits (late Pleistocene and Holocene)

We studied the solifluxive and aeolian deposits linked with the last cold period, as well as some podzolic soils and lagoon formations existing some miles South of Espinho, to draw a picture of the climatic and eustatic variations after last interglacial times.

We found a clear difference between the area North of Espinho and the area to the South of this town.

At the North of Espinho we found solifluxive deposits inter stratified with aeolian ones. We think that wet cold and dry cold climate alternations during Würm caused this situation. The younger aeolian deposit belongs to Holocene.

To the South of Espinho the aeolian processes are still working in a rather intense way. The persistence of aeolian sedimentation can be explained by the general trend for subsidence of this area (figures 5 and 6). The reason for this subsidence might be its location in the northern part of Western Meso-Cenozoic basin of Portugal.

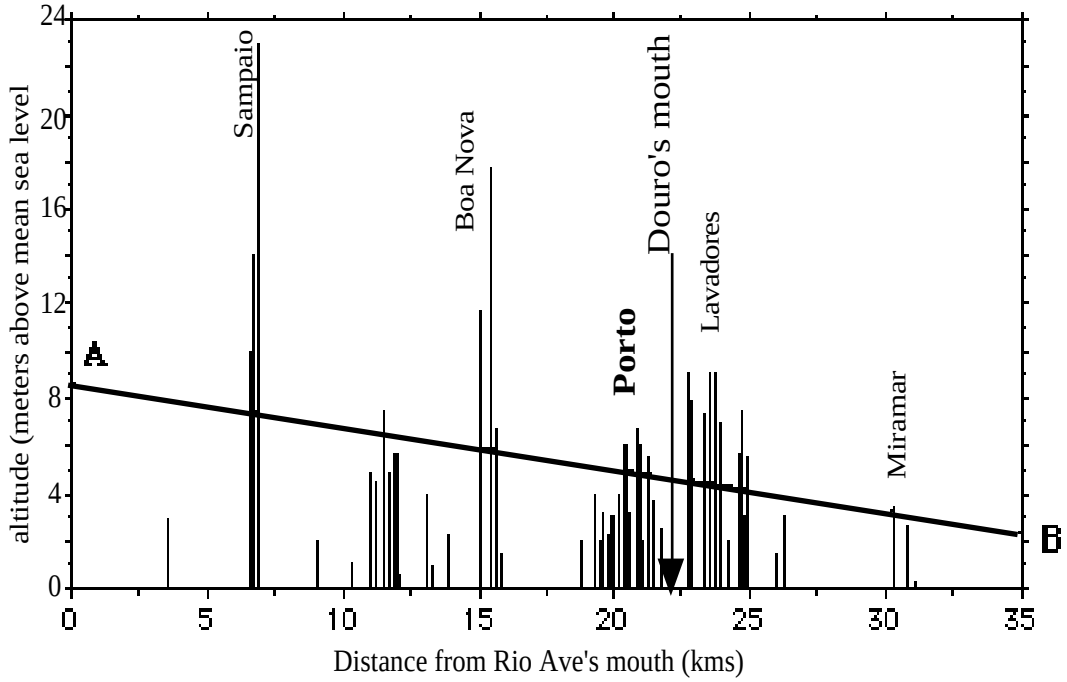

Fig. 6: The altitude of bedrock outcrops within the beaches from Porto region and its regression straight (A-B)

The area between Rio Ave and Rio Leça

The general ideas we explained about littoral platform of Porto region need a further discussion because there is a difference between what we can see from Rio Leça to the North or to the South.

At figure 1 we can see that marginal relief is much more straight at the South of Porto. There are almost no fluvial deposits to the North of Rio Leça. Besides that, we never found any deposit similar to level I deposits that appear to the South of Rio Leça (see figure 5).

Porto-Tomar fault stays inland at the South of Porto, and, probably, this explains the strength of marginal relief (figure 1). To the North, this fault reaches the littoral. So, we may expect an important fault zone there, which will come at least till Boa Nova beach latitude.

Figure 7 shows the topography to the North of Boa Nova beach. We can see that, in this area, marginal relief is much less visible than to the South. Besides that, the beginning of marginal relief stays at an altitude of about 75 m to the North of Rio Donda. It was about 120 meters high to the South of Rio Douro.

Rio Donda dissymmetrical valley, which interfluves stays at 50 m in the left margin and at 30 m in the right one, seems to mark the contact between two different areas. The relative elevation of the area between Rio Donda and Rio Leça could explain a clear tendency for deposits to disappear (neither fluvial nor marine deposits can be find in this area). Between Rio Donda and Rio Ave, a relative depression could explain the conservation of some fluvial (Gião, Fajozes) or marine (Mindelo) deposits. At figure 7 we can see that fluvial valleys are structurally controlled. This could be explained because rivers follow structural zones of failure.

However, when we see a different geomorphological behaviour between these areas, and the separation between different areas seems to coincide with the most important fluvial valleys, we can assume that there must be some tectonic movement (tilting or faulting) to control these geomorphological features.

The existence of different blocks defined by river valleys in the North of Portugal has been discussed since C. Teixeira (1944). It is still referred in some recent studies (A. B. Ferreira, 1991).

We have studied the fractures in the bedrock outcrops which emerge from beach sands. We have plot these directions (figure 7). We found out that the two tardy-hercynian fault systems were present everywhere (from NW to NNW and from NNE to ENE). However, there are some differences among the beaches we have studied. At Labruge and Cabo do Mundo beaches there is a clear component of N-S direction. Boa Nova and Marreco beaches show a clear dominance of NNE-SSW direction. This direction seems to control much of the detail development of coast line in this area, even when the coast as a general orientation of NNW-SSE.

The different approach speed between Eurasian and African plate in the continental domain and in the oceanic one, after the achievement of the collision at Gibraltar's level, leads to the existence of a tension regime of NNE-SSW direction (A. Ribeiro, 1984). This happened in the west coast of Iberia, after Miocene, and it could explain the importance of this NNE-SSW direction in all the beaches we have studied.

Sampaio's area geomorphological interest

Sampaio area is a small pocket beach, about 15 km north of Porto (figure 8). There we find granite cliffs, controlled by fractures mainly of NNE-SSW direction. It is the last cliff area when we are travelling from Espinho to the North and the highest point exceeds 20 meters high.

We found two spots of a great geomorphological interest in this area:

- **A** - A wave cut notch (figure 9), hanging 9 meters above sea level. Nearby there is a consolidated beach deposit (D, figure 10).

The wave cut notch and the little bench that lies beneath it indicates a higher sea level. The marine deposit demonstrates it too. We never found such a didactic spot, with geomorphological and sedimentological testimonies of an ancient sea level together in the same place.

- **B** - Some 450m to the North we found:

1 - another marine deposit (figure 11), probably from the last interglacial period, lying 5 meters above mean sea level. This deposit is covered by a complex sequence:

2 - a solifluxive deposit were we lately found little pieces of coal which are going to be dated by C14;

3 - an aeolian consolidated deposit;

4 - another solifluxive deposit (similar to the "areno-pelitic formation" over spread in the North of Portugal).

This sequence demonstrates that, after the last interglacial, during Würm times (probably about 45.000 BP, M. A. Araújo, 1992), there has been a cold-wet period (first solifluxive deposit).

Afterwards the climate must have been dryer, with dune formation (deposit nº 3). The very well rounded sand grains may prove that there has been a type of littoral desert, with an intense aeolisation. The late solifluxive deposit has no coal to allow a datation. It could be related to a wet period, perhaps to the end of Würm, just as the grey-greenish silty sands we found at Cortegaça and Maceda (South of Espinho) and which were dated about 13800 BP (M. A. Araújo, 1992).

It is the only place where we can find such a complex sequence that resumes the partial sequences we found near Lavadores (South of Porto, M. A. Araújo, 1992).

The altitude at which the two marine deposits are lying is rather different:

- 9 meters at the fossil wave cut notch (A);

- 5 meters at the base of B sequence.

This has lead us to suppose that some vertical movements are taking place in this area. Probably, the cliffs that close Sampaio beach are undergoing a recent uplift. This uplift could be concentrated in some fracture zones with neotectonic movement. This could explain the strong relationship between cliff development and structural orientations (figure 12).

In figure 8 we plotted the directions of 160 fractures[2]. There is a close relationship between this fracture diagram and the orientation of the cliffs we can see in the map. NNE-SSW to NE-SW directions are clearly dominant, as it happened in some of the beaches of figure 7. This pattern could be produced by Quaternary reactivating of tardy-hercinyan faults, related to the development of a NNE-SSW tension in the western Iberian coast.

Because it is one of the highest littoral places in the northern Portuguese coast and marine deposits of the last interglacial stays at a rather high level, we think that it might demonstrate that there is a correlation between high late interglacial deposits, vertical uplift and relatively high coastlines, as the figure 6 seems to indicate.

Sampaio beach offers another great point of interest, because there is a "castro" near the place of the Chapel (C)[3]. The castro of Sampaio began to be excavated recently.

It is very interesting for archaeologists because castros are generally shepard settlements located at high places, but this is the only one in northern Portugal to be facing the sea.

So, we think that this area has a strong scientific interest, for different specialists. As these geomorphological and archaeological features allow the discussion of several problems concerning Quaternary studies, it could awake the interest of students of secondary and university level, and sensitise them for environmental and cultural conservation.

It is a very beautiful beach, not very windy. So, it is very demanded every Summer and in the week-ends. This can be rather dangerous because super occupation could destroy those geomorphological and archaeological remains. We think that it is urgent to do something to preserve them. So, we are co-operating with Vila do Conde city council to inform the students and to improve their environmental education.

We are trying to develop, among those students, the idea that the archaeological, geological and geomorphological inheritances must be respected and that the people should know that all these assets can never be replaced if they are destroyed.

CONCLUSIONS

As a conclusion, we think that scientists should never forget their responsibilities towards the society.

We must explain our studies in a way everybody can understand. There is always an easy and clear (not oversimplified) way of telling scientific discoveries.

In this society with so much information that none can assimilate it all, the way specialists tell things is very important to ensure its understanding by concerned people. We think that it is better to be understood by many non specialists that have some power to change the way things are done in the environment, than to explain highly complicated ideas to high specialised scientists. This is, perhaps, the only way to overcome simplistic and erroneous ideas about environmental problems, which won't do any benefit for our goals, but work for the misunderstanding and the refusal of environmentalists' ideas.

We think that we must take profit of the general interest that young people have for environmental problems and educate the students in the respect for nature and human culture.

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NOTES

[1] *Rañas* are very coarse and poorly calibrated alluvial fans, probably from Vilafranquian times, linked with an arid climate and/or tectonic movements. They appear around Toledo and in several places in Portugal.

[2] Only sharp fractures of more than 1 meter were count. Each one was indexed by its length. A 2 meters fracture would be count as two fractures... and so on. The directions were grouped in classes separated by 10° of azimuth. The first class, plotted as direction "N" began at 356° and goes till 5°.

[3] "Castros" are fortified settlements, sometimes older sometimes contemporaneous of the romanisation of the Peninsula.