

Marine platforms from Oporto area (NW Portugal): tectonics versus eustasy

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Abstract: The lower deposits of the littoral platform from Oporto region have a marine origin. There are 3 marine levels. The newer one must be from last interglacial. They appear to be deformed, as they occur at higher altitudes in the North of the studied area, and at lower ones in the South. The apparent tilting from north to south doesn't seem to have a regular pattern. There must be an interference of different fracture sets cutting the littoral platform into a puzzle of small blocks. The existence of sharp straight cliffs bordering raised erosion platforms points out to a deformation of last interglacial platforms.

INTRODUCTION

The Northwest corner of Iberian Peninsula is made up of old rocks of hercynian age (mainly granites, slates and other metamorphic rocks).

The Galician coastline is typically indented and characterised by its "Rias". However, at the south of Bayona a straight coastline replaces the Galician coastline and a planed surface, bordering the coastline, the "littoral platform", makes its appearance.

Since C. Teixeira (1944) the difference between northern Portuguese straight coast and Galician deeply indented coastline has been understood as an evidence for the subsidence of Galician area, leading to a typical "submersion coast".

However, H. Nonn (1966) and many Spanish researchers arrived to a different conclusion: the rias must be old, tertiary depressions, from several origins (tectonic, quimical weathering, fluvial or a combination of them).

The littoral platform is a planned area that goes till 120 meters high at Oporto area, and can be followed almost over all Portuguese coast. This platform is separated from the inland by a step which follows quite well Porto-Tomar fault and it is covered by several outcrops of cenozoic deposits.

MARINE VERSUS FLUVIAL DEPOSITS

The higher deposits have a fluvial origin, but the lower ones have a marine origin (M. A. ARAÚJO, 1991). At the upper, fluvial deposits, we found evidences of tectonic movements: mainly inverse faults affecting deposits probably from the boundary Tertiary-Quaternary (M. A. ARAÚJO, 1997-a, 1997-b).

Between the fluvial and marine deposits there is a quite straight step, about 30m high. It suggests that, during Quaternary the western part of littoral platform must have subsided along a sub-meridian fault. This process allowed marine erosion and sedimentation to take place in the depressed block. So, we believe that this step is primarily a fault scarp that was transformed, afterwards, into a fossil cliff. that is correlative of the higher marine level.

The study of sedimentological characteristics of the marine deposits allowed us to consider 3 marine levels. The distinction between them lies in their sedimentological nature, mainly in colour, bedrock weathering, clay mineral analysis and degree of consolidation. As we are in an uplifting area, the higher ones are also the older ones.

- Level I, the higher and older one (between 40 and 30 meters high), rather thick deposits, upon reddish bedrock;
- Level II (from 35 to 15 meters), at an intermediate position. Intense weathering of bed-rock, but not of a reddish colour;
- Level III (from 10 meters to mean sea level). Normally those deposits are iron cemented. The bedrock has only an iron "pâtine".

Within a certain area these three levels are staggered. However, the altitude of each one can vary from one place to another.

The newer marine deposits, probably from the last interglacial, are rather well preserved, so it is possible to detect that they appear at rather different altitudes, sometimes in very short distances.

We have plotted each level altitude against its distance from Rio Ave's mouth (M. A. ARAÚJO, 1997-a, fig.4). 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, we found many bedrock outcrops within the coastal zone, emerging from beach sands. Most of the times these bedrock outcrops have planned surfaces that represents remains of ancient marine platforms that were covered, once, by disappeared marine deposits, belonging, mainly to level III.

We have plotted the altitudes of those planned surfaces against the distance from Rio Ave's mouth (M. A. ARAÚJO, 1997-a, fig.5).

At that figure we get the same idea of a general tilting to the South, with many irregularities. These irregularities prove the existence of fragile movements, cutting the previous marine platforms into a puzzle of small blocks, controlled by different fracture sets: some approximately parallel to the coastline (NNW-SSE) and others oblique to it (ENE-WSW or NNE-SSW).

We can correlate the higher position of last interglacial deposits with the rare cliffs that exists in this generally low coast.

When deposits are lower, they show themselves beneath the actual beaches, mostly when erosion is taking place, and the coastline has a lower character.

So, there seems to be a close relationship between the altitude of last interglacial marine platforms and coastline development. We believe that this correlation proves the importance of neotectonics in the building of present relief.

TECTONICS AND EUSTASY: SOME THEORETICAL ASSUMPTIONS

Before trying to understand the development of marine platforms and the incidence of neotectonics upon them we must analyse some morphological features related with those platforms.

Sunamura (1992) makes a typification of marine platforms. Accordingly to this author type A platforms (like the platforms that appear at Oporto area) are "gently sloping platforms without a significant topographic break, extending till the base of the cliff to the near shore sea floor below the low tide level". Although they appear between low tide level and high tide level, its altitude can be quite variable: they are lower in the exposed parts of the coast and higher inside the bays. The notches develop between high and low tide. They appear mostly at the place where waves break. So, there is a tendency for the notches to appear at high tide level, where the wave force is bigger, but its altitude can show some variations.

When there is a relative change in sea level, an ancient marine platform may become raised, above actual sea level. So, sea erosion begins to attack the outer part of that platform, carving into it to produce a lower one.

In the beginning of this erosion process, an advanced line of notches may appear at low tide level. If marine erosion has advanced a little more, the breaking of the waves can happen at a higher tide level and the notch should be at a higher altitude. The limit is, of course, the high spring tide level.

The evolution of marine platforms can reproduce, in a bigger scale, the evolution of a geomorphological surface. The actuation of tectonics or sea level changes upon a geomorphological surface may result in different consequences accordingly to the amplitude of base level variations (A. BRUM FERREIRA, 1992). We have made a kind of adaptation of this general model to the development of marine platforms. As in the previous model, the results of sea-land inter-action depend very much on the intensity of the relative sea-land displacements and also on structural and lithologic conditions.

1 - Sea-level variations and low intensity movements (epeirogenetic origin)

In this case, the inner part of the platform is no longer directly touched by the marine action. Its evolution should depend mainly upon the weathering. Only at the stronger storms the sea should touch it. So, its action is only related to an eventual cleaning of the surface from its weathering products (fig. 1-A).

Between this almost untouched surface and the lower part of it, constantly worked by the sea, a cliff begins to be carved, accentuating the separation between the two platforms.

This process should depend very much upon the resistance of the bedrock: this one will determine the velocity of evolution of the lower platform at the expenses of the uplifted older platform.

This is the case of the relationship between the recent marine surfaces that are embedded into older surfaces of last interglacial age (whatever the reason of this staircase development is eustatic, tectonic or both).

2 - Low intensity sea-level variations and medium intensity movements (epeirogenic origin)

In areas with some uplift it could be the situation of the earlier Holocene sea levels of about 5000 BP when, as it is commonly assumed, the sea level could have reached its post-glacial maximum (fig. 1-B). We can have a small bench between last interglacial marine surface (dated by its deposits) and the actual marine platform.

Sometimes the cliff between the two marine platforms vanishes and we have a polygenetic marine surface (figure 1 - B1), perhaps with a stepper gradient than we should expect and beginning above the high tide level. That can happen also at non uplifted areas where the Holocene sea level may be quite similar to the last interglacial one. In that case, recent marine platforms might be reusing ancient last interglacial platforms and widening them.

3 - Tectonic movements with fragile deformation.

Some times (M. A. ARAÚJO, 1997-a, fig. 4) the altitude of similar marine deposits has a strong variation from place to place. For instance, at Sampaio beach (Labruge, Vila do Conde, 20 km north of Oporto) we have a very impressive fossil notch, at an altitude of 9 m above MSL (mean sea level). Some 80m to the North, a very similar deposit, probably of the same age, have an altitude of 5 m above MSL (M. A. ARAÚJO, 1997-c).

The first one is hanged upon a very sharp cliff, which is, very probably, a fault scarp of NNE-SSW orientation. This orientation is very important all over the Sampaio beach area, as we can see at its large scale topographic map. We assume that this is a recently raised platform. Recent marine erosion had no time to build embedded platforms at these false, tectonic cliffs (figure 1-C). Only a very small notch is cutting the rigid wall where the last interglacial fossil notch is hanging.

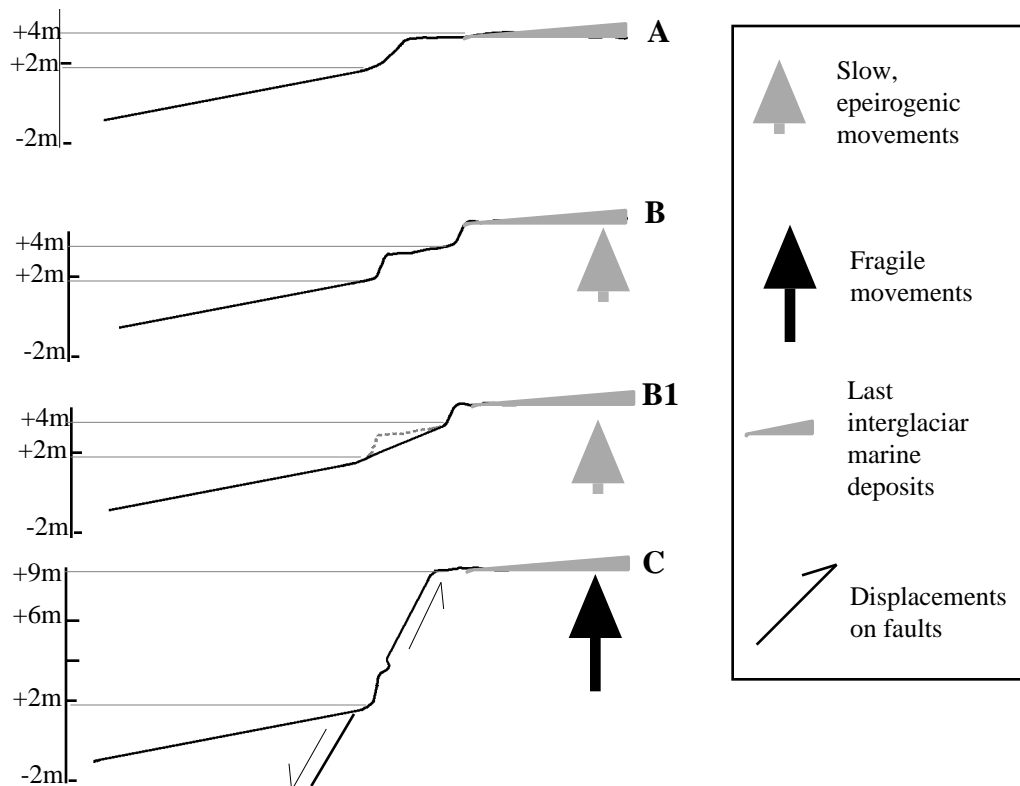


Figure 1: The relationship between different marine platforms (see text for explanation)

Figura 1: A relação entre diferentes plataformas marinhas (ver explicação no texto)

SOME CONCLUSIONS

We can point out the possibility of the existence, inside the actual beach area, of several different platforms:

- 1 - Recent marine platform (from low tide to high tide level).
- 2 - Higher holocene platform, somehow rose above high tide level (often a tiny sketch only available in areas where there is some uplift).
- 3 - Last interglacial platform: can occur from high tide level till about 9-10 m above MSL. In some places it seems to be disturbed by neotectonics. In that case the boundaries between different outcrops of the same platform are clearly structural features.

Obviously, the existence of these three levels makes the study of the littoral rock platforms rather hazardous and uncertain.

However, its identification remains an important target because it is impossible to understand relative land-sea movements without fully understanding the morphological development of marine platforms.

The deposits lying above the platforms are the best distinctive features to identify those platforms. However, we are dealing with tiny deposits lying near sea level. So, even when they are iron cemented, they could be easily destroyed by sea erosion, mainly if they didn't suffer a clear uplift that could put them outside the reach of the sea. That's why some of the best-preserved deposits appear at places where some tectonic uplifting seems to be taking place.

However, even when the deposits are preserved we can't be sure about their age, unless you are able to perform reliable datations. However, this is a difficult task to accomplish with this deposits that have no carbonates.

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