

IV International Symposium ProGEO on the
Conservation of the Geological Heritage

Jurassic Heritage and Geoconservation in Portugal: Selected Sites

Field Trip Guide Book



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The Jurassic of the Peniche Peninsula (Central Portugal): an international reference point of great scientific value and educational interest

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Abstract: The Peniche Peninsula represents the most important section for the study of Lower Jurassic sediments in Portugal and provides a record of around 20 million years of Portuguese geological history before the opening phase of the Atlantic Ocean. Dominated by a beautiful and unique Atlantic Ocean landscape, the international scientific relevance of this section was recognised recently by the International Subcommission on Jurassic Stratigraphy, which proposed Peniche as a Toarcian Global Stratigraphic Section and Point. In addition to the natural landscape and scientific interest of the site, Peniche also constitutes an important area for education and training in the various fields of sedimentary geology, such as palaeontology, stratigraphy, sedimentology and geomorphology. Within the context of the geology of Portugal, these features confirm the value of the geological heritage of this outcrop. The aim of this work is to present several geological aspects of the heritage value of the outcrop, emphasizing the zoom effect from international to regional or local importance. The relevance of the geological heritage of the Lower Jurassic of Peniche is therefore argued here in terms of its scientific and educational significance.

Keywords: Geological Heritage; Sedimentary Geology; Lower Jurassic; Peniche; Portugal.

Introduction

The Lusitanian Basin, located in the West Iberia margin, reveals several outcrops of major importance in the study and understanding of the Portuguese Lower Jurassic (Duarte & Soares, 2002; Azerêdo et al., 2003; Duarte, 2004; Duarte et al., 2004). Amongst several important and internationally-recognised sectors such as Rabaçal, S. Pedro de Moel or Porto de Mós (Duarte, 2003a,b, 2004; Duarte, 2005), the most representa-

tive succession, which is of great geological value (Duarte, 2004; Henriques, 2004), can be observed along the cliffs of the Peniche Peninsula (Cabo Carvoeiro) (Fig. 1, plate 3). The recent proposal by the International Sub-commission on Jurassic Stratigraphy, included in the International Commission on Stratigraphy, to nominate Peniche as a Toarcian Global Stratigraphic Section and Point (Elmi, 2002; Elmi *in* Duarte et al., 2004; Elmi et al., 2005) proves the international significance of this section, in addition to its nomination as a Geosite (according to the GEOSITES project; (Wimbledon, 1996). In fact, the Peniche outcrop encompasses four features that confirm its importance as an internationally and nationally significant geological heritage: (1) It is a beautiful place, with a landscape dominated by the Atlantic coast and karstic morphologies; (2) its various geological features are of great scientific value and international interest; (3) the large number of geological training sessions and public visits to this geosite in recent years confirm the importance of the Lower Jurassic section of Peniche in terms of educational activities; (4) within a perimeter of approximately 10 km, the Peniche Peninsula records almost all the Lower Jurassic (with the exception of the Hettangian), including some singular geological and geomorphological phenomena.

The scientific relevance of the Peniche outcrop

The Lower Jurassic deposits in the Lusitanian Basin are normally well exposed and dominated by carbonate sediments. In Peniche, the Cabo Carvoeiro Lower Jurassic section consists of a thick succession, more than 450m thick. It ranges in age from the early Sinemurian, consisting of dolomitic limestones and limestones, to the early Middle Jurassic (Aalenian?), composed of oolites/sparites/grainstones. These sediments are divided into five formations (Fig. 2, plate 3).

The Peniche Lower Jurassic series has always been scientifically important, ever since the first published papers in the nineteenth century (Choffat, 1880), up to its more recent nomination as a Toarcian GSSP (Elmi, 2002; Elmi *in* Duarte et al., 2004; Elmi et al., 2005). The quality of the Peniche outcrop, which is well exposed and displays continuity in its

vertical facies, and the extensive present-day knowledge has enabled the type-section of three lithostratigraphic units to be defined for the early Pliensbachian-late Toarcian Lusitanian Basin (Duarte & Soares, 2002). The large number of international publications dealing with its palaeontology, stratigraphy and sedimentology (Dommergues et al., 1981; Wright & Wilson, 1984; Guery, 1985; Phelps 1985; Dommergues, 1987; Rocha et al., 1987; Elmi et al., 1988, 1996; Almeras, 1994; Duarte, 1995, 1997, 1998; Fernandez-Lopez et al., 1999, 2000; Duarte et al., 2004, among others), testify to the great scientific interest and impact of this section. Two of the most important international scientific meetings in the field of sedimentary geology hosted by Portugal, namely the 2nd International Symposium on Jurassic Stratigraphy and the 23rd International Association of Sedimentologists Meeting (Coimbra, 2004), included specialist field trips to Peniche (Rocha et al., 1987; Duarte et al., 2004) (Fig. 3, plate 3).

The geological heritage

1. International relevance

The Pliensbachian–Toarcian transition is well exposed at Ponta do Trovão (Fig. 1, plate 3), yielding Tethyan ammonites associated with some NW European classic species (Elmi *in* Duarte et al., 2004). These are assemblages that constitute good markers for world-wide correlations and for this reason the section was proposed as an important reference in establishing the Toarcian Global Boundary Stratotype Section and Point (Elmi et al., 1996, 2005; Elmi, 2002). This proposal has involved intense scientific research over the past year, mainly chemostratigraphic (Oliveira et al., 2005a, b) and related to some microfossil groups such as calcareous nannofossils (Oliveira et al., 2005b) and ostracod studies. Independently of the International Commission on Stratigraphy resolution, however, Peniche will always be an international reference point for Early Jurassic studies. This fact may justify the nomination of the area as a Geosite (Duarte, 2004), following the recommendations of the Geosites Project, supervised by the IUGS Global Geosites Working Group (Wimbledon, 1996).

2. Educational activities in the field of sedimentary geology

In addition to the international scientific value of the Peniche cliffs, there are other important aspects, namely those of an educational (didactic-pedagogical) and geo-touristic nature, which are of local or regional relevance. As previously stated, this section displays crucial data for the study of the Lusitanian Basin Lower Jurassic carbonate succession. Moreover, as the outcrop is in good condition, different types of educational activities related to sedimentary geology can be carried out there, taking advantage of the extensive scientific knowledge available. Many of these activities have already taken place, ranging from undergraduate geology training sessions to scientific activities aimed at the general public (Duarte, 2003, 2004). The section is frequently studied and visited by senior research groups, geology undergraduates, secondary school teachers (on training sessions) and students, whose interest highlights the huge didactic and pedagogical potential of this region. Its cultural potential is also quite high, due to intense public interest (Fig. 4, plate 3), especially through the “Geology in the summer” programme sponsored by the Portuguese Ministry of Science and Technology (Fig. 5, plate 3).

Regardless of the type of interest, some geological features are unique in terms of Portuguese geology and the educational potential of this outcrop will therefore be analysed in terms of the various fields of sedimentary geology (palaeontology, stratigraphy and sedimentology), and, consequently, in terms of Earth history.

Palaeontology

In Portugal, the Cabo Carvoeiro section is known for its palaeontological wealth and diversity. The fossils used as time or facies indicators are easily accessible for all possible educational activities. The relative dating of the series by index fossils (ammonites) is a good initial exercise, involving the comparison of specimens from different families. In fact, the rich ammonite assemblages recorded along the section, from the uppermost Sinemurian Echioceratids to the middle Toarcian Hildoceratids, allow

for a good time control of the series (Mouterde, 1955; Dommergues et al., 1981; Phelps, 1985; Dommergues, 1987; Elmi et al., 1996) and some interesting biostratigraphic pedagogical exercises.

The section displays a large vertical variation of invertebrate marine macrofossils and ichnofossils. The former consists of molluscs (in addition to ammonites, there are also belemnites, bivalves and gastropods), brachiopods (terebratulids, rhynchonellids and spiriferinids), echinoderms (crinoids and echinoids) and corals. In terms of heritage and geoconservation, the following singular fossil record is particularly relevant (Fig. 2, plate 3): (1) the benthic fauna (*Pholadomya* and *Gryphaea*) association in the *raricostatum* Zone; (2) an unusual concentration of belemnites in the uppermost Pliensbachian (Fig. 6, plate 3; *spinatum* Zone); (3) the tiny brachiopod (*Koninchella* fauna) and pyritous ammonite (Dactylioceratids) association in the *polymorphum* Zone; (4) an unusual concentration of crinoid ossicles in the Upper Toarcian deposits (Fig. 7, plate 3).

Apart from this systematic exercise in classification, the fossil record also constitutes an important tool in the understanding of the evolution of the depositional environment. The application of the Principle of Uniformitarianism, based on the fossil record, is normally of great interest to the general public.

Stratigraphy and Sedimentology

As described above, this outcrop displays the most complete Early Jurassic succession in Portugal, revealing five formations: Coimbra, Água de Madeiros, Vale das Fontes, Lemedé and Cabo Carvoeiro (Fig. 2, plate 3). Due to their good exposure and biostratigraphic data (Mouterde, 1955; Phelps, 1985; Dommergues, 1987; Elmi et al., 1996), three of them (Vale das Fontes, Lemedé and Cabo Carvoeiro) show in this section its type-locality (Duarte & Soares, 2002).

The marked vertical changes of facies (lithofacies, biofacies and ichnofacies) and the major sedimentary structures observed throughout the succession makes this outcrop an interesting natural laboratory in

terms of practical work in carbonate sedimentology. Shallow – and deep-water carbonate facies may be seen along the whole section, including intra-oosparites/grainstones, hemipelagites, lumpy marls and limestones, black shales or turbidites. The evolution of sedimentary facies observed in this section shows successive environmental changes between shallow-water carbonates (early Sinemurian), distal homoclinal carbonate ramp facies (lowermost Pliensbachian to lowermost Toarcian) and outer to middle submarine fan deposits (Wright & Wilson, 1984; Guery, 1985; Duarte, 1997, 1998; Duarte & Soares, 2002; Duarte et al., 2004). In this area, the Toarcian series of Peniche is very specific in comparison to other points of the basin normally composed of marl-limestone alternations (Duarte, 1997). In fact, this singular point in the Toarcian palaeogeography of the Lusitanian Basin includes siliciclastics (mainly quartz and feldspar) and resedimented shallow-water limestones (peloidal-oolitic grainstones).

This succession, interpreted by Wright & Wilson (1984) as the result of regressive submarine fan evolution, represents a highly intuitive depositional model for any educational activity. The carbonate facies correspond to allodapic sediments fed from the uplifted Hercynian block of Berlenga, an island which today lies to the northwest of Peniche (Wright & Wilson, 1984; Duarte 1995, 1997) (Fig. 8, plate 3).

The Toarcian outcrop of Peniche is also an open book in terms of sedimentary structures, from pre-depositional to biogenic (ichnofossils): fining- and coarsening-upward, groove casts, load casts, ripple marks, planar cross stratification, channels, amalgamated beds, perforations, ferruginous surfaces, *Chondrites*, *Planolites*, *Zoophycos* and *Skolithos*.

In terms of the whole Lusitanian Basin, Peniche also represents an area where it is possible to see and recognize the main sedimentary discontinuities (second and third- order sequence boundaries) observed between the Sinemurian and the Toarcian (Wright & Wilson, 1984; Guery, 1985; Duarte, 1997, 1998; Duarte et al., 2004). In addition, the evolution of deposits can be always complemented by other sedimentological parameters such as microfacies, clay and some geochemical minerals (Duarte, 1995, 1997, 1998).

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Plate 3

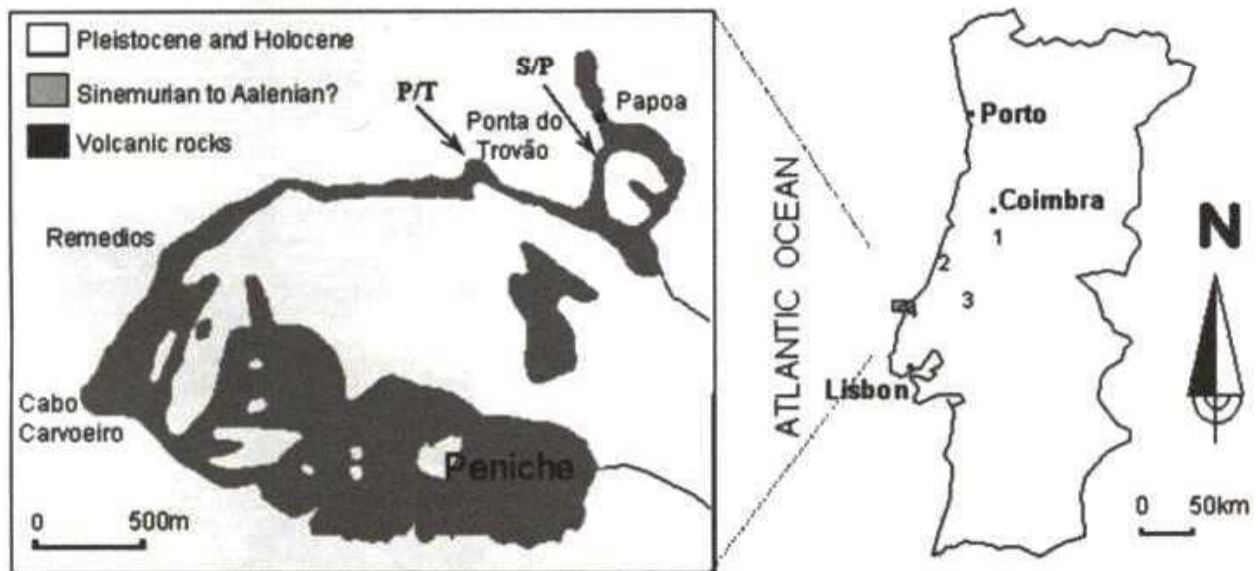


Fig. 1 – Location and simplified geological map of the Peniche Peninsula (S/P, Sinemurian-Pliensbachian boundary; P/T, Pliensbachian/Toarcian boundary).
1. Rabaçal; 2. S. Pedro de Moel; 3. Porto de Mós.

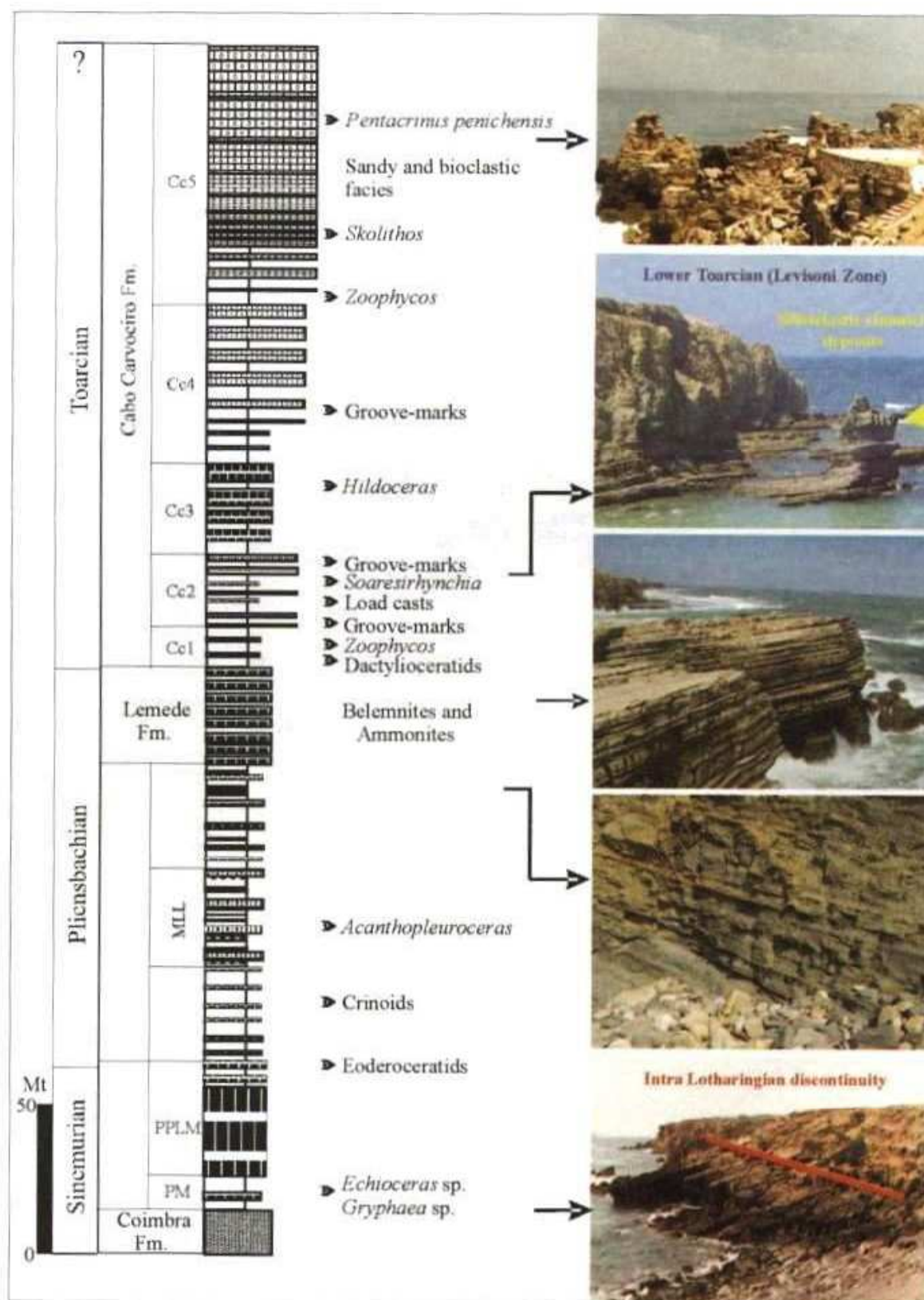


Fig. 2 – Upper Sinemurian – upper Aalenian (?) succession at Peniche: Lithostratigraphy (in Duarte et al., 2004), main sedimentary events and some outcrop features.



Fig. 3 – Middle Toarcian calciturbidites of Cabo Carvoeiro (Peniche) observed during the 23rd IAS Meeting field-trip "Early Jurassic carbonate evolution in the Lusitanian Basin (Portugal): facies, sequence stratigraphy and cyclicity" (September 19th, 2004).

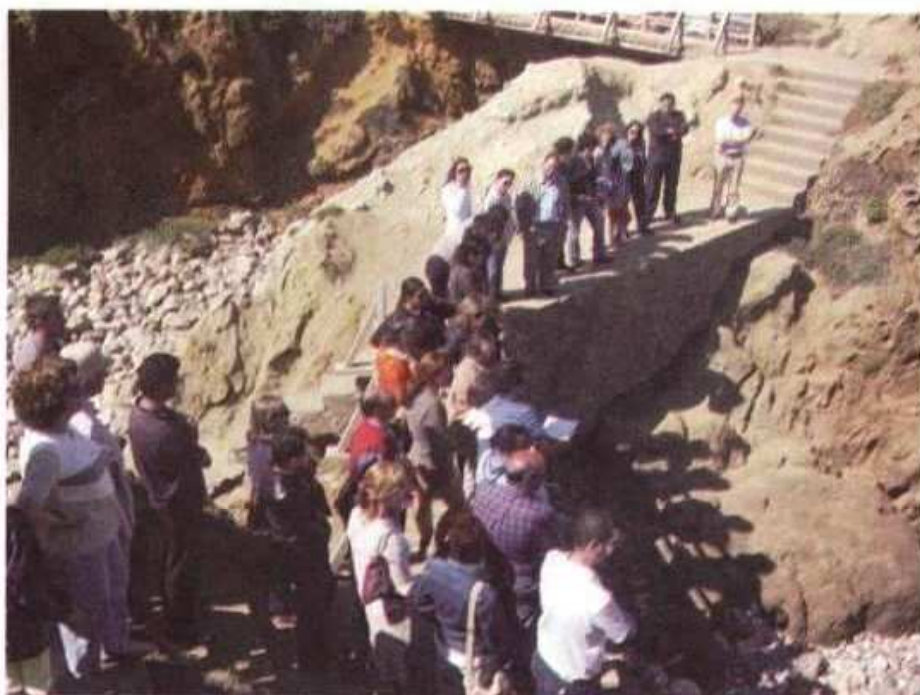


Fig. 4 – Natural science educational activity which took place during the 1st Heritage Meeting of the Municipality of Peniche (June 4th, 2005) (Duarte, 2005; photo: R. Venâncio).



Fig. 5 – Geological educational activity for the general public at the Peniche Lower Toarcian series (August, 2002).



Fig. 6 – Accumulation of belemnites and bivalves at the top of the limestone bed (Ponta do Trovão).



Fig. 7 – Crinoidal ossicle facies-rich in the Peniche Upper Toarcian (Remédios).

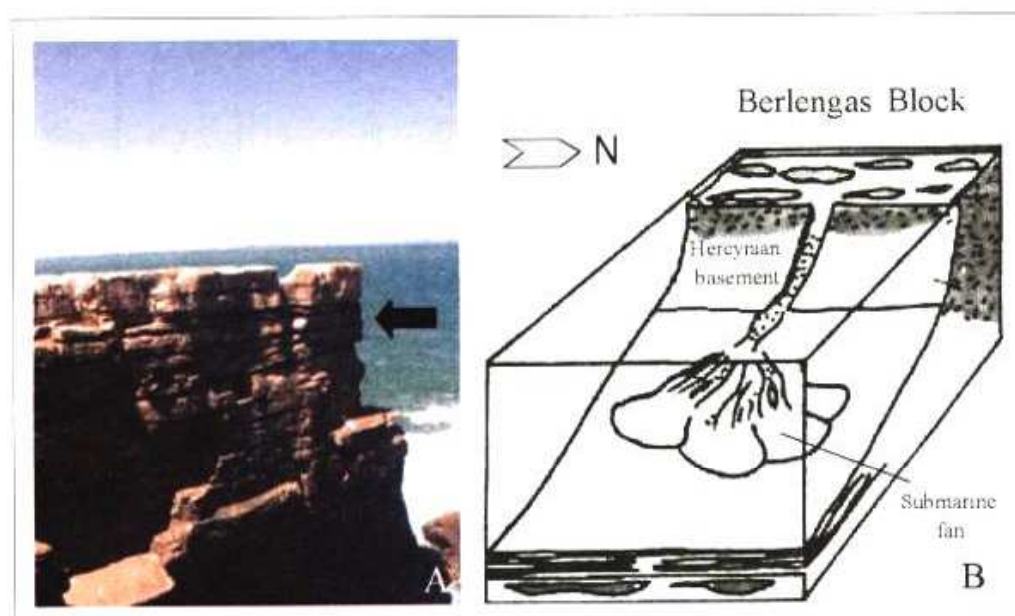


Fig. 8 – (A) Upper Toarcian allodapic (oöpelparites/grainstone) facies in the Remedios area (arrow indicating palaeocurrent from W-NW); (B) Submarine fan depositional model (Wright & Wilson, 1984), a very intuitive model to explain the middle-upper Toarcian deposits of Peniche.

Field Trip Map

