LUSITANIAN BASIN FIELD-TRIP

"Petroleum System Elements in the Lusitanian Basin - an introductory overview"

19-20 November 2010

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GALP Energia

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Edited by:

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FIELD-TRIP PROGRAM

DAY 0

GALP Office - Introductory briefing (1 hour) about the Lusitanian Basin, its sedimentary infill and identified petroleum systems, with emphasis on their distinct elements.

DAY 1

STOP 1A - São Martinho do Porto – Large-scale diapiric deformation and Upper Jurassic deltaic siliciclastic reservoirs.

STOP 1B - Peniche - Lower Jurassic source-rock and carbonate and mixed clastic-carbonate reservoirs.

STOP 1C – Baleal – Middle Jurassic calciclastic turbidites with reservoir potencial.

STOP 1D – Paimogo – Upper Jurassic reservoirs in fluvio-deltaic sandstones.

Presentation (1 h) on “Multi-scale analysis of petroleum systems”, *at Hotel Golf Mar*.

Dinner and overnight at Hotel Golf Mar.

DAY 2

STOP 2A - Santa Cruz – Upper Jurassic reservoir and trap: outcrop observation, reservoir and seal facies analysis, diapiric structure analysis.

STOP 2B - Torres Vedras – Lower Cretaceous fluvial siliciclastic reservoirs.

STOP 2C - Montejunto – Upper-Jurassic basin-scale Petroleum System: regional structures and sub-basins, regional seismic lines and outcrop-scale structures and facies.

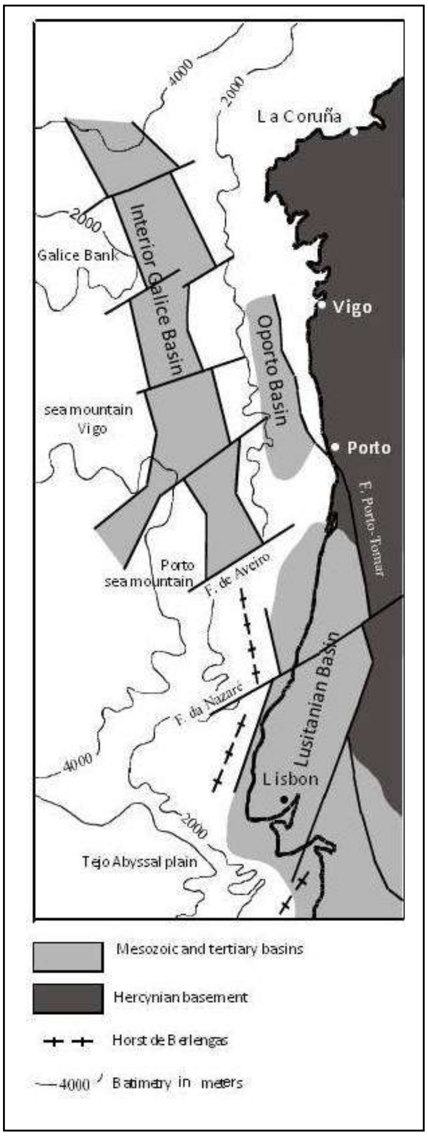
Return to Lisbon.

		Day 1		Day 2	
		Outcrops	Observations	Outcrops	Observations
EVOLUTIVE STEPS	INVERSION				
	DRIFT 3			Torres Vedras	Reservoir
	DRIFT2				
	DRIFT1				
	RIFT2	S. Martinho Lourinhã	Reservoir Salt dynamic Salt wall trap Reservoir	Santa Cruz Torres Vedras Montejunto	Salt dynamic, Reservoir Salt wall trap Source rock Reservoir Salt dynamic Seismic scale outcrop Reservoir Sedimentary overburden
	SAG 1B				
	RIFT 1B	Peniche	Source rock		
	SAG 1A				
	RIFT 1A				

The Lusitanian Basin was initiated during a late Triassic rifting phase and belongs to a family of periatlantic basins (e.g. Jeanne d'Arc Basin, Scotian Basin). It is located on the Portuguese part of the western Iberian margin (Fig. 1). The basin is nearly 130 km wide and about 340 km long; its onshore area totals over 23 000 km^2 (Fig. 2). It is located between hercynian basement rocks, namely, in the east the Iberian Meseta and to the west a marginal horst system (the Berlenga and Farilhões islands are emerged parts of this system).

It connects southwards with the Alentejo and the Algarve Basins and northwards, via a basement ridge, to the Oporto (or Galicia) Basin, bounded by the Porto and Vigo seamounts and by the Galicia Bank. The axis of maximum subsidence, which occurred mainly during the Jurassic, follows a general NNE-SSW structural orientation.

In the Mesozoic sedimentary record of the Lusitanian Basin, five great stages of infill are identified. They are represented by the following sequences, limited by unconformities: UBS1) upper Triassic - Callovian; UBS2) Oxfordian - Berriasian; UBS3) Valanginian - lower Aptian; UBS4) upper Aptian - lower Campanian; UBS5) upper Campanian – Maastrichtian (Wilson *et al.*, 1989, Cunha & Pena dos Reis, 1993).



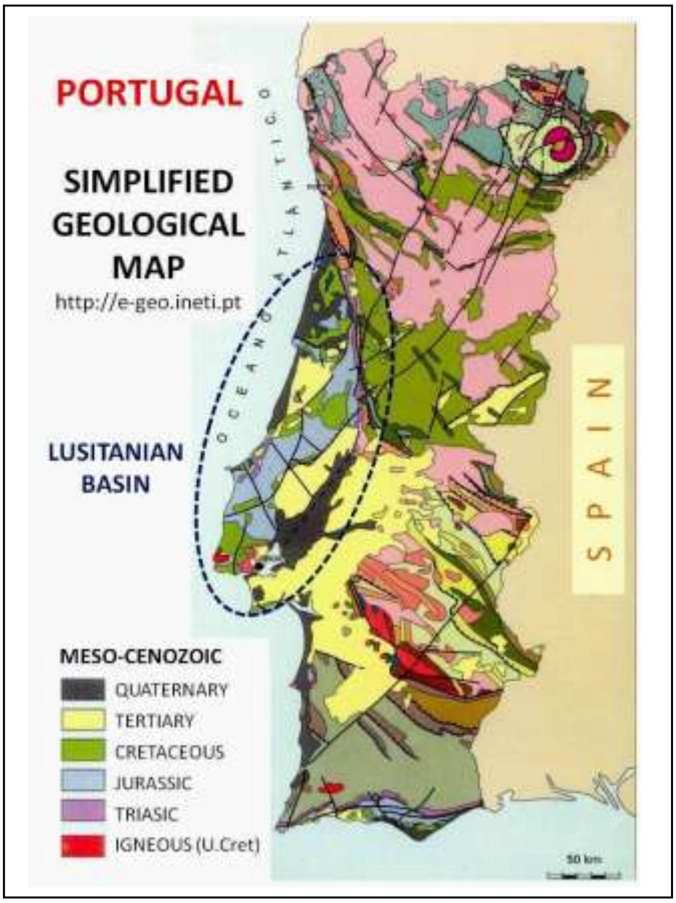


Fig. 2 - Simplified geological map of Portugal, showing the location and extension of the Lusitanian Basin.

Fig. 1 - Mesozoic basins on the West Iberian Margins, showing the position of the Lusitanian Basin and other related basins.

During the Mesozoic and part of the Cenozoic, the structures with a NE-SW and NNE-SSW direction had a mainly extensional behavior. But after the end of the Cretaceous and mainly during the tertiary Betic orogeny, the western rim of the Iberian Plate suffered a compressive deformation that led to a progressive inversion of the central axis of the basin, uplifting and bringing to the surface the thick layers deposited during the Mesozoic.

The Lusitanian Basin's evolution may be divided into 4 main geodynamic steps: i) a first west-tethyean rifting; ii) a second atlantic-oriented rifting; iii) a three-stepped north-atlantic break-up; iv) the tectonic inversion of the basin and uplift of most of the areas.

The first rifting episode (Late Triassic)

The first rifting episode began during the Late Triassic (Figs. 3 and 4), leading to the definition of a system of submeridian grabens and half-grabens, bounded westwards by the Galicia Bank-Berlengas trend. The sedimentary record includes coarse alluvial fan and fluvial deposits, followed by lacustrine and coastal sandstones, distally covered by evaporites.

A transgressive dolomitic limestone unit marks the beginning of a thick sag phase, composed of ramp marls and marly limestones, lower and middle Jurassic in age.

The second rifting episode (Late Jurassic-Early Cretaceous)

From the middle Oxfordian to the early Aptian, a second rifting phase occurred (Fig. 4). The Upper Jurassic to Lower Cretaceous rifting was driven by the alignment of the basin with the Central Atlantic opening. The basin has been re-oriented and new NE-SW oriented depocenters developed, with intense subsidence that triggered diapiric geometries, defined earlier following former basement faults.

The Oxfordian - Berriasian evolution of the Lusitanian Basin may be divided into three tectonic phases (Pena dos Reis *et al*., 1999). The initial phase was the onset of rifting which resulted in widespread carbonate deposition. Extensional climax was reached during phase two. This created highly subsident sub-basins and a significant siliciclastic influx. Phase three was a period of thermal subsidence overprinted by sea-level changes of presumed eustatic nature, which resulted in progradation of siliciclastic systems, overall shallowing and infill of the basin.

Three-stepped break-up and Drift (Early to Late Cretaceous)

The onset of the break-up of the crust and the beginning of the drift, followed three main steps: a first Late Jurassic - Berriasian one and two Early Cretaceous steps (Fig. 4). The break-up unconformity is therefore diachronous, jumping in three steps towards North.

The drift began and ended with magmatic activity, including igneous intrusions, S of the Lousã - Caldas da Rainha fault, while diapirism was intensified and reached extrusion.

Basin's Inversion

During the Late Cretaceous, a major geodynamic change resulted from the collision between the Iberian and African plates, leading to the beginning of an inversion process that continued through the Cenozoic with a maximum in Late Miocene. This inversion caused uplift and erosion of the central part of the basin, followed by the definition of two major tertiary basins (Mondego and Lower Tagus), on each side of the high central sector.

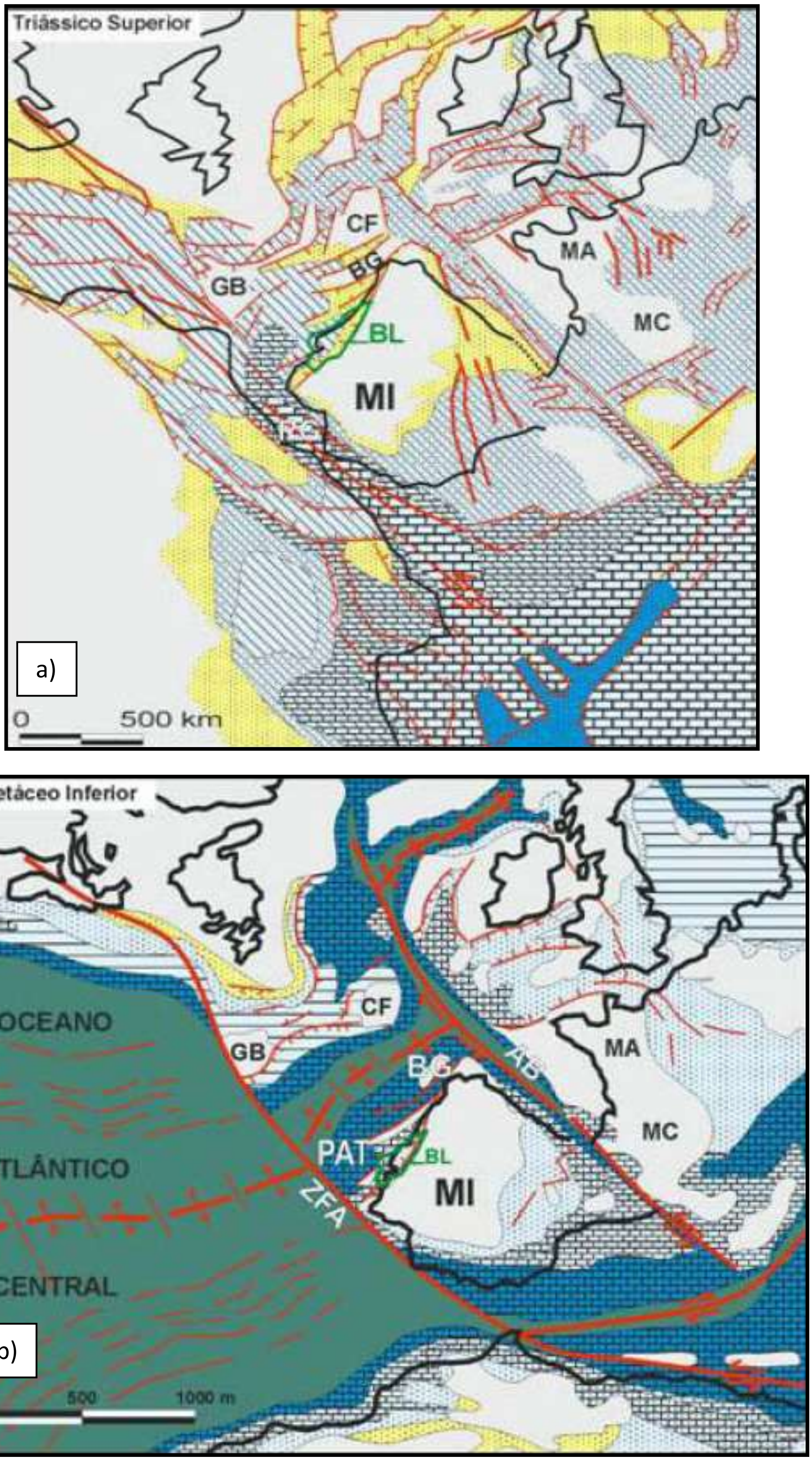


Fig. 3 – Geodynamic and paleogeographic framework of the Iberian Peninsula (MI) in Central and North Atlantic opening; a) Upper Triassic; b) Lower Cretaceous (adapt. Ziegler, 1988).
BL – Lusitanian Basin; MC – Central Massif; PAT – Tagus Abyssal Plain; BG – Galicia Basin; GB – Grand Banks; CF – Flemish Cap; MA – Armorican Massif; ZFA – Azores/Gibraltar Fault; AB – Biscay Gulf.

THE BASIN STRATIGRAPHY AND THE PETROLEUM SYSTEMS

The geodynamic framework and the resulting tectonic, climatic and sedimentary input produced a complex and diversified infill of the basin, which is represented in the Stratigraphic Chart of figure 4.

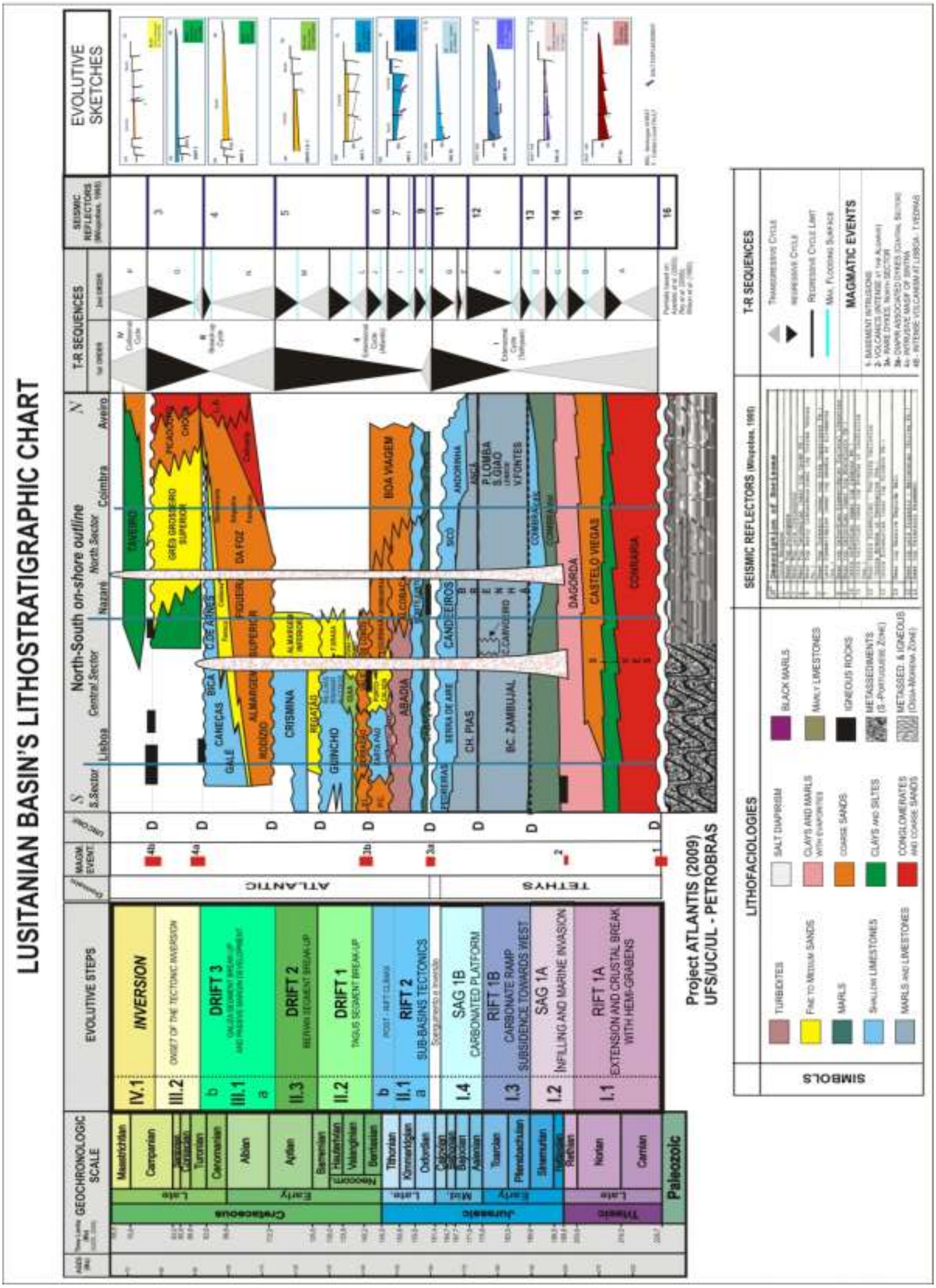


Fig. 4 – Stratigraphic Chart

Figure 5 shows a simplified model with its different source rock reservoirs and seals, together with the evolution of the processes of maturation and migration of the Petroleum systems recognized on the on-shore Lusitanian Basin (Western Iberia, Portugal). Three Petroleum Systems are recognized, on the basis of its main source-rocks ages (Pena dos Reis & Pimentel, 2009): i) Sub-salt system (Paleozoic); ii) Lower system (Early Jurassic); and iii) Upper system (Late Jurassic). The petroleum systems elements are characterized and articulated in space and time, looking for a broad and integrated view in its geological framework.

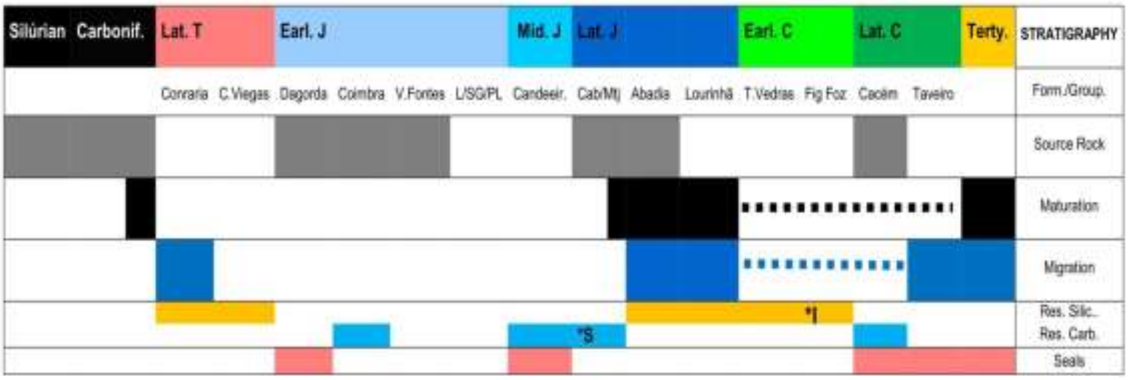


Fig. 5 – Simplified Event Chart of the Lusitanian Basin's petroleum systems (Pena dos Reis & Pimentel, 2010).

STOP 1A – SÃO MARTINHO DO PORTO

***Main Focus** – Upper Jurassic rifting sediments in relation with diapiric activity.*

***Petroleum systems elements and processes** - Sandstone reservoir, Salt dynamic, Salt wall trap*

Geological framework

The region belongs to the Estremadura trench, a cortical structure that was formed in the extensional phase of late Jurassic, with a general orientation NNE-SSW. The Caldas da Rainha salt dome (Fig. 6) is an asymmetric structure in a transversal cross section (with a low tilt in the west flank and a more abrupt tilt in the east) that separates two late Jurassic basinal domains: to the west, the Peniche block (where S. Martinho is situated; Figs. 8 and 9) is characterized by a moderate subsidence; to the East, the Bombarral and Ota blocks define a domain where the subsidence is more intense. The thick Upper Jurassic clastic succession is organized in fluvio-deltaic systems (Bernardes, 1992), infilling a fast subsiding area following the rift climax. To the south (Montejunto), these systems change to deep sea turbidites.

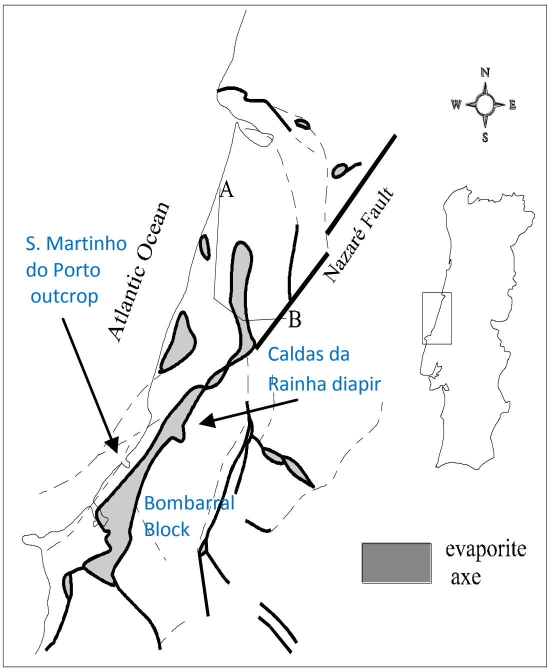


Fig. 6 – Geological Framework o f the Caldas da Rainha piercing salt dome.

Observations

The S. Martinho do Porto area allows scenic and detailed observations of the western border of Caldas da Rainha diapir (Figs. 7, 8 and 9). The late Jurassic sediments dip westwards at a gradually decreasing angle. The lower sediments include shallow limestones and coastal bay clayey materials, overlain by a new limestone package. These sediments are followed by a thick Kimmeridgian deltaic succession, shown in the front page of this guidebook. This package may be considered a good reservoir, acting also as overburden for the Jurassic source-rocks. This unit is limited by a major transgressive surface overlain by a several meters thick oncolitic bar, considered Tithonian in age.

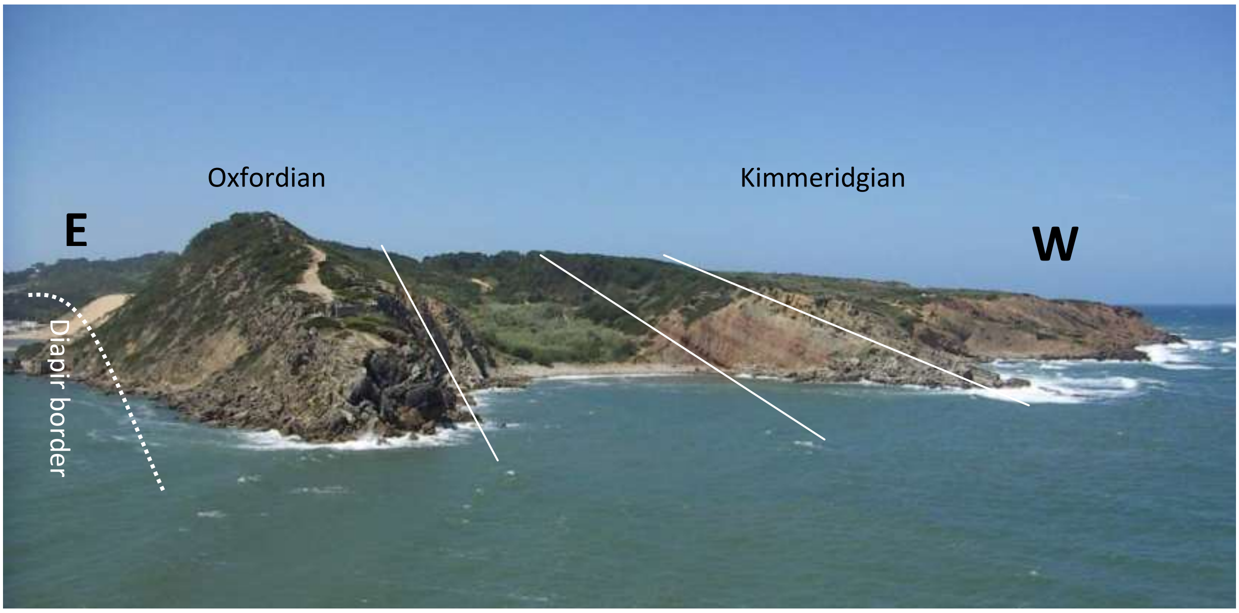
Close to the harbour, it is possible to observe an inverse fault, bounding the Hetangian evaporitic marls (from the diapiric core) of the Dagorda Formation and the Oxfordian limestones of the Cabaços Formation.

In this area and others further north, the salt wall acts as a boundary of the oil migration that may reach the surface as is the case of Leiria or Paredes de Vitória (both places located in the northern sector of the basin).

Fig. 7- Aerial view of the visited area. The red line separates the eastern diapiric depression with a half circle sea gulf, from the western coastal cliffs where the fluvio-deltaic sediments outcrop (Fig. 9).

Fig. 8 – Google Earth view of Caldas da Rainha diapir, with S. Martinho do Porto location. The white dot corresponds to the observation point and the white area to the observed cliff of figure 9.

Fig. 9 - Stratigraphy of the uplifted late Jurassic deposits in S. Martinho do Porto region (Oxfordian and Kimmeridgian), close the western border of Caldas da Rainha diapir. See figure 8 for location.



[STOP 1B– PENICHE]

Main Focus *– Lower Jurassic open marine ramp deposits, related with the first Late Triasic rifting, including one of the main source-rocks of the basin.*

Petroleum systems elements and processes - <u>Source rock</u>

Geological Framework

After the infllill of the first intra-continental rifting semi-grabens, an expansive shallow-marine sequence has been deposited all along the basin (*Coimbra Formation*). This Sinemurian dolomitic unit is separated from the overlying marly units by a regional discontinuity, a 2nd Order Sequence limit (Fig. 4). The overlying sequence shows a rapid transition to deep marine facies. Pliensbachian layers suggest increased subsidence and deepening of the basin, with deposition of black-shales presenting good source-rock characteristics (Fig. 5). In this particular area of the basin, Toarcian layers show the increasing influence of detrital input, initially siliciclastic and then mostly calciclastic.

Observations

At the Peniche Peninsula, a continuous 450 m thick lower Jurassic sequence may be observed along its coastal cliffs. Biostratigraphic control is based on ammonites and allows a detailed ciclicity analysis (Fig. 17; Duarte, 2004). Several stops will be made along this sequence, to illustrate the main features and geological moments.

i) Papoa - This stop clearly shows the 2nd Order limit between the massive dolomitic *Coimbra Formation* and the laminated calcareous sequence, marked by a ferrugineous bioturbated hardground. The overlying deposits start with bioclastic limestones and centimetric marly intercalations, quickly gradding to marly mudstones rich in ammonites, representing an intense deepening of the basin (*Água de Madeiros Fm*) (Figs. 10 and 11).

Fig. 10 - 2nd Order Unconformity between the massif dolomitic Coimbra Fm and the laminated marly Água de Madeiros Fm.

Fig. 11 - Panoramic view with the Papoa isthmus (*Coimbra Fm*) to the left and the North Beach to the right.

ii) North Beach - This second stop shows the Pliensbachian *Vale das Fontes Fm*.. “Lumpy Marls and Limestones”, with TOCs up to 5%, give place to the “Marly Limestones and Bituminous Facies”, with TOCs up to 15%, marking the peak transgression phase of this sequence (Fig. 17; Duarte, 2004). These organic-rich centimetric layers are part of the so-called “Brenha Source-Rock”, present in most areas of the basin, although with different maturation stages, reflecting different overburden thicknesses. The palinofacies analysis pointed to a predominance of terrestrial remains (Matos, 2009), which may be explained by the proximity of the Berlengas block and its uplift in the early Jurassic (*vd.* the following Peniche stops) (Figs. 12, 13 and 14).
The western cliffs show regressive marly limestones of the *Lemede Fm* (Fig. 12).

Fig. 12 – View of the Vale das Fontes Fm (front plan) and Lemede Fm (back plan); detail of a 10 cm thick organic-rich black-shale layer.

iii) Trovão - This third stop shows the Pliensbachian/Toarcian proposed GSSP (Elmi, 2006). The top layers of the late Pliensbachian yellowish marly limestones (*Lemede Fm.*) represent condensed interval with abundant belemnites. Toarcian sedimentation *(Cabo Carvoeiro Fm.)* begins with dark gray marls and clays with pyritous ammonites; centimetrical to metrical yellowish intercalations of subarkosic sands may be seen on the western cliffs (Wright, 2004). These terrigenous inputs resulted from the uplift of the Berlengas block, an early Jurassic rift-shoulder, active on the western border of the basin (Figs. 13 and 14).

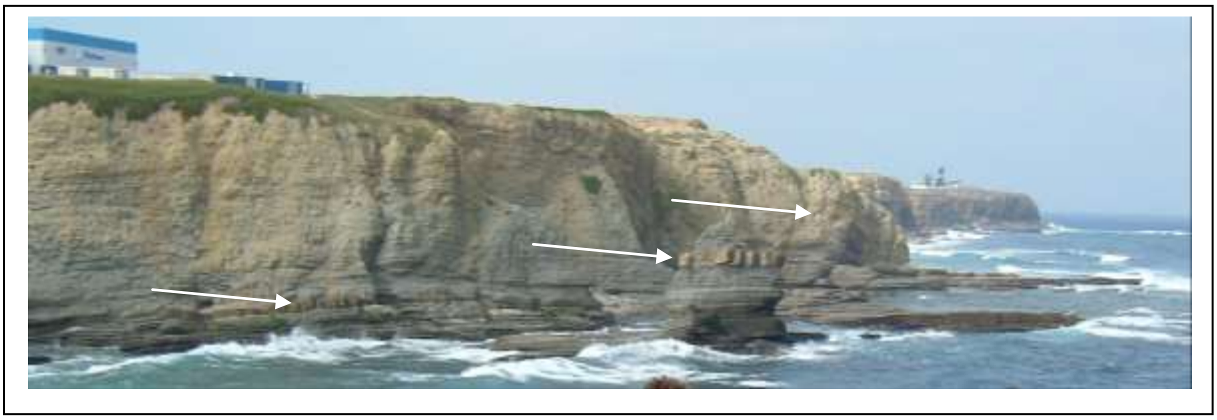


Fig. 13- Toarcian *Cabo Carvoeiro Fm*. with gray marls and arkosic brownish layers (white arrows).

iv) Remédios – Carvoeiro Cape - The cliffs along the road leading to the Carvoeiro Cape expose abundant whitish limestones with intense carsification, showing amalgamated channel fill geometries and clear bipolar cross-bedding structures (*Cabo Carvoeiro Fm*) (Fig. 14). An overall thickening and coarsening upward pattern may be detected along these over 300 m thick succession. These deposits have been interpreted as outer fan lobes resedimented carbonates, fed by carbonate shoals exposed at the uplifted Berlengas rift-shoulder (Wright, 2004) (Figs. 13, 14, 15 and 16).

Fig. 14 - Toarcian Cabo Carvoeiro Fm with stacked re-sedimented calcicastic deposits.

Fig. 15 - Toarcian highly carsified carbonates at Cabo Carvoeiro ligghthouse.

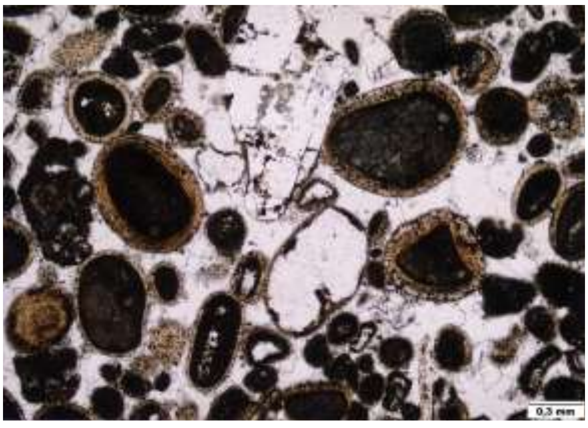


Fig. 16 - Microphotography of oosparite grainstone resedimented carbonates of the Cabo Carvoeiro Fm. (*in* Duarte, 2006).

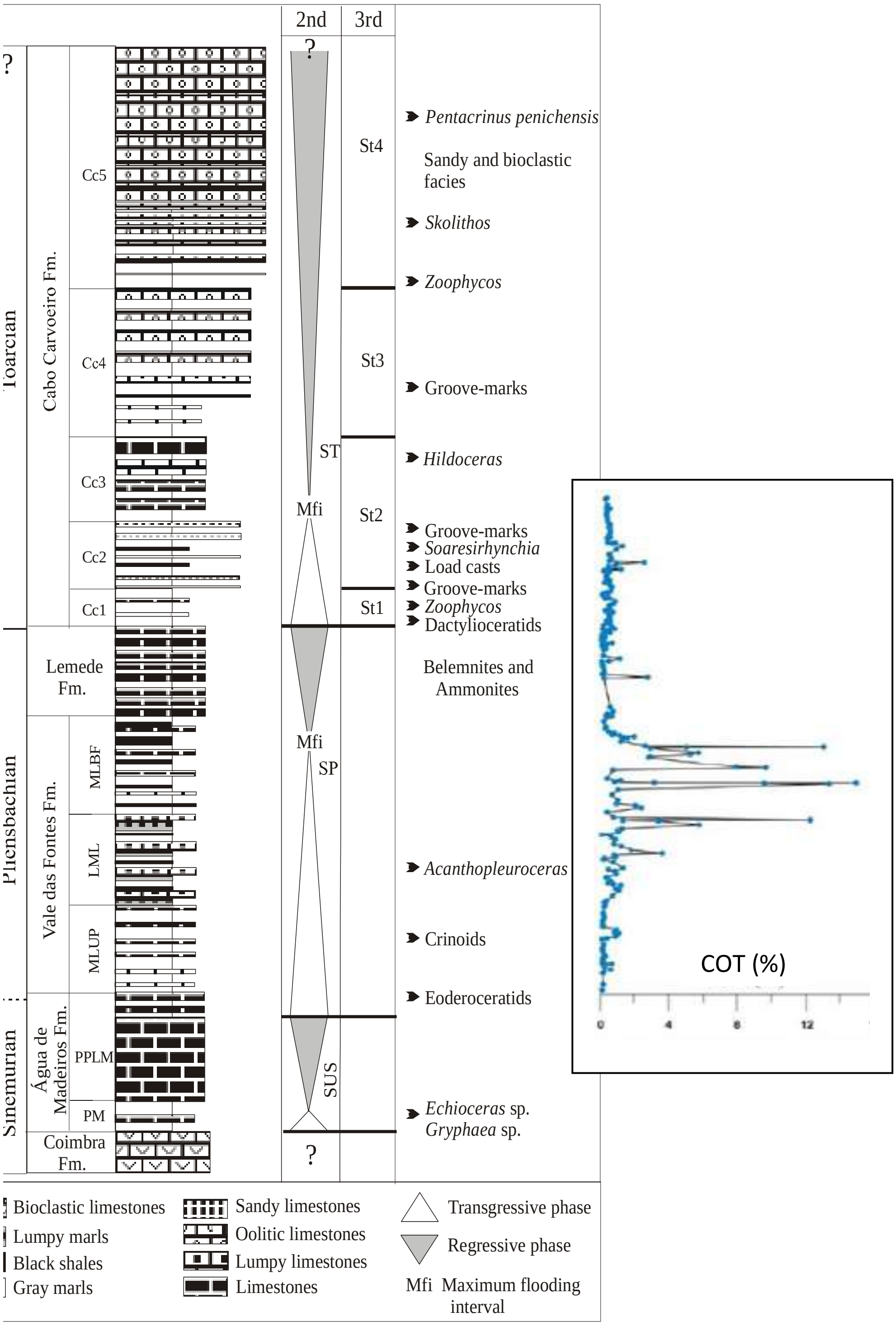


Fig. 17 - Synthetic section of Sinemurian - upper Aalenian(?) from Peniche (Duarte *et al*., 2004) and TOC values in the Vale das Fontes Fm (Oliveira, 2007).

STOP 1C – BALEAL

Main Focus *– Middle Jurassic calcareous debris-flows.*

Petroleum systems elements and processes *- Potential calciclastic reservoir down-dip*

Geological Framework

The Middle Jurassic sequences outcropping at Lusitanian basin´s eastern border (Maciço Calcário Estremenho) correspond mainly to high energy carbonate inner ramp depositional systems, with hundreds of meters of stacked calcareous sandbodies (Azerêdo, 2004). On the western parts of the basin, outcrops are scarcer and they show quite different facies associations, with monotonous massive to laminated limestones, deposited in deep marine conditions, interpreted as the distal parts of those carbonate ramps. Such is the case at Cabo Mondego and Baleal, in both cases with clear evidences of mass-flows and gravitic re sedimentation.

Observations

The small Baleal peninsula is composed of Upper Bajocian marly limestones (Fig. 18), proeminent from the neighboring Upper Jurassic fluvial deposits which can be seen on the beach cliffs towards the North. An overall observation at the northern tip of the peninsula shows rhythmic alternations of decimetric gray/yellowish limestones and dark gray marls, in tabular layers dipping c.36º towards ENE. A closer observation shows the presence of irregular and discontinuous layers of coarse grained calciclastic facies (Fig. 19), described in detail by Azerêdo (1988).

Limestone conglomerates contain 2-10cm long clasts, sometimes up to 100 cm long, mainly of micritic limestones with “filaments”. The matrix is composed of sandy mudstone, showing synsedimentary soft-sediment deformation. Calcarenitic layers are also present, isolated or capping the conglomeratic layers, with packstone and grainstone textures.

These deposits correspond to sediment gravity flows (debris-flow and mud-flow), deposited in a distally steepened ramp, resulting from sporadic inputs on a dominant low energy hemipeleagic environment (Fig. 20). Directional structures are scarce and both a provenance from the distant eastern inner ramp or from a proximal western basin border, are acceptable hypothesis for the moment (*vd.* Azerêdo, 1988).

Fig. 18 – Upper Bajocian marly limestones at Baleal.

Fig. 19 -Detail photo of a single calcareous-debris-flow layer at Baleal.

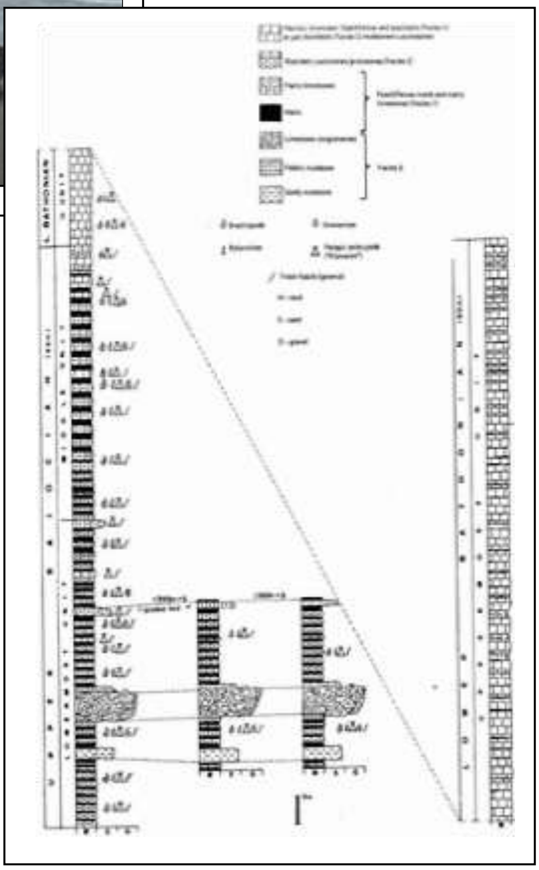


Fig. 20 - Lithostratigraphic column of the Baleal Middle Jurassic sequence (thickness of thinner beds is exaggerated) (*in* Azerêdo, 1988).

STOP 1D – PAIMOGO

***Main Focus**: Observation of Upper Jurassic fluvio-deltaic deposits with reservoir characteristics.*

Petroleum systems elements and processes – Fluvio-deltaic s*iliciclastic* *Reservoir*

Geological Framework

The upper Jurassic of the Lusitanian Basin is composed of thick siliciclastic deposits, related to increased accommodation space created by intense subsidense. These deposits are the geological record of the second rifting event of the basin. The climax of this episode correspond to the deep turbiditic deposits of the Abadia Formation (seen in Santa Cruz), which are followed by a shallowing and prograding siliciclastic sequence – the Lourinhã Formation (Hill, 1988).

This formation presents an association of fluvio-deltaic deposits, in which several Members have been defined according to its facies and paleoenvornments (Hill, 1988). Between Peniche and Santa Cruz, the vertical sequence presents over 500 m thickness, showing the alternation of those members, in response to mainly eustatic controls.

Observations

This large-scale outcrop, extending 2 km from the fort of Paimogo to the Areia Branca beach, shows around 100 m of Upper Jurassic fluvio-deltaic deposits from the Lourinhã Formation (Figs. 21 and 22).

The lower part corresponds to the Praia Azul Member, with silty clays and fine sands with massive to laminated facies. Grayish colors indicate preservation of organic matter and rare ostreids indicate brakish conditions. Some sandy bodies show hummocky structures, pointing to reworking in shallow and agitated conditions. The paleoenvironmental reconstruction points to a deltaic front. As we go up in the sequence, brownish to reddish colours become predominant and sandy bodies become thicker, larger and gradually predominant (Fig. 22). This evolution points to the progradation of meandering fluvial facies into the deltaic environment. The thicker sands represent lateral accretion point-bars, whereas the thinner bodies represent crevasse-splays intercalated in the floodplain clays.

These deposits present good reservoir facies, with porous sands in connected bodies, a good outcropping analogue to the North Sea's Statfjord Formation (Keogh *et al.*, 2008).

Fig 21 – Fluvio-deltaic sandstones and clays of the Lourinhã Fm at Paimogo.

A

B

Fig. 22 – A) Photomosaic of upper Jurassic fluvio-deltaic deposits at Paimogo, Lourinhã Formation; B) Representation of the proportion between floodplain clays (white), sandy point-bars (blue) and sandy crevasse-splays (green), S of Paimogo); the insert shows the position of photo A.

STOP 2A – SANTA CRUZ

Main Focus – *Upper Jurassic rifting sediments in relation with diapiric activity.*

Petroleum systems elements and processes – Turbiditic to Fluvial *Siliciclastic* *Reservoirs, Salt wall* *Trap, Salt dynamics.*

Geologic Framework

The Caldas da Rainha structure was responsible for the early separation of two major subsidence areas (Wilson, 1979, Canérot *et al.*, 1995); towards the NW reduced values are common and to the SE, corresponding to a half-graben block located between the Pragança fault and the Caldas da Rainha structure, intense tectonic subsidence occurred (Fig. 23).

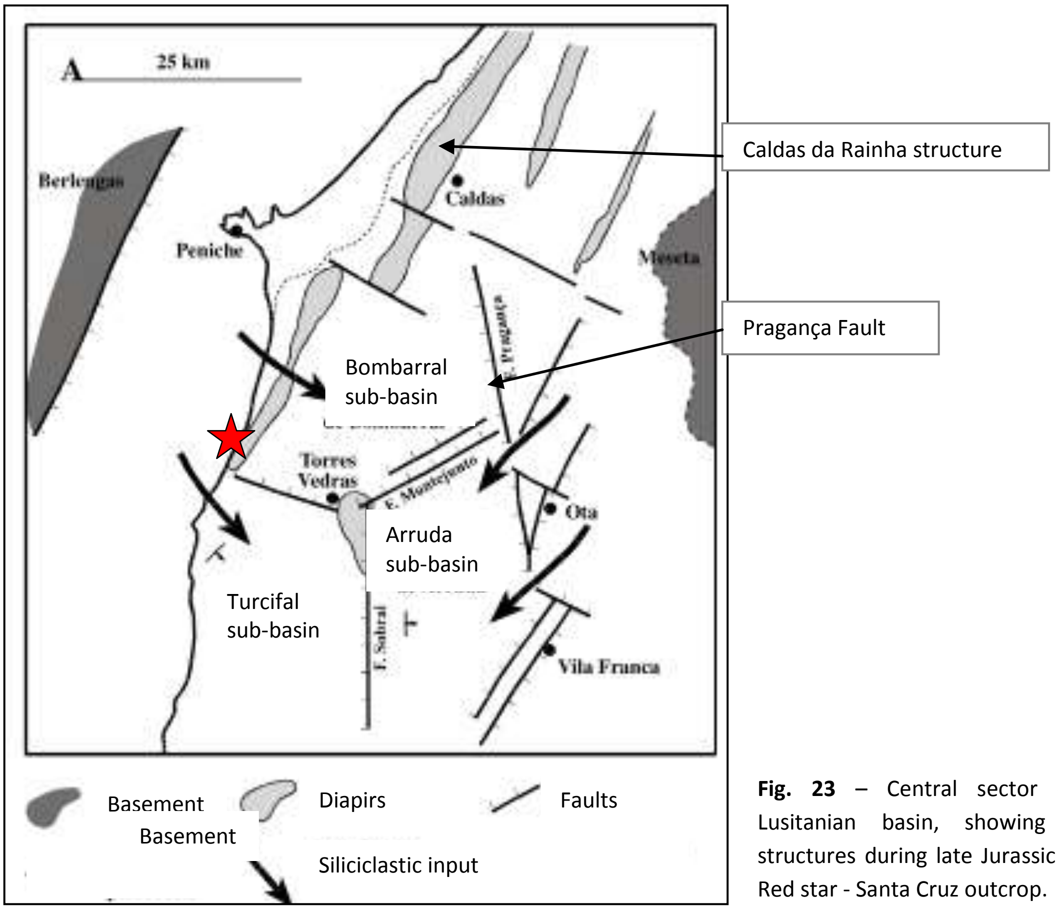


Fig. 23 – Central sector of the Lusitanian basin, showing active structures during late Jurassic rifting. Red star - Santa Cruz outcrop.

The Bombarral sub-basin that corresponds to the last area, was therefore defined since the beginning of the Late Jurassic sedimentary cycle. The Santa Cruz region corresponds to the westernmost outcrop of Upper Jurassic sediments, likely related to the western basement border of Lusitanian Basin. The sedimentation is mainly siliciclastic, organized in several litostratigraphic units and records the more important conditions of the 2nd rifting occurrence (Fig. 24).

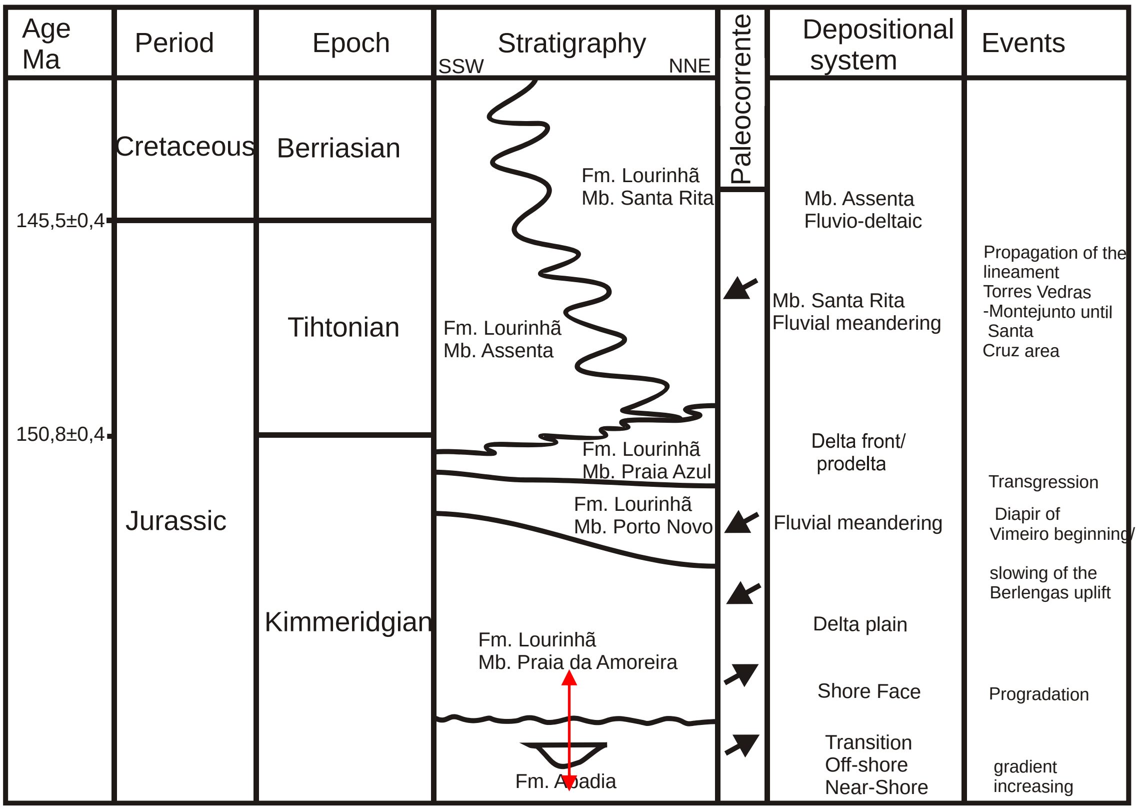


Fig. 24 - A general stratigraphic scheme of Santa Cruz region (Ravnas et al., 1997). The red arrowed section is outcropping in Santa Cruz beach.

The outcropping diapiric geometries allow the observation of several geologic features suggesting the relation between the salt motion and the sedimentation (Fig. 25).

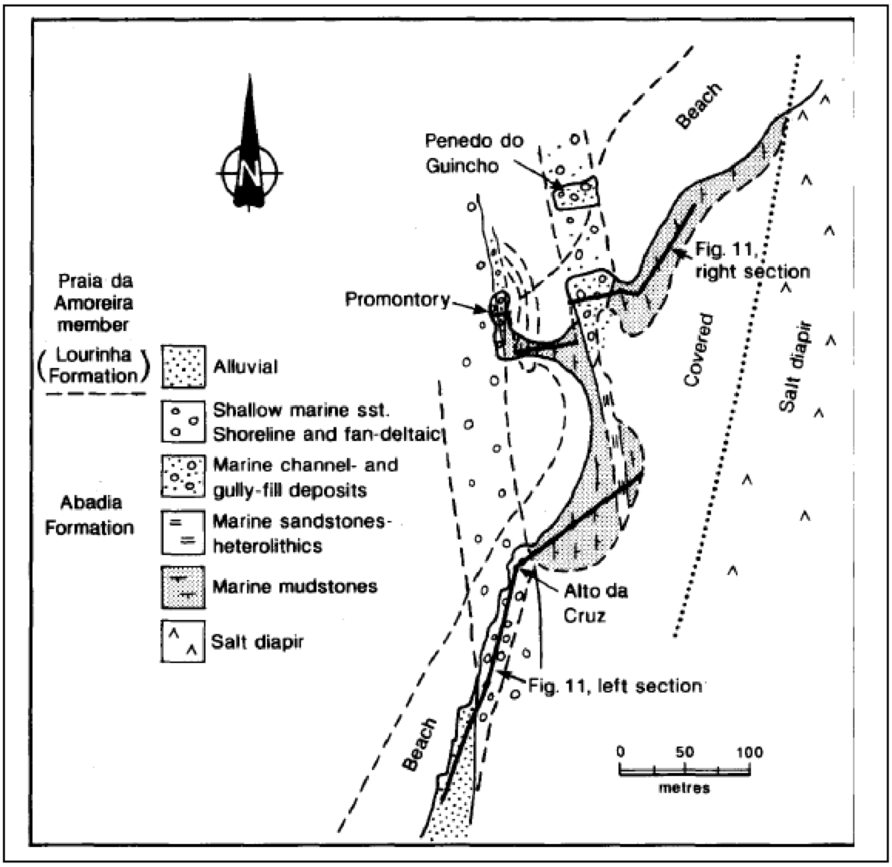


Fig. 25 - General interpretation of the Santa Cruz beach outcrop (Ravnas *et al.*, 1997).

Observations

This coastal outcrop presents upper Jurassic sediments related to the second rifting event, including Kimmeridgian turbidites related with the climax, next to a diapir wall (Fig. 26). These sediments are incised by a submarine flow conglomerate (Fig. 27). The package is overlain by coastal and fluvial sands (Ravnas *et al.*, 1997) of the transition to the post climax phase (*Amoreira* Fm). This succession shows an apparent geometry of adaptation to the diapir, with decreasing dip towards South (Fig. 28).

Fig. 26 – Santa Cruz diapir: highly deformed clays with gypsum and dolomitic layers of the Hetangian Dagorda Fm. (left) in contact with grey limestones of the Oxfordian Montejunto Fm (right).

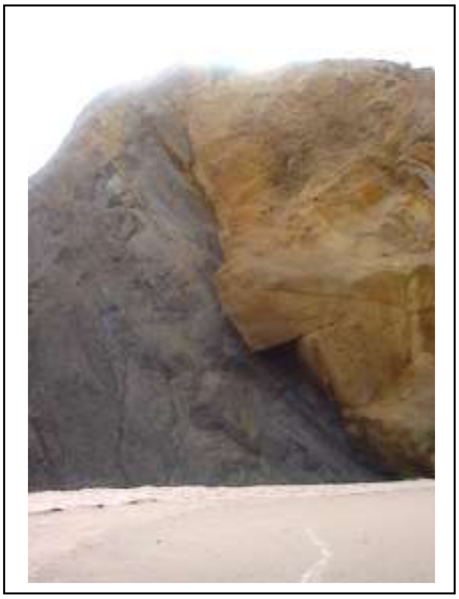


Fig. 27- Coarse grained submarine canyon incised into fine-grained turbidites of the Kimmeridgian Abadia Formation.

Fig. 28 - Sandy layers of the Kimmeridgian Lourinhã Formation, highly deformed by the diapiric intrusion and piercing (to the left).

STOP 2B - TORRES VEDRAS

Main focus – Observation of Lower Cretaceous fluvial sandstones and clays.

Petroleum systems elements and processes - *Braided fluvial siliciclastic Reservoir.*

Geologic framework

After the Upper Jurassic rift climax, subsidence and accommodation space were highly reduced and the Lusitanian Basin became gradually filled-up. Depositional systems passed gradually from open marine to coastal and deltaic, and later to paralic and fluvial environments, in the Lower Cretaceous. The sedimentary record includes two second order T-R cycles (Valanginian -Barremian and Barremian - Albian, each one containing several third order-cycles (Rey & Dinis, 2004). Coastal paralic environments were restricted to the depocentric areas around Lisbon, reaching Torres Vedras only in the the maximum Hauterivian transgression. In this region, most of the sedimentary record is represented by braided fluvial deposits, all along the Lower Cretaceous.

Observations

The selected outcrop is a good example of the braided fluvial facies of the Lower Cretaceous in this region (Fig. 29). The sequence is deformed by the diapiric intrusion 3 km E of Torres Vedras (Matacães), dipping around 15-20º to the NNW (Fig. 29). An overall view shows the presence of sandstones and clays with very different and strong colours, reflecting the local depositional dynamic.

These deposits resulted from a braided fluvial system, with multiple channels crossing each other and alternating channel incision and sandy infill, followed by floodplain deposition of fine silts and clays.

The first 20 meters will be observed in more detail, with channel geometries, conglomeratig lags and bars, sandy fillings and overbank fines (Fig. 28). These different sedimentary facies have very different reservoir characteristics, with coarser facies showing higher porosities and finer facies acting as meter-scale seals.

This sequence is a good example of compartmented siliciclastic reservoir, with an interesting net-to-gross and porosity. Connectivity may be a major problem, but regional fractures and fault, mostly related with diapiric intrusions, may be important to improve it.

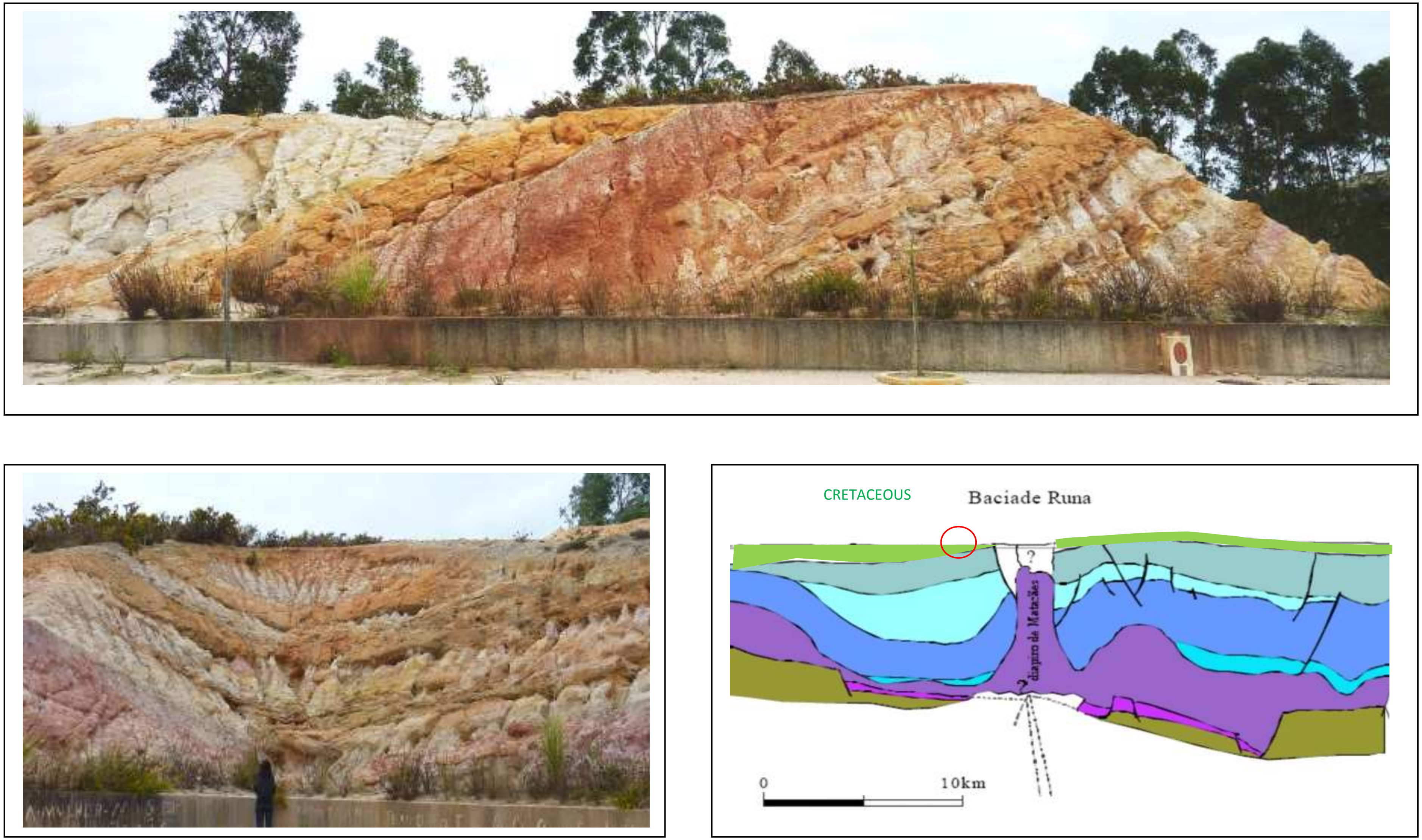


Fig. 29 - Fluvial siliciclastic reservoir in Torres Vedras, showing alternanting sands and clays (A), dipping to NNW (B), due to the diapiric intrusion of Matacães (C; adapt. Kullberg, 2000).

STOP 2C – MONTEJUNTO

Main focus – *Salt dynamic*

Petroleum systems elements and processes - *Seismic scale outcrop, Reservoir, Sedimentary overburden*

Geological Framework

Between the Caldas da Rainha alignment and the Vila Franca fault, there is a subsiding area (Fossa da Estremadura) where the activity of the structures produces three depocentres (Bombarral, Arruda and Turcifal), where about 1000m of sediments was accumulated during this stage.

The maximum subsidence occurs in the Arruda depocentre around the structural alignment of Montejunto, causing the deepening of the basin and the rupture of the carbonate platform of the Montejunto Formation, and the definition of an unconformity. Nevertheless, during this episode of low relative sea level, the sedimentation of the marls and limestones with ammonites continues in a regime of external platform controlled by NE-SW faults, and represented by the Tojeira member of the Abadia Formation. In the depocentric areas (SE) the merging of clastics, interpreted as lobules of distal turbidites arranged perpendicularly to those active faults, increases.

CRONOSTRATIGRAPHY (ATROPS & MARQUES, 1986)				FACIES	SEDIMENTARY MODELS	EVENTS	CLIMAX PHASES
Kimmeridgian	Ac.	Fm.		*Marls	* Shelf and basin facies	Subsidence slowing * infill and shallowing	LATE
	Div.						
	Hypes.		Mb. CABRITO	*Clastics (sandstones and conglomerates, with breccias)	* canyon-submarine fan (prox - middle turbidites) to NW	* Incision and clastics	
	Plat.		Mb. CASAL DE RAMADA	*Marls and limestones. Calcareous breccia; olistolits	* Basin facies. Scree breccia and submarine fan (middle to distal turbidites) to NW	Maximum subsidence * First progradation Differentiation of a tectonic scarp Deep carbonate sedimentation	MIDDLE
Late Oxfordian	Plan.		Mb. TOJEIRA	* Marls and limestones	* distal platform	Platform break-up * Subsidência speeding * Basin deepening	EARLY
	Bim.	Fm. MONTEJUNTO					

Fig. 30 – General stratigraphic framework of the Montejunto area (Pena dos Reis & Corrochano, 1998).

At the beginning of the Kimeridgian, the conditions of maximum subsidence are produced (Pena dos Reis *et al.*, 1997; Pena dos Reis and Corrrochano, 1998) (Fig. 30). At the beginning of this stage the platform restructures itself, rising blocks controlled by NE-SW directed faults, mainly next to the eastern limit of the area, where large horsts (structural horsts of Ota and Vila Franca), separated by narrow hallways, were shaped.

Observations

In this area of the basin, this stage begins with the member Casal da Ramada from the Formation of Abadia, formed by facies that are characteristic of a deep sedimentation, including marls and grey lutites with fauna that typifies the Biozone *platynota* (Atrops and Marques, 1986). Depending on the active faults, strong levels of breccia and calcareous olistolits with evidences of karstification, seen as deposits of unstable slope, occur (Fig. 31). Above, lutites and sandstones appear that correspond to deep turbidític fans (member Cabrito and higher levels from the Abadia Formation), which expose the beginning of the progradation of the siliclastics systems from SW and W, over the facies of the basin. Another source of clastics that feed the depocentre of Arruda, are the high blocks of the faults that form the eastern banks of the sub-basins (Pragança, Montejunto and Sobral) and the sediments deriving from the Iberian Meseta.

Fig. 31 – View of the inverse fault bounding the Montejunto carbonate platform from the overlying Abadia turbidits. Large blocks on the left are olistolits. See Fig. 31 for a seismic section including this area.

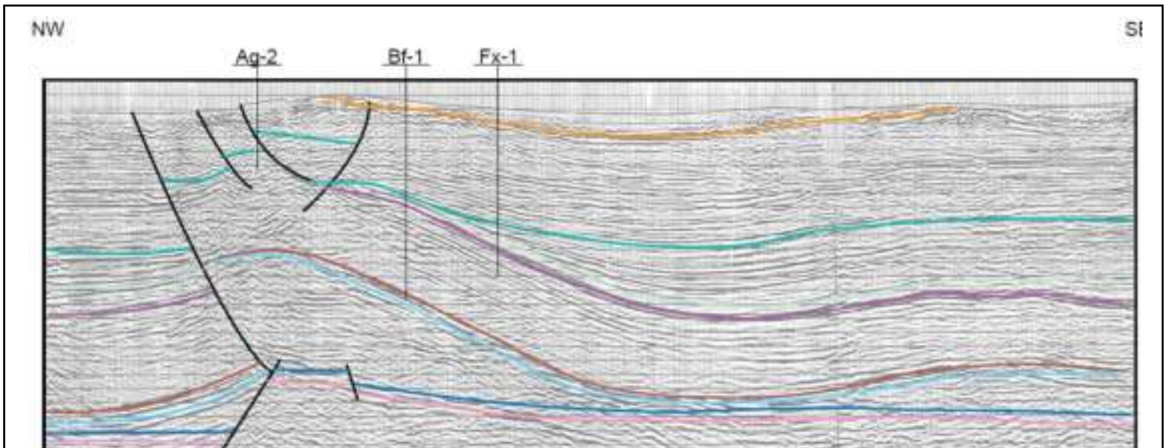


Fig. 32 – Seismic line AR-9-80, in the Montejunto region, with interpretation by Rasmussen et al. (1988). The assimetric salt anticline (left) can be seen in the figure 31. The growing structure of the right hand side of the anticline corresponds to the Oxfordian (Cabaços and Montejunto Fms) sin-rift limestones.

REFERENCES

Atrops, F. & Marques, B. (1986). Mise en évidence de la zone à Platynota (Kimméridgian inférieur) dans le Massif du Montejunto (Portugal): conséquences stratigraphiques et paléontologiques. *Geobios*, Lyon, 19 (5), pp.537-547, 3 fig., 1 pl.

Azerêdo, A. C. (1988) – Calcareous debris-flows as evidence for a distally steepened carbonate ramp in West-Central Portugal. *Comunicações dos Serviços Geológicos de Portugal*, Lisboa, t.74: 57-67.

Azerêdo, A. C. (2004) – Middle Jurassic inner ramp lithossomes at the Maciço Calcário Estremenho. *In* L. V. Duarte & M. H. Henriques (Eds.), *IAS 2004, 23rd Meeting, Field Trip Guide Book, Carboniferous and Jurassic Carbonate Plataforms of Iberia*, 1: 79-86.

Bernardes, C. A. (1992) - A sedimentação durante o Jurássico Superior entre o Cabo Mondego e o Baleal (Bacia Lusitana): Modelos deposicionais e arquitectura sequencial. *Tese de doutoramento* (não publicada). Universidade de Aveiro, 261 p.

Cunha, P. Proença & Pena dos Reis, R. (1993) - The Cretaceous unconformity-bounded sequences (Upper Aptian - Lower Campanian and Upper Campanian - Maastrichtian?) in the Lousã - Pombal region. *Field trip guide, 1st General meeting - IGCP Project nº362 - Tethyan and Boreal Cretaceous*, 5-18.

Dinis, J. L., Rey, J., Cunha, P. P., Callapez, P. & Pena dos Reis, R. (2008) - Stratigraphy and allogenic controls of the western Portugal Cretaceous: an updated synthesis. *Cretaceous Research, 29 (5-6): 772-780.*

Duarte, L. V. (2004) – The Upper Sinemurian – Upper Toarcian sucession in the Peniche peninsula. Lithostratigraphy and Sequence Stratigraphy. *In L. V. Duarte & M. H. Henriques (Eds.), IAS 2004, 23rd Meeting, Field Trip Guide Book, Carboniferous and Jurassic Carbonate Plataforms of Iberia, 1: 58-60.*

Duarte, L. V. (2006) - The Peniche Section. *In* R. Pena dos Reis & N. Pimentel, *Curso de Campo na Bacia Lusitânica (Portugal)*, Coimbra, 87 p.

Elmi, S. (2006) - Pliensbachian/Toarcian boundary: the proposed GSSP of Peniche (Portugal). *Volumina Jurasica*, Warsaw, 4: 5-16.

Pena dos Reis, R. & Corrochano, A. (1998) - Arquitectura deposicional controlada pela etapa paroxismal do rifting no Jurássico superior da Bacia Lusitânica (Portugal). Caso da região a SO de Montejunto. *In* J. T. Oliveira & R. P. Dias (Eds.), *V Congresso Nacional de Geologia, Livro Guia das Excursões,* 15-20.

Pena dos Reis, R. & Pimentel, N. L. (2010) – Sistemas Petrolíferos no *on-shore* da Bacia Lusitânica - uma visão geológica integradora *in "Ciências Geológicas – Ensino e Investigação e sua História"* Volume II, Capítulo I - Geologia e Recursos Geológicos; 143-156.

Pena dos Reis, R. Cunha, P. M. R., Dinis, J. L. & Trincão, P. (1999) - Geologic evolution of Lusitanian Basin during Late Jurassic (Portugal). In Hall & Smith (Eds.), Advances in Jurassic Research, *GeoResearch Forum*, Trans Tech Pub, Zurich, 6: 345-356.

Pena dos Reis, R. Proença Cunha, P & Dinis J. (1997) - Hipersubsident depositional event associated with a rift climax in Late Jurassic of Lusitanian Basin (W Portugal). *IV Congresso de Jurássico de España*, Alcañiz, 101-103.

Rasmussen, E., Lomholt, S., Andersen, C. & Vejbæk, O. (1998) - Aspects of the structural evolution of the Lusitanian Basin in Portugal and the shelf and slope area offshore Portugal. *Tectonophysics* 300; 199–225.

Ravnas, R., Winsdelstad, J., Mellere, D., Nøttvedt, A., Sjøblom, T. S., Steel, R. J., Wilson, R. (1997) - A marine Late Jurassic synrift succession in the Lusitanian Basin, western Portugal - tectonic significance of stratigraphic signature. *Sedimentary Geology*, 114: 237– 266.

Veiga, L.C.V. (2007) - Biostratigrafia de Nanofósseis e Estratigrafia Química do Pliensbaquiano – Toarcianio inferior (Jurássico inferior) da região de Peniche (Bacia Lusitânica, Portugal). *Tese de Doutorado* (2 vols), Inst. Geociências, UFRGS, Brasil.

Wilson, R. C. (1979) - A reconnaissance study of Upper Jurassic sediments of the Lusitanian Basin. *Ciências da Terra (UNL)*, 5: 53-84.

Wilson, R. C. L., Hiscott, R. N., Willis, M. G. & Gradstein, F. M. (1989) - The Lusitanian basin of west-central Portugal; Mesozoic and Tertiary tectonic, stratigraphic and subsidence history. *In* A- J. Tankard & H. Balkwill (Eds), *Extensional tectonics and stratigraphy of the North Atlantic margins*. *American Association of Petroleum Geologists, Memoir* 46: 341-361.

Wright, V.P. (2004) – Submarine fan evolution of the Toarcian, Peniche. *In* L. V. Duarte & M. H. Henriques (Eds.), *IAS 2004, 23rd Meeting, Field Trip Guide Book, Carboniferous and Jurassic Carbonate Plataforms of Iberia*, 1: 67-70.