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EVOLUTION OF DEEP-MARGIN EXTENSIONAL BASINS: THE CONTINENTAL SLOPE BASINS OFFSHORE WEST IBERIA

A new set of multi-channel (2D) seismic reflection data, acquired by TGS-NOPEC in 2000 and 2001, has been used to characterise the tectono-sedimentary evolution of the continental slope basins offshore west Iberia. The new data were compared with seismic and well information on the Porto and Northern Lusitanian Basins. The deep margin north of the Nazaré fault is intersected by northwest- to northeast-trending normal faults that bound distinct Mesozoic half-graben/graben sub-basins. East-northeast faults separate sectors with distinct tectono-sedimentary evolutions. On the interpreted profiles, the thickness of the Cretaceous rift-related units is relatively minor and wedge-shaped syn-/post-rift packages are limited to two sub-basins. In contrast, the more than 1000 ms two-way travel-time (TWTT) of Late Cretaceous-Cenozoic sediments mark an important period of post-rift subsidence accompanied by substantial sediment supply from hinterland areas. The models for the formation of passive continental margins suggest that crustal heterogeneities, basement Hercynian structures and the relative position of the zone of ductile stretching underneath the upper crust controlled the subsidence history and physiography of the offshore basins during the Mesozoic rifting. This complex setting was further disturbed by the Alpine tectonism, which increased the basin compartmentalisation, rejuvenated hinterland and intra-basin sediment-source areas, caused local deepening on the margin and triggered halokinesis.

Data and methodology

In this work, 3,720 km of 2D seismic reflection lines from the deep-offshore margin north of the Nazaré Fault (western Portugal) have been analysed and correlated with seismic data from the shallower Porto and Lusitanian Basins (Fig. 1). The seismic interpretation followed the methodology of Mitchum et al. (1977) and Hubbard et al. (1985). The criteria of Driscoll et al. (1995) were used to identify key tectonic events in the study area. In addition, the tectono-stratigraphic framework of Prosser (1993) was central to the seismic-stratigraphic analysis of syn- and post-rift packages in the deep-offshore basins. Data from key wells located in the Porto and Lusitanian Basins plus DSDP/ODP information from the deep Galician Margin (Wilson et al., 2001), Porto Margin (Groupe Galice, 1979) and Jeanne D'Arc Basin (Driscoll et al., 1995) have been used to characterise and date the interpreted seismic units (Table 1).

Seismic Stratigraphy

In total, nine seismic units were identified and correlated with the seismic-stratigraphic framework of Wilson et al. (2001). Their age, internal character, stratigraphic significance and lithology are summarised in Table 1.

New information on the deep-offshore basins of west Iberia

A correlation between the seismic-stratigraphic units on the continental shelf (Porto and Lusitanian Basins) and those in the deep-offshore basins north of the Nazaré Fault was attained using the interpreted information (Table 1). Three main sub-basins separated by major transfer faults were identified on seismic data within the Peniche Basin (Fig. 1). These sub-basins are presently segmented by northwest- to northeast-trending normal faults that bound the main

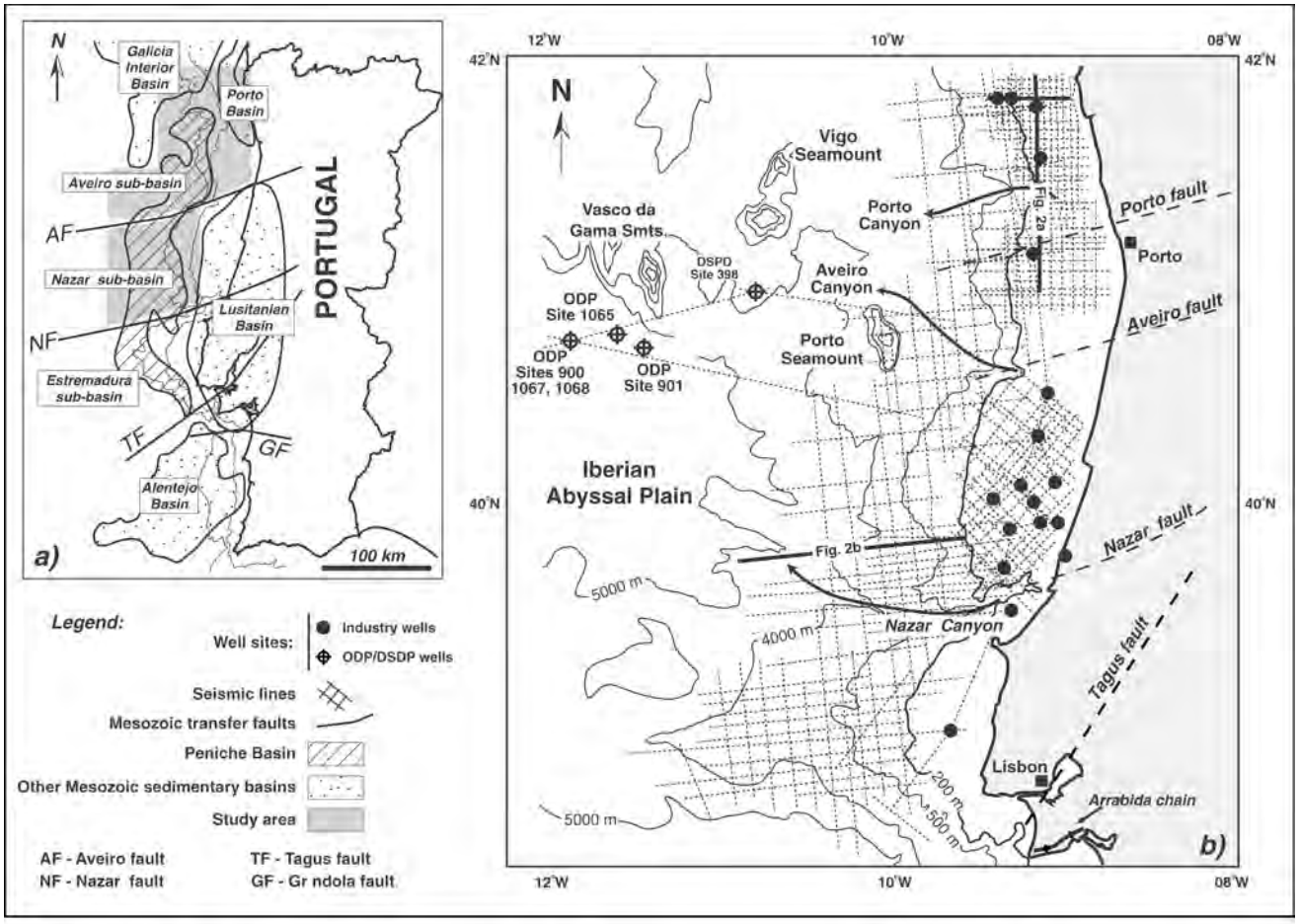

Figure 1. (a) Location of the study area and main offshore basins; (b) interpreted seismic and well data set.

bathymetric features of the continental slope and rise (Fig. 2). The northernmost Aveiro sub-basin, bounded to the south by the offshore prolongation of the Aveiro Fault, was filled by Mesozoic sequences that reach more than 3.0 s TWTT in thickness within distinct half-graben/graben sub-basins (Fig. 2a). The Mesozoic units are covered by >1.0 s TWTT of Cenozoic sediments. Salt structures locally pierce a moderately deformed overburden on the flanks of submarine mountains.

The central Nazaré sub-basin, bounded to the north by the Aveiro Fault and to the south by the offshore prolongation of the Nazaré Fault, shows relatively thick Jurassic units (up to 1.5 s TWTT) covered by relatively thin (<1.1 s TWTT) Late Berriasian-Aptian packages (Fig. 2b). Post-Aptian units are considerably developed in this region, reaching more than 1.5 s TWTT in thickness. Salt structures are scarce in the Nazaré sub-basin, in which the formation of easterly-tilted half-grabens predominated throughout the Meso-Cenozoic (Fig. 2b). This latter setting contrasts with the margin south of the Nazaré sub-basin, covered by folded and faulted sedimentary units most likely deformed during the Cenozoic compressional phases recorded in the shallow offshore basins.

The interpreted seismic data confirms the segmentation of the western Iberian margin in separate structural blocks on which distinct sedimentary basins developed during the Mesozoic rifting. These latter basins present sharp differences in their structural fabric and tectonic evolution, parameters that controlled their rift- and Alpine-related sedimentary evolutions. In addition, the two-stage evolutionary setting proposed for passive margins (Manatschal & Bernoulli, 1999) is evident in the study area: 1) Early Cretaceous sub-basins showing rift climax units, most likely formed during the initial Boudinage Stage, are spatially constrained to a narrow (<100 km) region stretched along the

Table 1. Summary of the principal features of the stratigraphic units in the study area.

Seismic Units	Age of base	TWTT Thickness (ms)	Internal character, geometry and terminations	Probable Lithology (Maldonado, 1979; Marsaglia et al., 1996; Moita et al., 1996)	Units in ODP Leg 149 (Wilson et al., 2001)
C4	Middle Pliocene	0-500	Transparent to low-amplitude internal reflections. Locally wavy. Wavy base on the deeper margin. Rare baselap.	Interbedded sand- to clay-rich turbidites, hemipelagites and pelagites.	1
C3	Early/Middle Miocene	0-400	Moderate- to high-amplitude sub-parallel reflections. Wavy towards the west. Local downlap.	Interbedded sand- to clay-rich turbidites, hemipelagites and pelagites.	2
C2	Middle Eocene	0-400	Low- to moderate-amplitude internal reflections, sub-parallel to wavy, locally transparent. Comprises the lower part of a prograding wedge in the Nazaré Basin. W-prograding clinoforms on the deeper margin. Downlap on its base.	Interbedded sand- to clay-rich countourites, turbidites, hemi-pelagites and pelagites.	3
K3-C1	Cenomanian-Turonian boundary	0-800	Low- to moderate-amplitude internal reflections, sub-parallel to wavy. Wedge-shaped unit thickening towards the west. Downlap is observed.	Sandy to clayey turbidites, pelagic oozes and local debris-flow deposits.	4
K2	Aptian-Albian boundary	0-500	Moderate - to local high-amplitude westerly-tilted clinoforms, mounded at places. Wedge-shape seismic unit thickening towards the west. Downlap visible on its base.	Pelagic oozes, local debris-flow deposits and turbidites. Serpentinite breccia with peridotite blocks and claystone drilled in Leg 149 (Site 899).	5
K1	Berriasian/Early Valanginian	0-1,750	Low- to moderate-amplitude internal reflections. Localised growth onto basin-margin structures. Fills half-graben/graben blocks close to the continental slope. Onlap onto its base.	Syn- and post-rift clayey and sandy turbidites. Higher sand rates related to active fault structures and to submarine canyons. Carbonate levels may be present in the association.	6
J3	Early Oxfordian	0-800	Moderate- to high-amplitude parallel reflections showing localised growth onto basin-margin structures. It underlies syn-rift units in the Nazaré Basin and comprises an intermediate package showing growth in the Aveiro Basin. Baselap is visible. Chaotic to low-continuity, irregular reflections observed in the Aveiro Basin.	Pre-rift siliciclastic (fluvial/deltaic?) and carbonate material in the Nazaré sub-basin. Marine siliciclastics (turbidites) in the deeper areas of the Aveiro and Nazaré sectors. Sandstones, clays and carbonate beds of transitional to deltaic/fluvial environments in the Porto Basin.	
J2	Sinemurian?	0-1,250	Low- to high-amplitude sub-parallel reflections, locally chaotic. Wedge- to lensoid-shaped. Baselap onto a high-amplitude continuous reflector. Shows growth in the Aveiro Basin.	Marine carbonates and shales.	
T-J1	Triassic	0-500	Chaotic to parallel internal reflections. Wedge- to lensoid-shaped unit, locally tilted. Occurs at the base of half-graben/graben blocks. Baselap is visible.	Continental to shallow marine siliciclastics and evaporites.	

continental slope; 2) Listric blocks and their associated (deep) detachments faults, formed during the Detachment Fault Stage, are observed west of the latter sub-basins and show scarce or no rift climax units.

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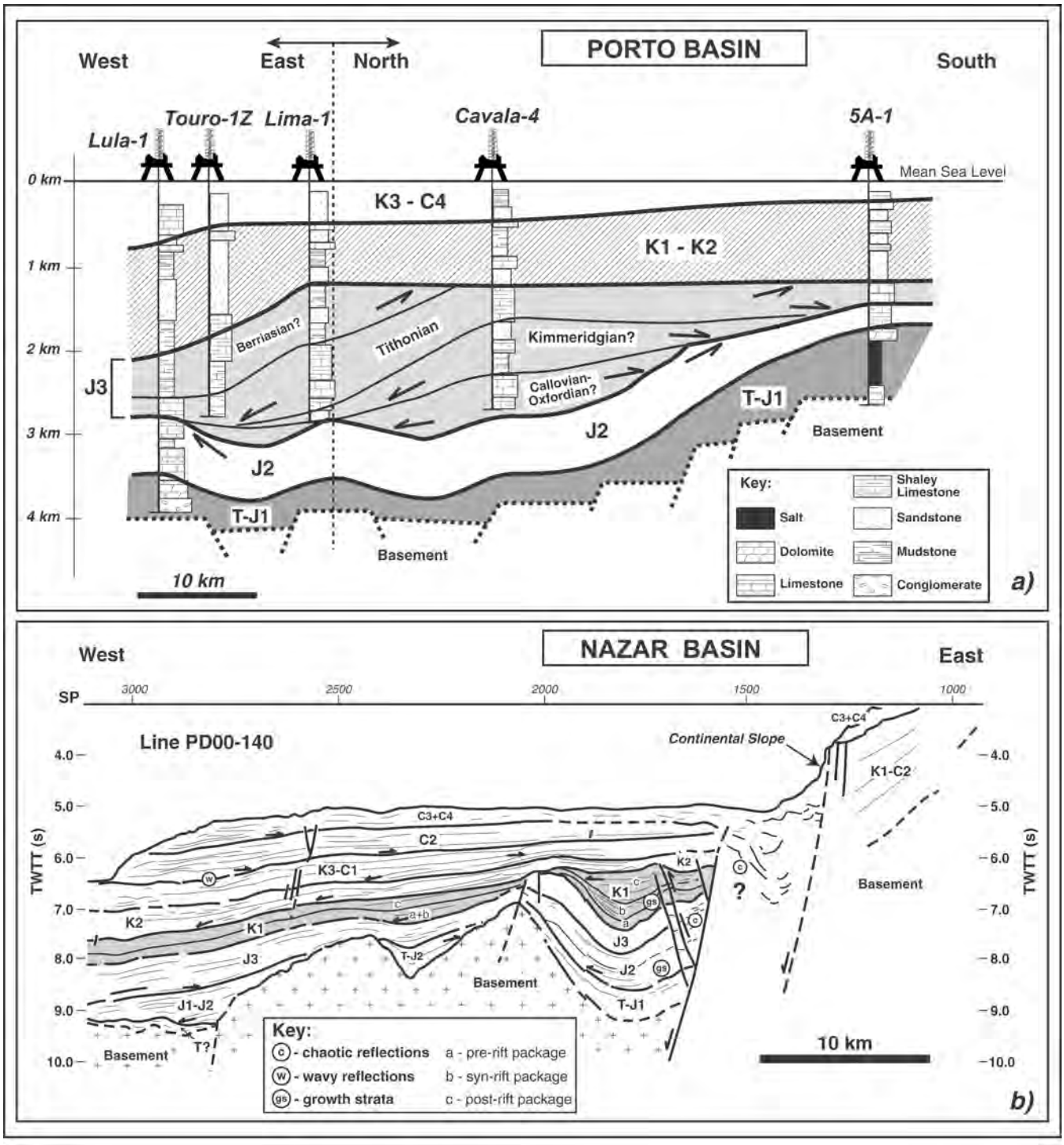

Figure 2. (a) Schematic section showing the main seismic-stratigraphic units in the Porto Basin. (b) Interpreted line drawing of line PD00-140, located in the Nazaré sub-basin. Note the existence of rift-related growth strata in the Early Cretaceous unit K1. Figure (a) taken from Moita et al. (1996). Figure (b) used with the permission of TGS-NOPEC.

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