The ESCI-València Trough vertical reflection experiment: a seismic image of the crust from the NE Iberian Peninsula to the Western Mediterranean

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Abstract: The València Trough project of the Spanish ESCI (Estudios Sísmicos Corteza Ibérica) programme focuses on deep seismic profiling at the NE Iberian margin. Up to 450 km of vertical reflection seismics have been acquired to map the present crustal structure of an area affected by successive extensional and compressional tectonics since Cenozoic times. A NW-SE crustal transect is made by a 50 km-long segment in the Iberian mainland that connects the ECORS-Pyrenees profile to the Mediterranean coast, followed by a 400 km-long line crossing the València Trough and its flanks and reaching the South Balearic basin. All the new vertical reflection data have been used to obtain the crustal sections presented in this paper, after a complete reprocessing of data on academic basis to improve the resolution of some crucial areas. Beneath sedimentary sequences well differentiated in each area, the upper crust is characterised by a general absence of reflectivity along the transect, in contrast to a highly reflective, laterally varying lower crust. The Neogene extensional tectonics has not produced a significant crustal thinning in the Iberian mainland, where the Moho is found around 32 km depth. Along the flanks of the València Trough the continental crust is affected by a strong thinning of 14-15 km that takes place in 50 km horizontal distance and concerns mainly the lower crust. Beneath the Balearic promontory, the reflectivity pattern suggests that compressional tectonics could have reached there deep crustal levels. High-reflective Messinian sediments and evidences of recent extensional tectonics characterise the South Balearic basin, where the crust seems to be very thin (about 6 km) and possibly of oceanic type. Further investigations by velocity-depth measurements are needed to constrain this continent-ocean transition.

Keywords: ESCI profiles, NE Iberian margin, vertical seismic profiling, processing, València Trough, Balearic promontory, South Balearic basin, crustal reflectivity, transect.

Resumen: Dentro del programa hispano ESCI (Estudios Sísmicos Corteza Ibérica), el proyecto "Surco de València" se centra en la adquisición de perfiles de sísmica de reflexión en el margen nor-oriental de Iberia. Entre 1991 y 1992 se adquirieron 450 km de líneas sísmicas para contribuir a la determinación de la estructura cortical actual de una zona afectada por una tectónica cenozoica con episodios sucesivos extensionales y compresionales. Los perfiles sísmicos forman una transecta cortical NW-SE, compuesta por un segmento terrestre de 50 km de longitud que conecta el extremo sur del perfil ECORS-Pirineos con la costa mediterránea, y seguido por una línea de 400 km a través del Surco de València y el promontorio Balear, hasta la cuenca Sud-Balear al SE de Mallorca. En el trabajo se presentan las diferentes secciones corticales obtenidas del análisis de todos los nuevos datos de sísmica de reflexión vertical. Se ha efectuado un reprocesado completo de los datos a nivel académico que ha permitido mejorar la resolución de algunas zonas de especial interés. Bajo la secuencia sedimentaria, bien diferenciada en cada área, la corteza superior muestra una notable ausencia de reflectividad a lo largo de toda la transecta, que contrasta con una elevada reflectividad en la corteza inferior. La tectónica extensional neógena no ha producido un adelgazamiento cortical significativo en el segmento terrestre, en el que se observa bajo los Catalánides y la cuenca de El Camp (Reus) un Moho sub-horizontal a unos 32 km de profundidad. Se ha elaborado una sección conjunta ECORS-ESCI que muestra la continuidad de las estructuras reflectivas en la corteza inferior, bajo la cuenca del Ebro hasta la costa mediterránea. En la sección marina se identifica la potente cobertera sedimentaria neógena, y se observa una clara variación lateral de la reflectividad en la corteza inferior. A lo largo de los flancos del Surco de València, la corteza continental se adelgaza sensiblemente (pierde 14-15 km en unos 50 km de distancia horizontal). El adelgazamiento parece afectar sobre todo a la corteza inferior. Bajo el promontorio Balear, la reflectividad es compleja en la corteza inferior, con sucesivas bandas reflectivas paralelas y buzantes, lo que sugiere que la tectónica compresiva en esta zona ha afectado a niveles profundos de corteza. La imagen reflectiva se pierde rápidamente hacia el SE, donde se apunta un adelgazamiento cortical progresivo. La cuenca Sud-Balear se caracteriza por sedimentos mesinienses muy reflectivos y fracturados, que denotan la importancia de la tectónica extensional más reciente. La corteza parece ser muy delgada, de unos 6 km de espesor, y posiblemente de tipo oceánico. No obstante, deberían llevarse a cabo estudios más detallados, sobre todo de la distribución velocidad-profundidad, que permitan precisar la naturaleza de la transición continente-océano en el Mediterráneo Occidental.

Palabras clave: perfiles ESCI, margen oriental Península Ibérica, sísmica de reflexión vertical, procesado, secciones corticales, Surco de València, promontorio Balear, cuenca Sud-Balear, transecta.

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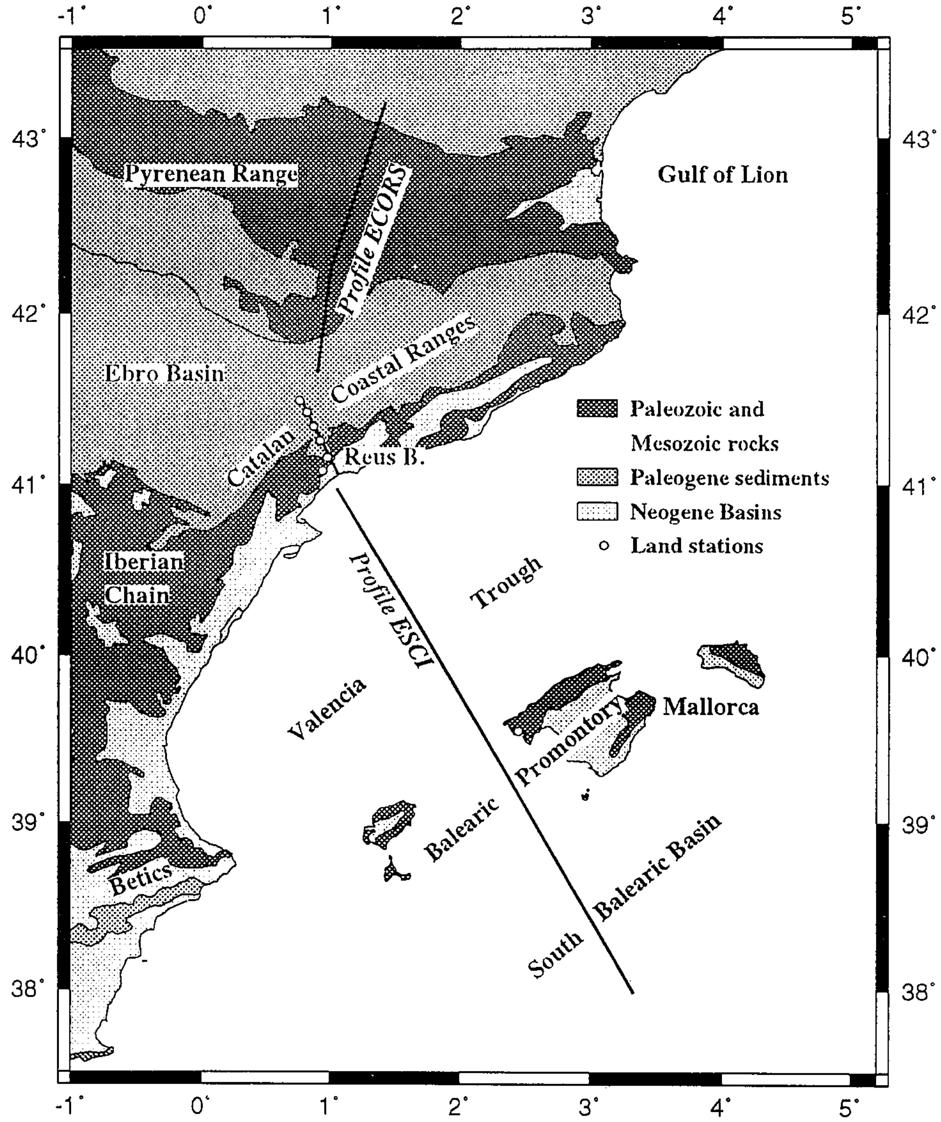


Figure 1.- Geological scheme of the NE Iberian margin showing the near-vertical ESCI-València Trough seismic reflection profiles and the land stations.

The Spanish ESCI Programme (Estudios Sísmicos Corteza Ibérica) was established to promote seismic investigations in national areas of key geodynamic interest. The NE Iberian margin, affected by successive extensional and compressional tectonics since Cenozoic times, was considered one of the priority areas to develop seismic reflection profiling. Hence, the ESCI-València Trough project was founded with the basic aim of characterising the lithosphere in the basins around the València Trough and revealing the transition between continental and oceanic structures.

The València Trough is the axis of a Neogene basin developed as a result of the subsidence induced by: a) extension related to the European continental rift; b) flexure in the foreland of the Betic-Balearic orogen. Additional effects to be considered are the Mesozoic extension associated to the basin formation in the Iberian Chain, and the Neogene extension in the South Balearic basin. The information provided by this project should tackle targets such as:

a) Architecture and geometry of the València Trough, to differentiate between symmetric and asymmetric extensional models. This includes the expression at depth of the extensional fault systems in the Catalan side, detachment levels and basal thrust of the Betic-Balearic system.

b) Seismic signature of the lower crust and upper mantle. This includes the analysis of lateral variations of the Moho in the area affected by the Neogene rift to establish the extensional mechanisms in the lower crust.

Taking into account the geophysical results coming from previous experiments and the funds available for our project, the working group decided to concentrate the efforts in completing a NW-SE structural transect. This transect would extend the seismic image of the ECORS-Pyrenees profile towards the Western Mediterranean, and provide for the first time a continuous structural image between a thickened crust of an Alpine range (the Pyrenees), across a thinned continental crust (València Trough) up to a locally thickened continental crust corresponding to the eastern end of the Betic Alpine range which finally gives place to an oceanic-type crust (South Balearic basin).

To achieve this, a 50 km-long profile on land was implemented between the southern end of the ECORS profile and the Mediterranean coast (Fig. 1). Moreover, a

400 km-long marine profile was acquired from the offshore prolongation of the land segment up to the South of Mallorca island.

In this paper, the analysis of the vertical reflection data and the final sections will be presented, as well as an overall description of the whole transect. More specific studies, including the wide-angle reflection informations available and discussing possible geodynamic implications of the seismic data will be developed in subsequent papers.

Geological and geophysical setting

The Cenozoic geodynamic evolution of the NE Iberian margin is considered to follow four main stages (Roca & Desegaulx, 1992; Vegas, 1992). The Late Cretaceous-Oligocene period was affected by a compressive regime related to the collision of the Eurasian plate and the Iberian microplate. A Late Oligocene-Early Miocene stage is related to the south-west propagation of the western European rift system and to the opening of the Provençal basin. The Early Miocene-Middle Miocene is associated with the compression deformation of the Betic-Balearic thrust belt and finally in Middle Miocene-Present period the area has been extensionally reactivated, although in some sector of the eastern Betic range compression has been recognised and is still working at present.

Many geological and geophysical studies have been carried out in the area during the last decade. Most of them have been concentrated in the València Trough and its margins. They are compiled in a special volume (Banda & Santanach, 1992a) and in a review article (Banda & Santanach, 1992b). A number of structural results show that the València Trough corresponds to a zone of strongly attenuated continental crust. Sediment thicknesses range from 1 km to around 6 km with velocities from 2.2 km/s to near 6 km/s (Banda & Santanach, 1992b). The upper crust reaches 12 km depth along the area with associated velocities of 6.0-6.2 km/s (Banda *et al.*, 1980; Gallart *et al.*, 1990; Dañobeitia *et al.*, 1992). Near-vertical profiles coming mostly from the Valsis experiment (Watts *et al.*, 1990) show a non-reflective pattern for this upper crust (Torné *et al.*, 1992; Collier *et al.*, 1994). The lower crust is characterised by rather low velocities, with a possible exception near the axis of the trough (Dañobeitia *et al.*, 1992), and it displays strong lateral variations in thickness and reflectivity along the trough (Watts *et al.*, 1990; Collier *et al.*, 1994). The derived crustal structure is in agreement with the gravimetric studies undertaken in the area (Torné & Banda, 1988; Watts *et al.*, 1990; Torné *et al.*, 1992; Gallart *et al.*, 1994). Finally, upper mantle velocities ranging from 7.2-7.9 km/s are reported at the València Trough area (Gobert *et al.*, 1972; Banda *et al.*, 1980; Dañobeitia *et al.*, 1992; Pascal *et al.*, 1992) in contrast to values of 8.1 km/s observed in the mainland (Zeyen *et al.*, 1985; Gallart *et al.*, 1990). Studies on subsidence history and thermal evolution (Watts & Torné 1992a-b; Maillard *et al.*, 1992; Roca & Desegaulx, 1992; Morgan & Fernández, 1992; Banda & Santanach, 1992b; Janssen *et al.*, 1993; Torres *et al.*, 1993; Collier *et al.*, 1994) favour a high degree of structural asymmetry for the València Trough and its flanks with respect to previous interpretations viewing the trough as a rift formed by pure shear (Vegas *et al.*, 1980).

Although the crustal reflectivity along strike in the Iberian and Balearic continental margins has been imaged in the Valsis experiment (Pascal *et al.*, 1992; Torné *et al.*, 1992; Collier *et al.*, 1994), a complete seismic picture of the lateral evolution of the deep crust across strike is still lacking. There is no information on the structural linking from the Ebro basin to the Mediterranean coast and on the nature of the thinning associated to the València Trough in this transition area. Morphology of the onshore/offshore transitions on the Catalan and Balearic margins is not constrained and variations in the reflectivity of the lower crust as well as in the geometry of the Moho are still not controlled in detail. Finally, no regional seismic reflection data had previously been recorded at the South Balearic basin where few geomagnetic measurements (Galdeano & Rossignol, 1977; Cassano, 1991) and one refraction experiment (Hinz, 1972) suggested the existence of a thin crust.

The ECORS-Pyrenees and ESCI-València Trough seismic reflection profiles altogether provide a 600 km-long crustal transect mapping the lateral evolution between a thickened continental crust (Pyrenees), a thinned continental crust (València Trough), a local crustal thickening (Balearic promontory) and an oceanic-type crust (South Balearic basin).

Data acquisition and processing

Up to 450 km of land and marine deep seismic reflection data were collected in the NE Iberian margin

	Profile ESCI on land	*Profile ESCI at sea*
Shot by	CGG (02/91)	GECO-Prakla (03/92)
Energy source	dynamite (20 kg)	airguns (7118 cu. ins.)
Shot point interval	240 m	75 m
Source depth	20 m	7.5 m
Number of traces	240	180
Trace interval	60 m	25 m
Near trace offset	90 m	180 m
Far trace offset	7230 m	4655 m
Streamer depth		15 m
Sample rate	4 ms	4 ms
Record length	25 s	20 s
Fold of recording	30	30

Table I.- Acquisition parameters for the near-vertical land and marine ESCI-València Trough profiles.

Table II.- Processing sequence for near-vertical ESCI-València Trough seismic profiles. In the middle part are listed common steps for land and marine lines. Specific parameters are within each column.

Profile ESCI on land		*Profile ESCI at sea*
	Resampling	
	-- 4 -> 8 ms	
	-- Anti aliasing filter applied	
	Geometry	
-- crooked line : 30 m bin width		-- 12.5 m bin width
	Data edition	
	Bandpass filtering	
	-- 0-50 Hz	
		F-K filtering
		-- -10 to +10 ms/trace (only applied to the first 50 km)
	Amplitude compensation	
	-- Spherical divergence correction	
	Energy balance	
Refraction statics		**Demultiple**
-- two layer model		-- Wave equation demultiple
-- weathering velocity 1900-4000 m/s		-- F-K demultiple
-- subweathering velocity 5000 m/s		
	CDP sorting	
Elevation statics		**Deconvolution**
-- floating datum, velocity 5000 m/s		-- Predictive : operator length 300 ms predictive gap 32 ms
	Dynamic corrections	
	-- Semblance and constant velocity analysis	
	-- NMO correction	
	-- Mute application	
Residual statics		
	Stack	
	-- fold 30	
	Elevation statics	
	-- final datum 400 m	
	Time and space variant bandpass filter	
	Scaling	
	-- 2 s window (AGC)	
	Time and depth migration	
	-- Finite differences algorithm	
	Semblance coherency filter	
	-- all velocity ranges	
	-- 20 traces window	

(Fig. 1) during 1991/92. Data acquisition and a first processing was carried out by CGG (land profile) and GECO (marine profile) companies. Afterwards, the data have been reprocessed at the Institute of Earth Sciences of Barcelona (Vidal, 1995) using ITA-Landmark software. Details concerning acquisition and processing parameters are shown in Tables I and II. The processing flow followed a standard approach of trace editing, amplitude loss recovery, prestack f-k and bandpass filtering, refraction and elevation statics, deconvolution, CMP sorting, dynamic corrections, residual statics, stacking, poststack filtering and scaling.

Special care was taken to perform static corrections along the land profile, which was processed into two separated segments to take into account the different geological units in the area. The first segment of the profile runs over the Neogene El Camp (Reus) basin. The second segment was shot over the Paleogene Ebro basin and the Palaeozoic of the Catalan Coastal Ranges, materials which have relatively similar seismic velocities. Two distinct velocity models, one for each zone, were produced and improved the upper crustal image. Residual statics corrections provided good results when computed by choosing high signal/noise ratio windows. Finally, all the sections displayed in the figures have an uniform datum of 400 m above sea level and a replacement velocity of 5 km/s has been considered.

At the marine profile the strong seabed reflector gives rise to a very dominant water layer multiple series in some areas which required attenuation. Combination of f-k and wave-equation demultiple techniques were found to be the most effective approach.

Due to the different frequency content of the land and marine profiles, poststack variant filters in depth and offset were applied.

Finally, both time and depth migrations were performed for the whole lines. In-line recordings onshore of the ESCI marine profile provide a complementary wide-angle data set (Gallart *et al.*, 1994, 1995; Vidal *et al.*, 1995; Vidal *et al.*, this vol.). Velocities coming from the forward modelling of these data were used for migration computations. Velocity changes in depth and offset were also considered.

The ESCI-València Trough transect

The complete time section along the whole ESCI-València Trough transect is presented in Fig. 2. More detailed time and depth sections are displayed and discussed in the following chapters.

Profile ESCI on land

Stacked and depth migrated sections for the profile ESCI on land are shown in Fig. 3. From NW to SE this profile crosses three main geological units: the Ebro basin over the first 24 km, the Catalan Coastal Ranges over the next 16 km and the El Camp (Reus) basin over the final 12 km (Fig. 1).

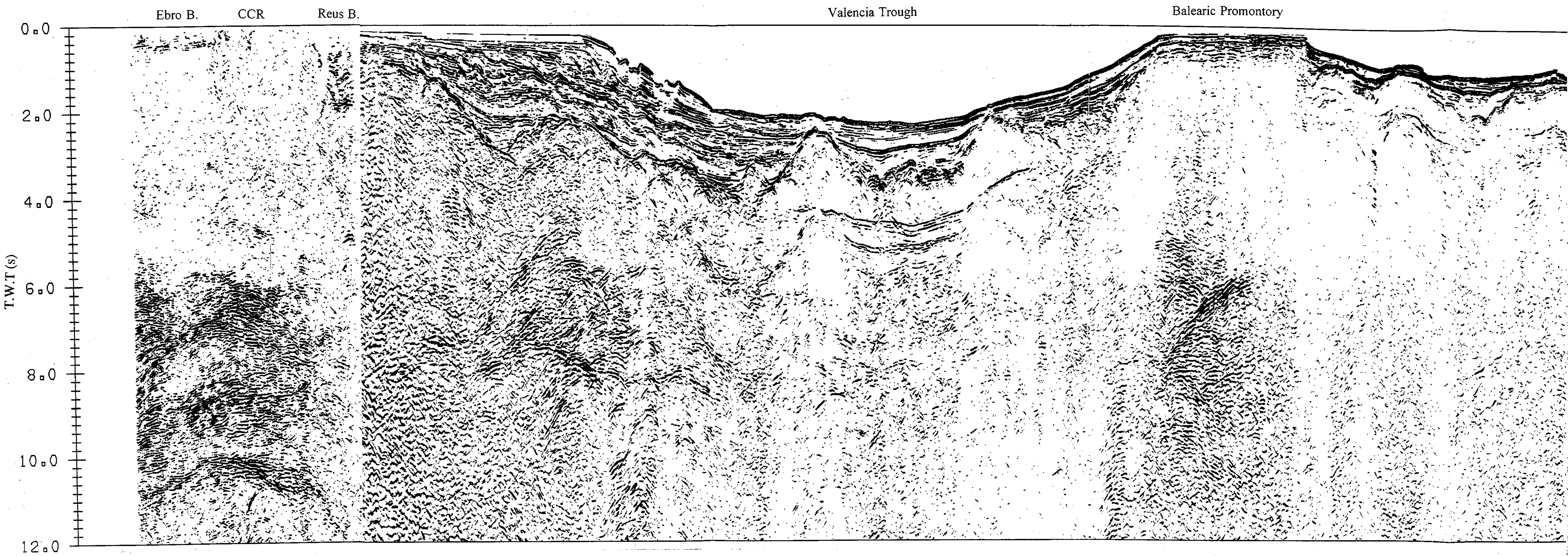
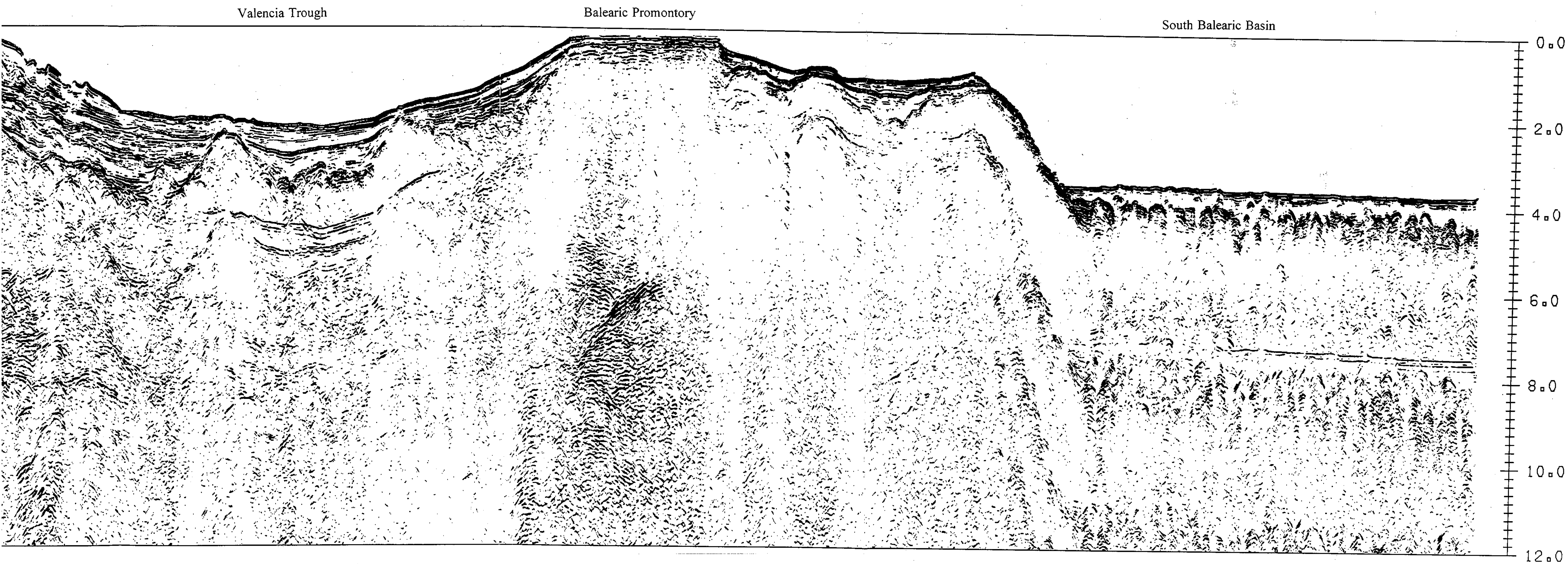


Figure 2.- Composite section of the near-vertical ESCI profiles on the Iberian mainland and at sea, across the València trough up to the South Balearic basin.


Valencia Trough
Balearic Promontory
South Balearic Basin
0.0
2.0
4.0
6.0
8.0
10.0
12.0

e South Bale-

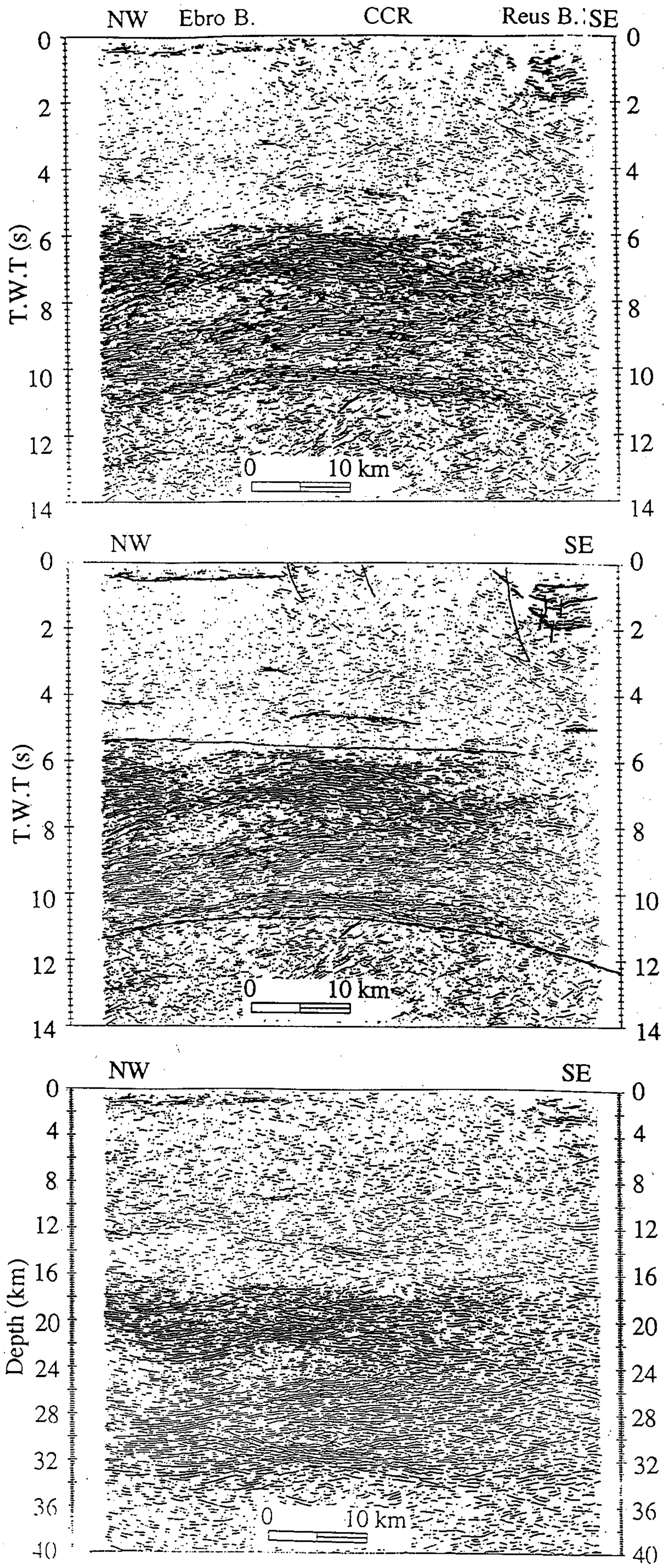


Figure 3.- (a: top panel) stacked and (c: bottom panel) depth migrated sections of the profile ESCI-València Trough on land. Main structural features are marked on (b: middle panel). CCR: Catalan Coastal Ranges.

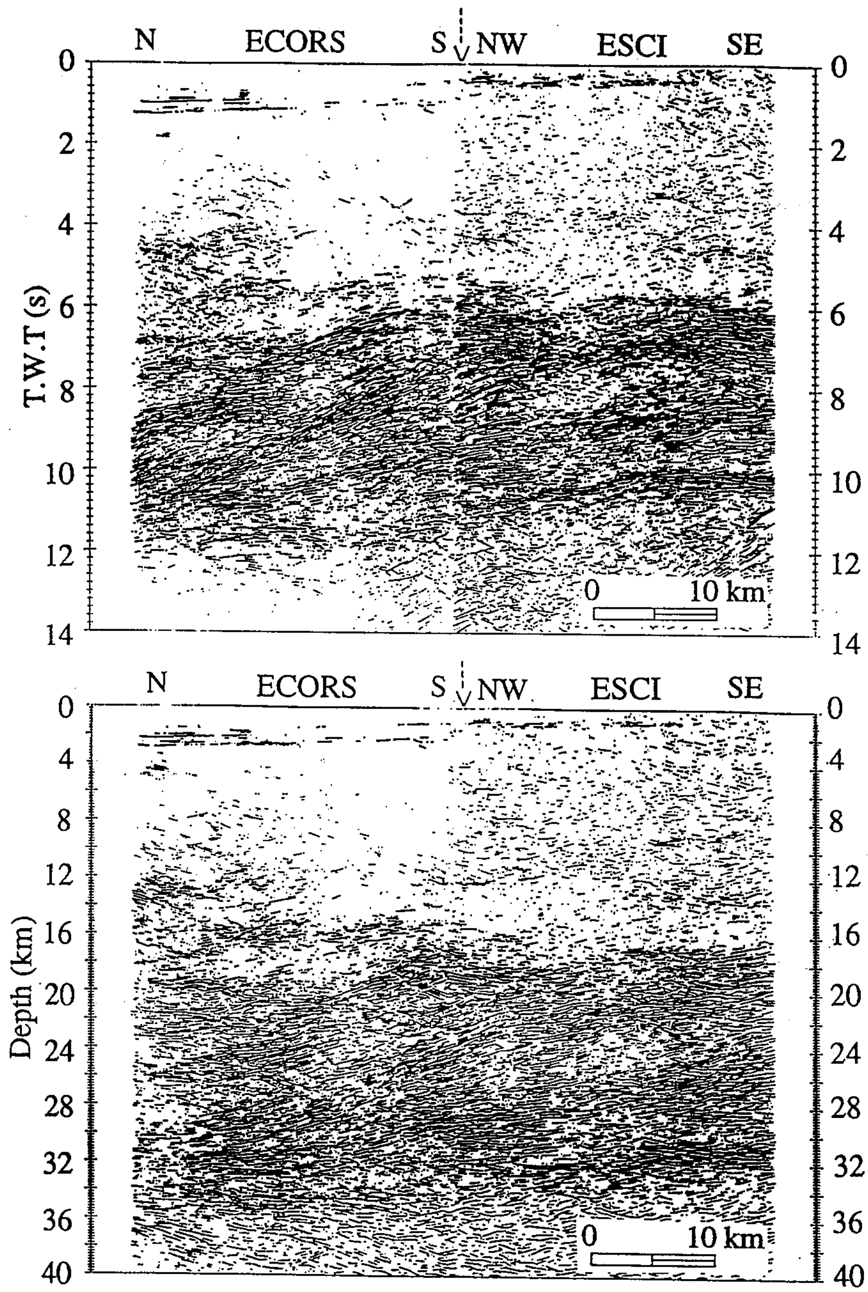


Figure 4.- Connection between the N-S ECORS and the NW-SE ESCI land profiles below the Ebro basin. (a: top panel) stacked and (b: bottom panel) depth migrated images.

Important lateral changes are found in the upper 2 s TWT along the line. The basement is imaged in the Ebro basin at about 0.5 s, shallowing towards the Catalan Coastal Ranges were a transparent upper part of the section is observed. The El Camp (Reus) basin has a 2 s thick Plioquaternary, Miocene and Mesozoic sedimentary sequence. These sediments are abruptly interrupted by a normal fault around 10 km inland. In this respect, some authors (Roca & Guimerà, 1992) proposed that the València Trough Neogene extension was carried out by a listric normal fault system. The profile ESCI on-land shows evidence of a steep fault but it is difficult to evaluate its morphology and the extent to which this fault penetrate the crust.

The upper crust shows few horizontal reflectors along the section in contrast to a highly reflective lower crust between 5.5 and 11 s. A band of strong reflectors at 11 s is attributed to the Moho, in agreement with the wide-angle interpretations in the area (Gallart *et al.*, 1994; Vidal *et al.*, 1995; Vidal *et al.*, this vol.).

Lower crustal reflectors display in the time section a general deepening to the North in the first 20 km of the profile and become horizontal under the Catalan Coastal Ranges. A change of the reflective pattern of the signal is observed below the El Camp (Reus) basin, at the southern 10 km of the line, characterised by a low-frequency scattered reflectivity. The complementary wide-angle constraints of this area (Vidal *et al.*, this vol.) suggest that this effect could be attributed to attenuation and scattering at the uppermost sediments of the energy from shots fired in a low-velocity weathered layer, rather than to structural changes in the deep crust. A second effect related to the sedimentary sequence is the deepening of the base of the crust in the area to about 12 s. This is due to the low velocities (2.4-3.0 km/s) at the uppermost 2 s of sediments, in front of the higher values (4.5 km/s) along the rest of the line. The depth migrated section (Fig. 3c) corrected this pull-down effect and shows the Moho almost horizontal at about 32 km along the whole section. The lower crustal reflectivity is imaged from 15 to 32 km (Fig. 3c).

The NW-SE oriented ESCI land profile was designed to connect the southern end of the N-S ECORS profile (Fig. 1) with the Mediterranean coast. In practice, logistic constraints and the requirement of sampling across strike the main structures of the Catalan Ranges resulted in a 15 km shift between the end of the two lines. However, assuming a lateral continuity of structures within this area of the Ebro basin, and considering that the acquisition parameters were identical for both lines, a poststack processing sequence (energy balance, semblance/coherency filtering, time and depth migration) has been applied to the ECORS profile (Vidal, 1995) in order to build up a continuous crustal image (Fig. 4). Migration velocities were taken from previous refraction studies in the area (Gallart *et al.*, 1980; Suriñach *et al.*, 1992). A high-reflective lower crust and a crustal thickening of 14 km is observed from the Ebro basin to the Spanish-French border (Vidal, 1995). Several geophysical studies related to this profile have been developed (ECORS Pyrenees Team, 1988; Choukroune & ECORS Team, 1989; Daignières *et al.*, 1989; Roure *et al.*, 1989; Desegaulx *et al.*, 1990; Choukroune *et al.*, 1990; Muñoz, 1992; Suriñach *et al.*, 1992, 1993). Here we will basically deal with the connection between ECORS and ESCI profiles (Fig. 4). A remarkable continuity, below the sediments, in the reflective pattern of the crust has to be pointed out. A transparent upper crust contrasts with a highly reflective lower crust from 5 to 12 s under the Ebro basin.

Profile ESCI at sea

The continuation at sea of the land profile constitutes a 400 km long deep seismic profile across the València Trough area up to the South Balearic basin (Fig. 1). To present and describe the whole line we divide it in three segments: the València Trough and its flanks, the Balearic promontory and the South Balearic basin.

The València Trough and its flanks. The stacked and depth migrated sections for the first 220 km of the marine line, from the Catalan coast to the Balearic promontory, are displayed in Fig. 5. Most prominent structural units (Vidal, 1995) are marked in the time section.

The sedimentary sequence is well resolved along the profile. We distinguish syn-rift and post-rift levels and the principal structural units are in agreement with previous interpretations in the zone (Roca & Desegaulx, 1992). The differences in structural style at the northwestern and southeastern NE Iberian margin allow two distinct domains to be distinguished (Fontboté *et al.*, 1990): the Catalan-Valèncian domain, characterised by extensional block faulting and the Betic-Balearic domain, dominated by folding and thrust faulting. The position of the boundary between these two domains is unclear. Some authors consider it to be located near the axis of the València trough (Roca & Guimerà, 1992; Roca & Desegaulx, 1992) while other interpretations place it in the southeast, close to the Balearic promontory (Maillard *et al.*, 1992). Along the ESCI profile (Fig. 5) extensional features in the Catalan flank can be inferred up to the centre of the trough showing the extensional synrift tectonics in the area. Nevertheless, the limit between extensional and compressional structures could not be easily imaged. From the centre of the trough to the Balearic promontory the evidences of the compressive front are masked by the existence of some structures (Fig. 5b) which could be of volcanic type, as suggested in previous interpretations (Maillard *et al.*, 1992) according to the magnetic anomalies present in that area (Galdeano & Rossignol, 1977).

Below the sediments the upper crust is mostly transparent. There are few evidences of upper crustal features along the whole segment. Lower crustal reflectivity is in general weaker on the marine profile than on the land segment. A 3 s-thick band between 5 and 8 s TWT is observed between 30 and 60 km offshore. The reflector at 8 s is associated to the base of the crust which has a 19 km thickness (Fig. 5c) in agreement with the wide-angle results in the area (Vidal *et al.*, this vol.). A similar reflective image was found in the ENE-WSW Valsis-819 profile (Torné *et al.*, 1992) which crosses the ESCI sea line at 35 km offshore. In the central part of the València Trough the presence of remnant strong water multiple energy perturbs the resolution of the deep crustal structure. The Balearic flank of the València Trough is characterised by an absence of laterally coherent deep reflections. The volcanic-type structures evidenced in the area could produce an important absorption of the energy justifying the lack of deep reflectivity there. On the other hand, a high reflectivity beneath 5 s is concentrated on the northwestern side of the Balearic promontory. This crustal reflective pattern will be discussed in the next section.

The lateral evolution of the lower crust and Moho across the Iberian onshore/offshore transition is not well resolved. Fig. 6 displays together the profile ESCI on land and the first 50 km of the marine line. This composite image shows inland a 5 s thick lower crust and the crust-mantle boundary at 11 s. Seawards, after 20 km without clear deep reflections, the bottom of the crustal reflectivity is observed around 8 s and the thickness associated to the lower crust is only 3 s. Other near-vertical seismic sections available in the area, from the Valsis experiment (Torné *et al.*, 1992; Maillard *et al.*, 1992), have similar features: clear deep reflective images along the Catalan platform and lack of resolution across strike of structures. Similarly, the features of the transition offshore the Balearic promontory are not well constrained. On the contrary, the wide-angle reflection data in the area, with very different sampling paths and energy/frequency content show clear reflections coming from the base of the crust in both areas and constrain the deep crustal features across strike (Gallart *et al.*, 1995; Vidal *et al.*, 1995; Vidal *et al.*, this vol.).

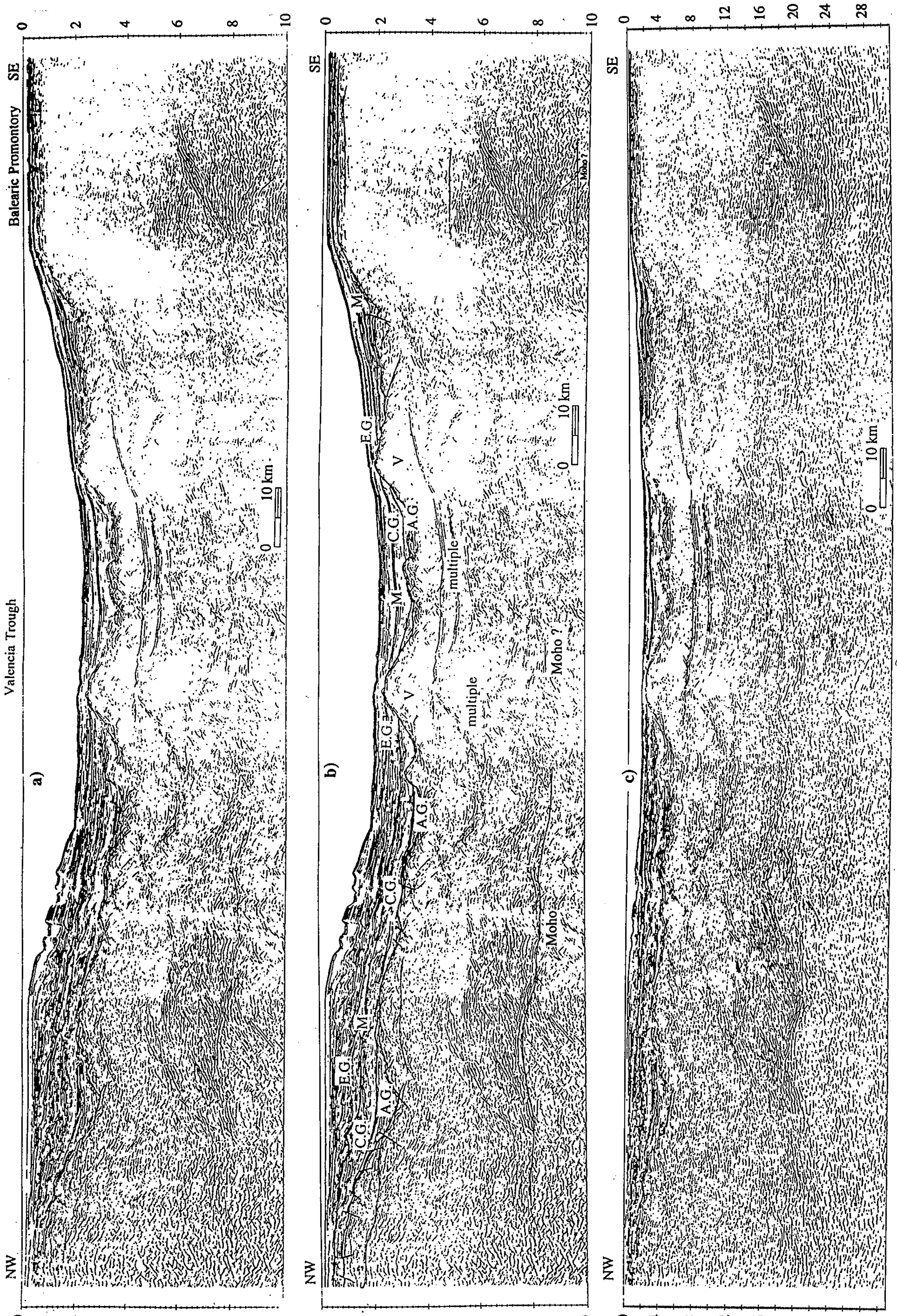


Figure 5.- (a), (b) stacked and (c) depth migrated sections of profile ESCI at sea for the València Trough and its flanks. The marked sedimentary sequence: Pliocene-Pleistocene (E.G.), Messinian (M), Middle-Late Miocene (C.G.) and Lower-middle Miocene (A.G.) is in agreement with previous interpretations in the area (Roca & Desegaulx, 1992). V indicates possible volcanic structures.

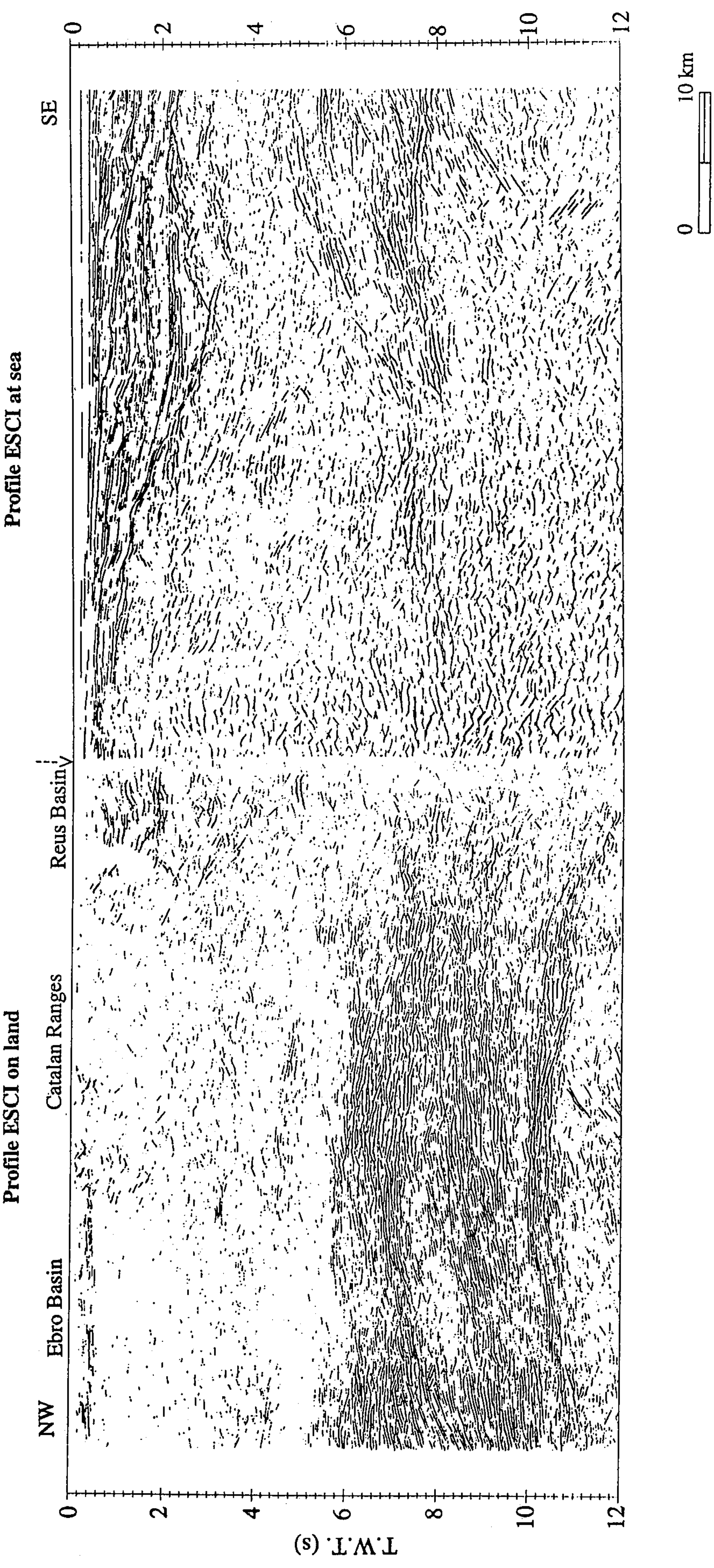


Figure 6.- Composite stacked section of the near-vertical ESCI-València Trough profiles on land (left side) and at sea (right side). The arrow marks the shoreline.

The Balearic promontory. The stacked and depth migrated seismic sections along the Balearic promontory and its connection with the South Balearic basin are displayed in Fig. 7.

The sedimentary sequence is well defined and the most prominent reflector is associated with the Messinian episode along the whole line. Extensional features could be observed affecting basement and sedimentary levels.

A lack of reflectivity is again observed for the upper crust. Deeper levels show important lateral changes. The first 40 km display a high reflectivity which should be associated to the lower crust. Along these first 40 km the depth migrated section (Fig. 7c) displays a thick deep crustal reflectivity from 12 to 30 km. A complex structure with horizontal and dipping reflectors could be observed. If we associate the crust-mantle transition to the bottom of the reflective zone (10 s or 30 km) this seismic

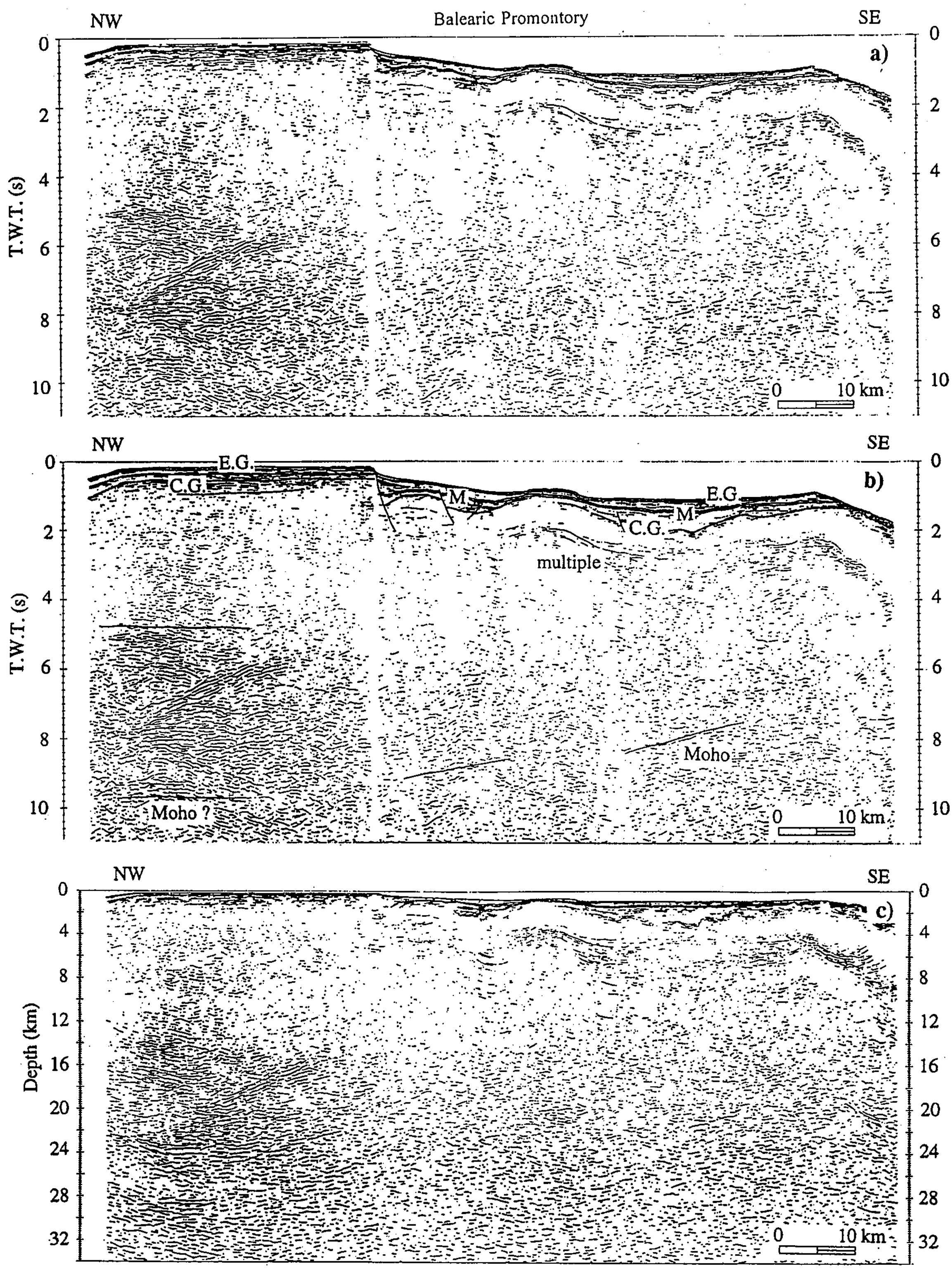


Figure 7.- (a), (b) stacked and (c) depth migrated sections of profile ESCI at sea for the Balearic promontory area. Sedimentary captions as in Fig. 5.

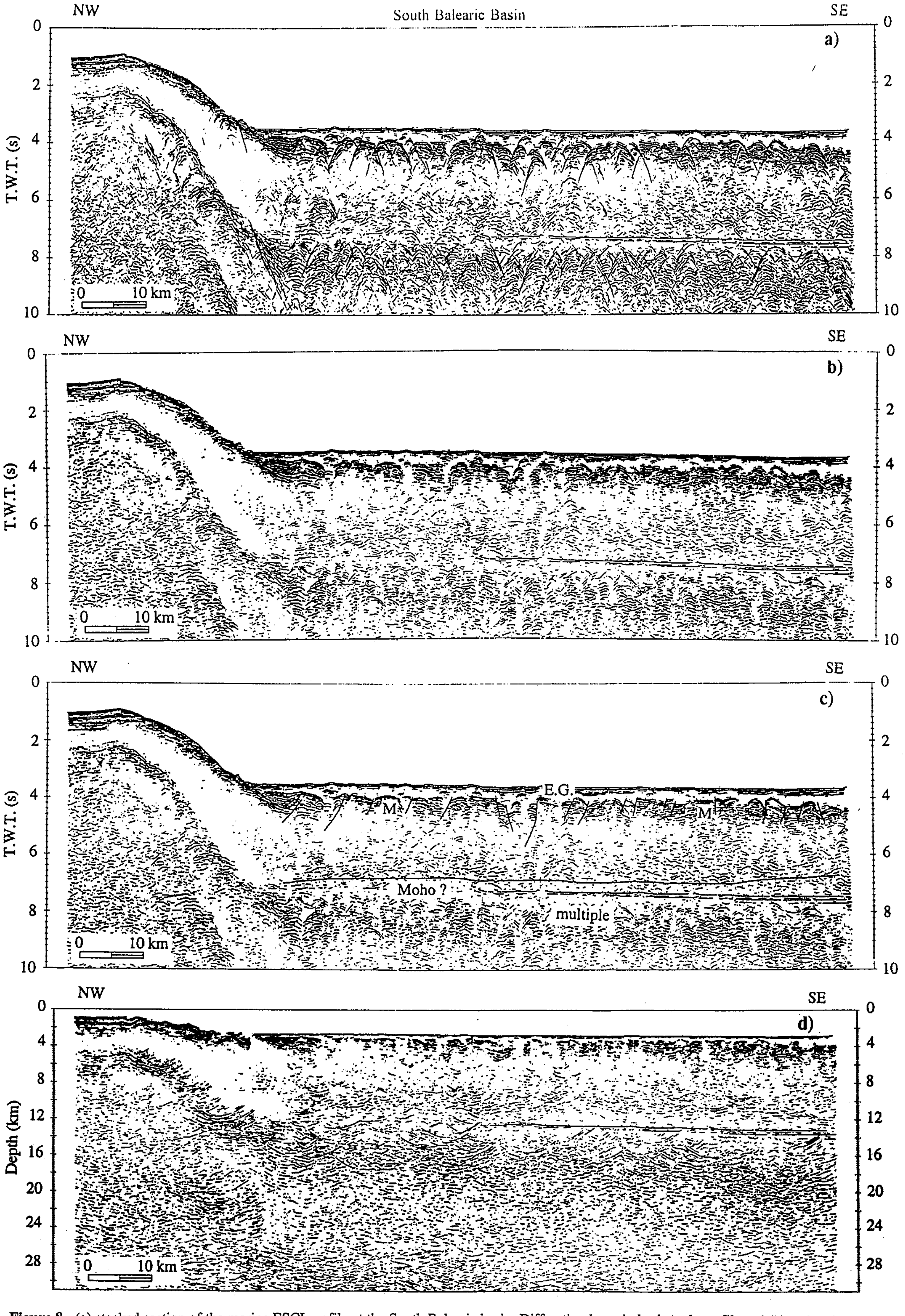


Figure 8.- (a) stacked section of the marine ESCI profile at the South Balearic basin. Diffraction hyperbolas have been filtered (b) and main structural features are marked (c) for this profile. (d) shows depth migrated results. Sedimentary captions as in Fig. 5.

image rises some discrepancies with previous studies along the Balearic slope from ESPs and vertical profiling (Pascal *et al.*, 1992; Watts & Torné, 1992a) or beneath Mallorca island from wide-angle data (Banda *et al.*, 1980; Dañobeitia *et al.*, 1992), which all reported Moho depths around 24-26 km. A more coincident explanation would be to associate in our profile the Moho to the prominent band of reflections around 8 s, and attributing the energy remnant to 10 s to mantle reflectivity. Alternatively, it can be argued that high-frequencies involved in near-vertical acquisition would resolve different reflective levels within the lower crust, at variance with the low-frequency sampling of the wide-angle approaches. The complex seismic image, with successive horizontal and dipping reflectors, could be related to the compressional stage at the Balearic promontory that may have caused a duplication in some crustal levels resulting in a thickened lower crust.

To the SE the crust is on the contrary very transparent, with only evidences of a deep reflector, shallowing southwards from 10 to 7 s TWT (30 to 18 km in depth) which is interpreted as the Moho. This different behaviour of a progressively thinned crust could be explained by the abrupt disappearance of the External Betic domain and its sudden shift by an anomalous thin crust which may be attributed to the Internal Betic domain.

The South Balearic basin. The southern 100 km of the ESCI marine profile are clearly different from the rest of the line. The obtained stacked section is displayed in Fig. 8a.

Below the Plioquaternary sediments we observe a highly reflective level at 4-4.5 s TWT. In a classical oceanic tectonic context this reflector would be associated with the oceanic basement. Nevertheless, considering the western Mediterranean geodynamic evolution as well as the structural results in comparable areas (de Voogd *et al.*, 1991) this reflectivity is attributed to the Messinian evaporitic sequence. The Messinian level appears clearly fractured throughout, suggesting an intense extensional activity. The stacked section (Fig. 8a) is full of diffraction hyperbolas which difficult the structural interpretation. A section after filtering of the diffraction branches is shown in Fig. 8b and interpretation in Fig. 8c. Depth migrated results are displayed in Fig. 8d. Normal faults along the area show extensional activity and salt structures affecting the Plioquaternary sedimentary cover. Similar images were found in the Gulf of Lion (de Voogd *et al.*, 1991).

Beneath the Messinian sequence we have no evidence of reflections which could be associated to the basement, apart from a short horizontal reflector pointed out at the end of the line, at about 4.5 s.

The deep crustal structure in the South Balearic area is not well constrained. A single reflective level is fragmentary observed along the line around 6-7 s TWT (Fig. 8). This level could be interpreted as the upper/lower crustal transition, and in this case, later strong multiples associated to the seaflor and to the Messinian level mask the crust/mantle transition. Alternatively, the reflections at 6-7 s can be associated with the base of the crust, which then reveal the presence of a much thinner crust (about 6 km) at this basin, with possible oceanic configuration. This would be in agreement with a velocity-depth interpretation of old, limited-quality refraction data in the same area (Hinz, 1972). Unfortunately, the coverage of the wide-angle data from the ESCI line recorded in Mallorca does not extend to the South Balearic basin and can not constrain this continent-ocean transition.

Conclusions

The ESCI-València Trough seismic programme has acquired in the NE Iberian margin up to 450 km of high quality land and marine vertical reflection data. After a standard processing by the acquisition companies, a complete reprocessing of the data has been undertaken on academic basis to enhance the depth images of some crucial areas. Moreover, new specific processing has been designed for the wide-angle information (Vidal, 1995) to produce combined sections that include all the small and large-aperture reflection data available.

The final sections presented in this paper document the lateral variation in the crustal structure along a transect from the Ebro basin, across the València Trough and its flanks, up to the South Balearic basin. The crustal image of the ECORS-Pyrenees profile is prolonged to the Mediterranean coast by the ESCI land profile. Similar processing of both lines confirms the remarkable continuity between them in the Ebro basin. The base of the crust remains at around 32 km depth up to the coast, indicating that in the profile area the Neogene extensional tectonics has not produced a significant crustal thinning inland.

In the Iberian mainland the lower crust is characterised by a persistent band of 5-6 s thick of high reflectivity, in contrast to short-wavelenght lateral changes of its reflective character along the marine profile, where the reflectivity band is at most 3 s thick.

Beneath the València Trough the different seismic sections available and the results on velocity-depth modelling, including the wide-angle analysis of the ESCI profile (Vidal *et al.*, this vol.), confirm that the crust is of continental type, although strongly attenuated. In the ESCI vertical section (Fig. 5), the Moho rises up to 17-18 km beneath the València Trough axis. Therefore, the ESCI transect reveals a crustal thinning of about 15 km that takes place in 50 km horizontal distance. This is among the strongest thinnings reported in comparable passive margins (Watts & Torné, 1992b). However, the lateral variation of the Moho is not fully constrained by the vertical section as the onshore/offshore areas lack resolution at depth. The multichannel wide-angle analysis performed (Vidal, 1995) reveals the steady thinning of the crust from the Iberian and Balearic margins to the centre of the València Trough.

Beneath the Balearic promontory, complex reflectivity observed in a thick lower crust indicates that compressional tectonics, although difficult to be evaluated in the present image of the upper crust, has reached deep crustal levels.

A further crustal thinning is evidenced towards the South Balearic basin. In the abyssal plain the section is characterised by a clear change in the reflectivity pattern with widespread evidences of recent extensional tectonics and a high-reflective Messinian evaporitic sequence. Below the sediments, the crust seems to be very thin (about 6 km), which suggest an oceanic nature. However, the continent-ocean transition in this area is not well resolved in the absence of reliable velocity-depth modelling. This appears as a major target for future studies in order to better constrain the geodynamics of the Western Mediterranean.

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