Results from the ESCI-N3.3 marine deep seismic profile along the Cantabrian continental margin

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Abstract: The seismic profile ESCI-N3.3, sub-perpendicular to the strike of the Variscan structures, has imaged the offshore continuation of the central section of the NW Iberian Massif. This study describes its main geological features and proposes tectonic interpretations based on geological information and constrained by available refraction/wide-angle reflection data. The main results include the identification of two Mesozoic-Cenozoic sedimentary basins, the occurrence of mid-crustal dipping events related to the fold and thrust tectonics of the Westasturian-Leonese Zone and the possible existence of a crustal-scale basal detachment for this zone. The reflectivity is generally high at lower crustal levels. In addition, dipping events appearing below the reflective lower crust might bear upon Alpine subduction zones.

Keywords: Deep seismics, Iberian Massif, North-Iberian continental margin, crustal structure, Variscan Belt.

Resumen: El perfil sísmico ESCI-N3.3, que discurre con una dirección normal a las estructuras varíscicas, refleja la prolongación del sector central del NW del Macizo Ibérico bajo la plataforma continental. Se describen las principales características geológicas del perfil sísmico y se proponen interpretaciones tectónicas utilizando información geológica así como datos sísmicos de gran ángulo registrados en tierra. Los resultados más significativos incluyen la identificación de dos cuencas sedimentarias meso-cenozoicas, la aparición de reflectores inclinados en la corteza media, relacionados con los pliegues y cabalgamientos de la zona Asturoccidental-Leonesa y la posible existencia de un despegue basal de escala cortical para esta zona. La reflectividad es, en general, alta en los niveles corticales inferiores. Por último, algunas reflexiones inclinadas que aparecen en el perfil por debajo de la corteza inferior reflectiva podrían estar relacionados con zonas de subducción alpinas.

Palabras clave: Sísmica profunda, Macizo Ibérico, margen continental Nord-Ibérico, estructura cortical, Cadena Varíscica.

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The ESCIN-3.3 seismic profile is part of an extensive multichannel seismic experiment accomplished along the Cantabrian region and the continental margin and deep sea areas offshore Asturias and northern Galicia (Álvarez-Marrón *et al.,* 1996). The experiment consisted of four deep multichannel seismic profiles named ESCI-N (Estudio Sísmico de la Corteza Ibérica Norte). Two of them were obtained on land and the other two at sea (Fig. 1).

This paper deals with the description and main tectonic implications of the easternmost part of ESCI-N3, the largest of the marine profiles (Figs. 1 and 2). This profile was envisaged with the purpose of getting insights into the Variscan structures and the evolution of the Cantabrian continental margin. It runs roughly perpendicular to the strike of the Variscan structures, crossing the transition from deep sea to the continental margin and is subdivided in three segments of different lengths and azi-

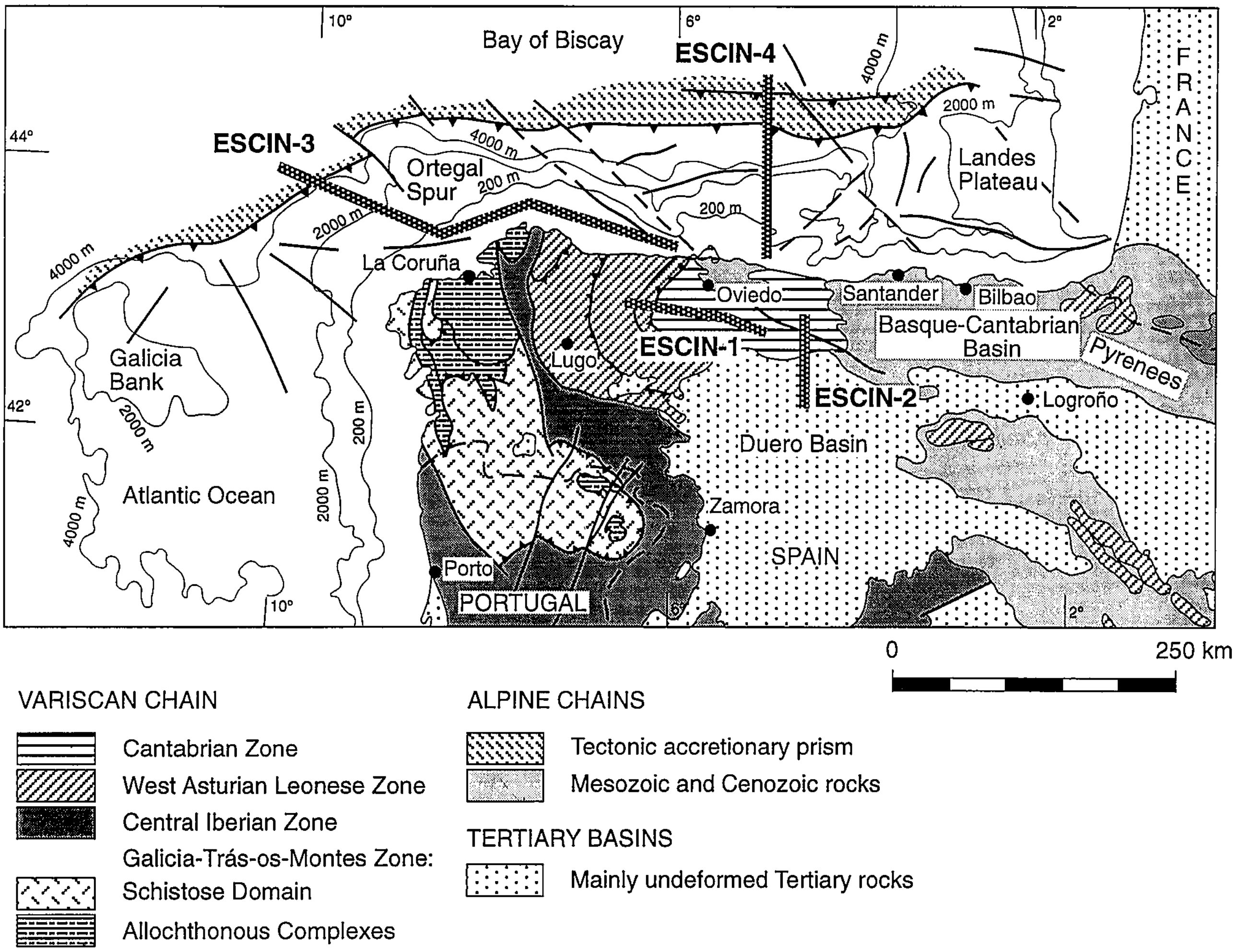


Figure 1.- Geological sketch of northwestern Iberia with location of the ESCI-N seismic profiles. Zones in the Iberian Massif after Julivert *et al.* (1972) and Farias *et al.* (1987). Offshore geology after Boillot & Malod (1988).

muths. The first one, to the West, is 141 km long, has a WNW-ESE strike, and its objective was the study of the transition between oceanic and continental crust as well as the structure of the margin. It is followed to the East by two segments, 98 and 141 km long and oriented WSW-ENE and WNW-ESE respectively, which were designed mainly to image the deep structure of hinterland areas of the Variscan orogen.

Geological setting

The Variscan basement

The basement outcrops almost continuously on land close to the surveyed area (Fig. 2) and, in this part of the Iberian Massif, it includes three different tectonostratigraphic zones: from East to West, the Westasturian-Leonese Zone, the Central Iberian Zone, and the Galicia-Trás-os-Montes Zone. The Variscan structures include overturned or recumbent folds with east vergence in all three zones. The recumbent folding was followed by east-directed thrusts and the ensemble affected by late folds with subvertical axial planes. From surface mapping and structural criteria, the geometry of the structures can be extrapolated to a depth of 5-15 km (Fig. 2). A picture of the structural evolution of the area may be seen in Pérez-Estaún *et al.* (1991).

The Westasturian-Leonese Zone (Julivert *et al.*, 1972) is characterised by a thick, pre-orogenic sequence that includes Upper Proterozoic terrigenous sediments with turbidite facies and shallow-water Lower Cambrian to Lower Devonian deposits. Internal deformation is conspicuous as well as regional metamorphism, which increases progressively toward the West from greenschists to amphibolite facies. Variscan granitoids are common in its western part. This zone is well-represented in the coastal section and, undoubtedly, in the profile. The western half of the zone is occupied by the Mondoñedo nappe, a thrust sheet with kilometric-scale recumbent folds (Matte, 1968) which are cut by a basal detachment with an associated ductile shear zone in its hangingwall (Marcos, 1973; Bastida & Pulgar, 1978; Martínez Catalán, 1985; Bastida *et al.*, 1986). Originally subhorizontal, the nappe was folded by a pair of steep open folds, the westernmost of which is an antiform in whose core outcrops the relative autochthon, forming the Xistral tectonic window (Martínez Catalán, 1985). The eastern half of the zone is known as the Navia and Alto Sil Domain (Marcos, 1973). It consists of a series of overturned folds and thrusts with a generalised dip to the West of between

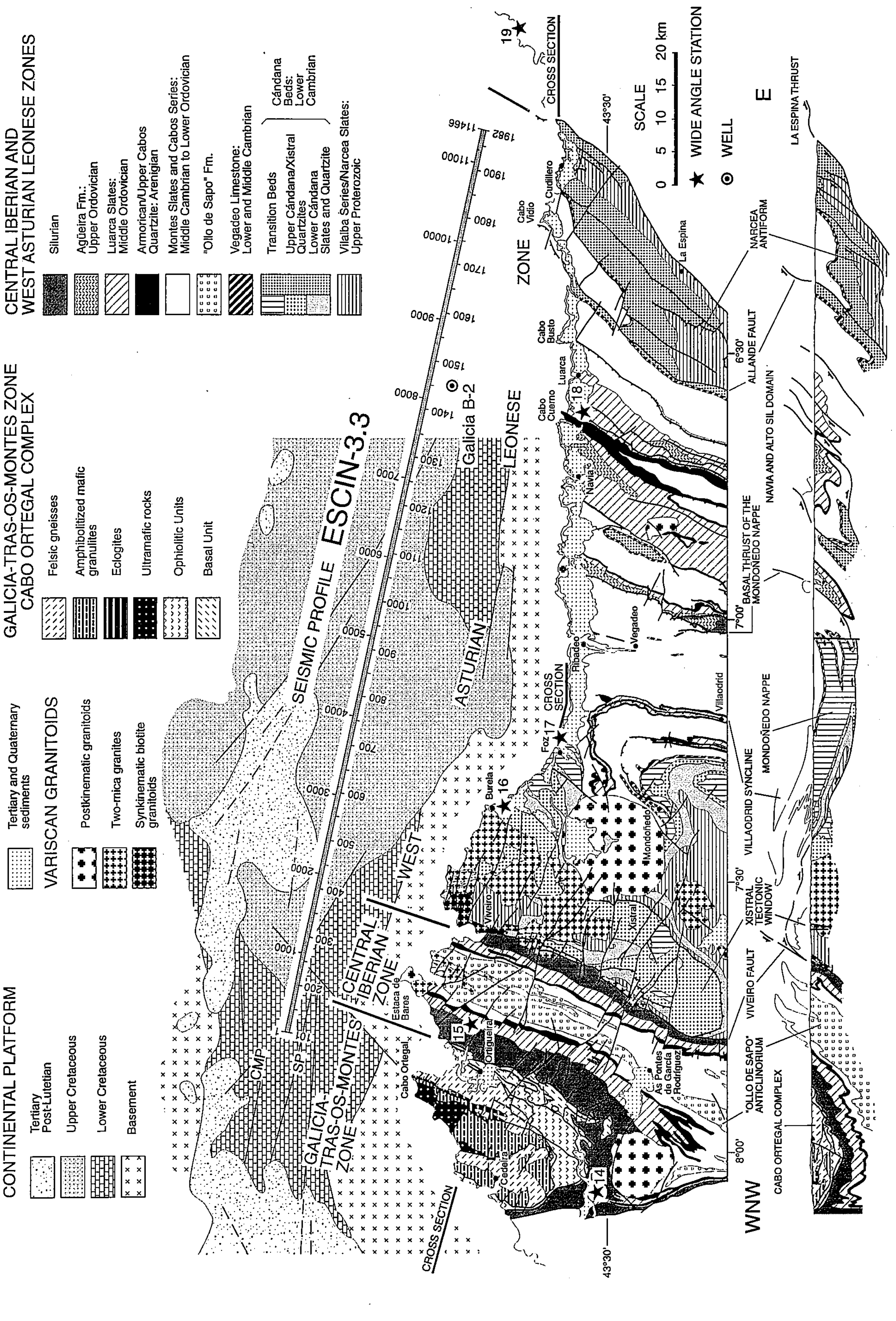


Figure 2.- Geological map and cross-section of the northern part of the Iberian Massif in the area surveyed by the profile ESCI-N3.3. Geology after Marcos (1973), Bastida *et al.* (1982), Martínez Catalán (1985) and Arenas (1988). Offshore geology after Lamboy & Dupeuble (1975). The location of the seismic line is shown, with indications of the shot point (SP) and common mid point (CMP) numbers. The situation of wide-angle stations 14 to 19 and of the Galicia B-2 drill is also shown.

30° and 50°. This domain continues beneath the Mondoñedo nappe and outcrops in the Xistral tectonic window. The eastern limit of the zone corresponds to La Espina thrust, an important detachment with a ductile shear zone in its hangingwall (Gutiérrez Alonso, 1992), which marks the transition from the hinterland to the foreland, represented by the Cantabrian Zone (Fig. 1).

The Central Iberian Zone (Julivert *et al.*, 1972) is represented in NW Spain by a narrow, arcuate band known as the "Ollo de Sapo" anticlinorium. Lower Ordovician clastics overlie the "Ollo de Sapo" Formation (Parga Pondal *et al.*, 1964), a porphyroid of subvolcanic to volcanoclastic origin. Deformation, metamorphism and Variscan magmatism are comparable to those of the previous zone. The anticlinorium is formed by the interference of recumbent folds and tight, subvertical late folds. In the coastal section, the main structures correspond to the recumbent set, but have been rotated close to a vertical position by the late steep folds (Bastida *et al.*, 1993). The eastern limit of the zone is the Viveiro fault (Fig. 2), a Variscan normal detachment which dips between 40° and 60° W (Martínez Catalán, 1985). The anticlinorium should continue towards the West beneath the Cabo Ortegal Complex, according to the geological map. The presence of this zone in the western part of the seismic profile is considered very probable.

The Galicia-Trás-os-Montes Zone (Farias *et al.*, 1987) consists of a stack of allochthonous units with different lithological associations and tectonothermal evolution. They include ophiolites and rocks that show the imprint of high-pressure metamorphism related to subductive processes. Two domains have been distinguished: the Schistose Domain, below, with Iberian affinities, and the Allochthonous Complexes, above, with ophiolites and high-pressure rocks. The ophiolites represent the suture of a collision between Gondwana and a terrain of unknown provenance and origin. This zone may be represented in the seismic profile by the Cabo Ortegal Allochthonous Complex, which outcrops in the core of a late, subvertical synform. Its eastern limb could continue to the North, reaching the seismic line but, due to the probable existence of faults, subparallel to the coast and with important displacements (Lamboy & Dupeuble, 1975), its presence in the profile is uncertain.

The Cantabrian margin

The northern Iberian continental margin was formed by a Late Jurassic-Early Cretaceous rifting process (Boillot *et al.*, 1979), originated by the counterclockwise rotation of Iberia with respect to stable Europe (Van der Voo, 1969; Sibuet, 1989), which lead to the formation of the Bay of Biscay oceanic crust. During the Tertiary, a change in the relative movement of Iberia and Europe gave rise to a convergence process that reactivated the margin, developing a marginal trench associated with the incipient southward subduction of the oceanic crust beneath the Cantabrian margin (Sibuet & Le Pichon, 1971; Boillot *et al.*, 1979; Grimaud *et al.*, 1982). Moreover, the convergence of the margin induced the inversion of the previous extensional basins, including the inversion of normal faults and the folding of the sedimentary cover. (Boillot *et al.*, 1971, 1979).

A map of the continental shelf between Cabo Ortegal and Navia was produced by Lamboy & Dupeuble (1975), based on single channel seismic profiles and seabottom sampling. According to it (Fig. 2), several normal faults run subparallel to the coast between 5 and 10 km to the north of the shore line. They separate the outcropping basement, to the South, from a sedimentary succession that includes Lower and Upper Cretaceous shallow marine sediments. Their thickness has not been quantified but increases rapidly from the bounding faults seawards. According to these authors, an intra-Cretaceous discordance is seen in the profiles and the Mesozoic sediments appear folded by a phase dated as probably Middle Eocene. The fold trend is parallel to the coast.

There are several commercial multichannel seismic profiles covering the area. In particular, a network of profiles striking N-S and E-W, named LC77, were acquired in 1977 by ENIEPSA covering the area from the north of Cabo Ortegal to the north of Foz. They give information concerning the sediments which supports the data of Lamboy & Dupeuble (1975). A published well log (Galicia B-2), 19 km to the N of Luarca (Querol, 1987), depicts 1416 m of Triassic to Albian sediments: clays, silts, sandstones and a thick package of 660 m of Aptian limestones. The lower 200 m, are described as Palaeozoic clays, indicating that the basement was reached.

Acquisition and processing

The marine profile ESCI-N3.3 was acquired during February, 1993, by the MV SeisQuest vessel. Acquisition and processing were done commercially by Schlumberger GECO-PRAKLA. The energy source was a tuned airgun-array of 5490 cu.in. (90 litres) with a width of 80 m to suppress out-of-the-plane energy. The pop-rate was 30 s (i.e. 75 m) registered during 20.5 s on a 4500 m long streamer, consisting of 360 channels and a 12.5 m group interval, providing a maximum coverage of 30 fold.

The profile has a length of 141 km and runs, with an azimuth of 102°, from 43° 57' N and 7° 47' W to 43° 40.7' N and 6° 4.3'W, imaging a section of the continental platform with a water depth of 80-150 m. Many side echoes were present along the profile, though in great part they were eliminated by the commercial processing. The data, acquired with a sampling rate of 4 ms, were resampled to 8 ms. For further details about the acquisition and processing, we refer to the description of profile ESCI-N3.1 in this issue and to Álvarez-Marrón *et al.* (1996). A frequency-wavenumber (f-k) migration with a velocity of 5 km/s has been applied by one of us (PAA) to the data.

The shots produced for the marine profile were recorded simultaneously by six portable seismic land-stations deployed along the shore and numbered 14 to 19 (Fig.

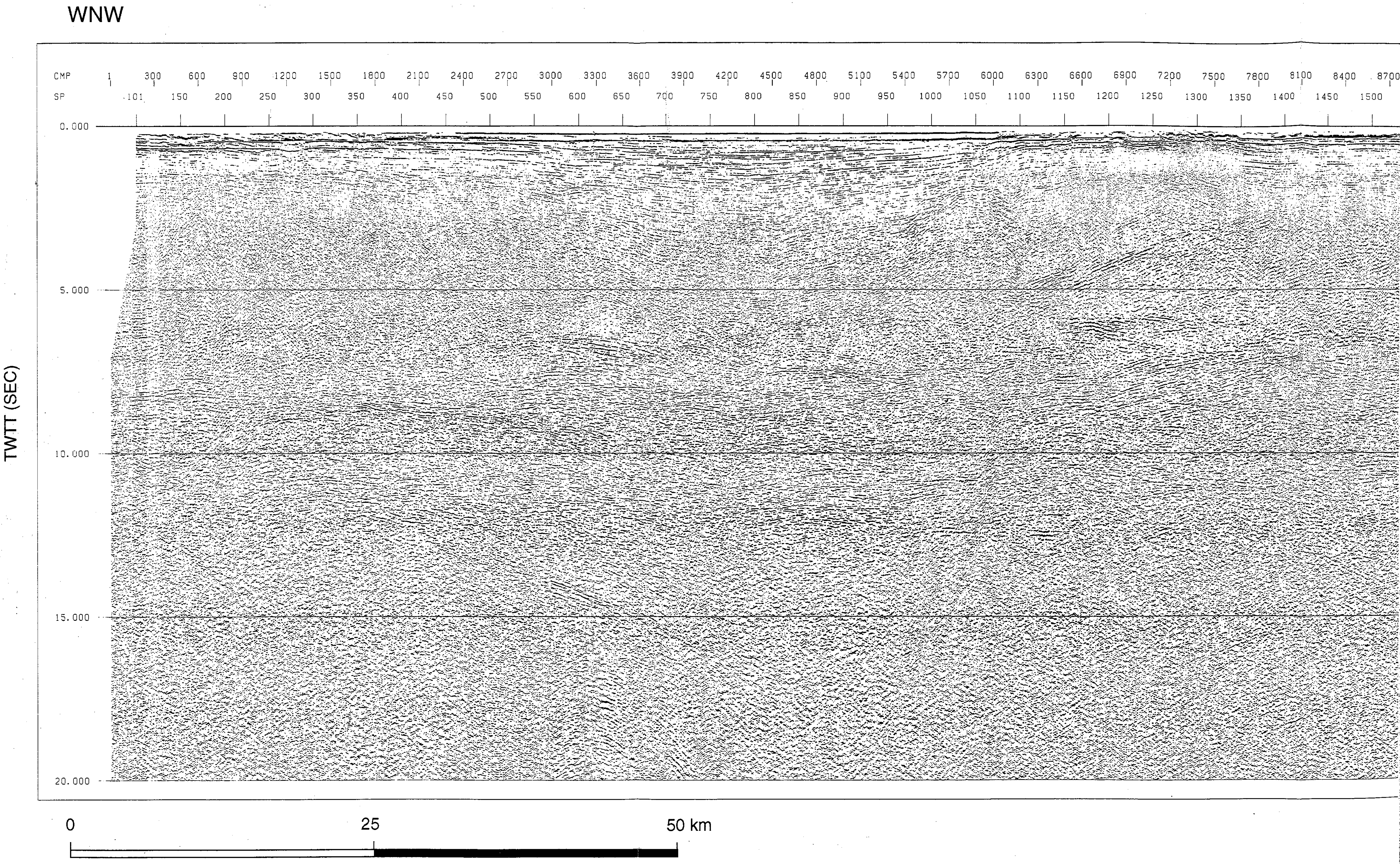
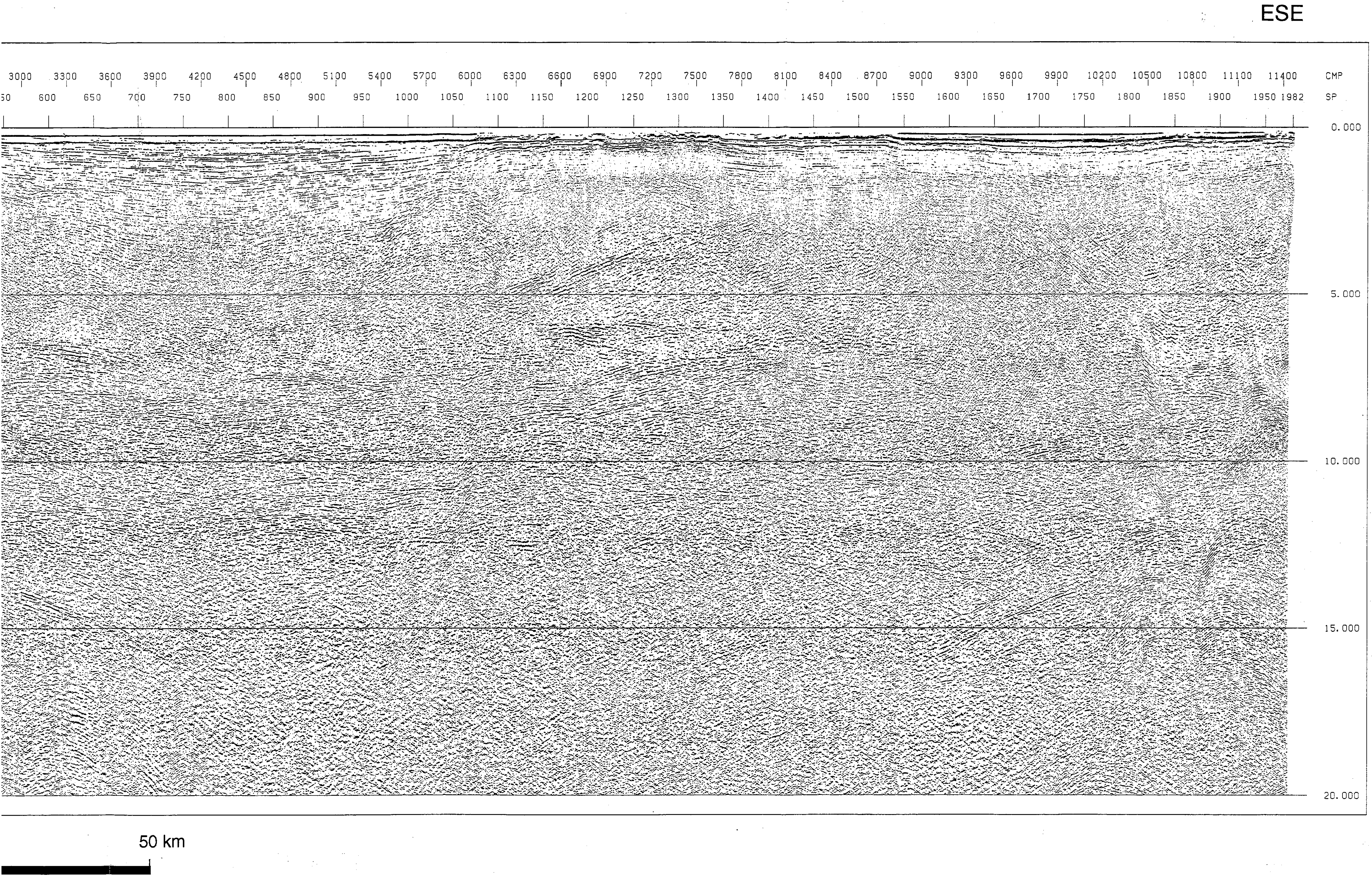


Figure 3.- Stack section of the profile ESCI-N3.3.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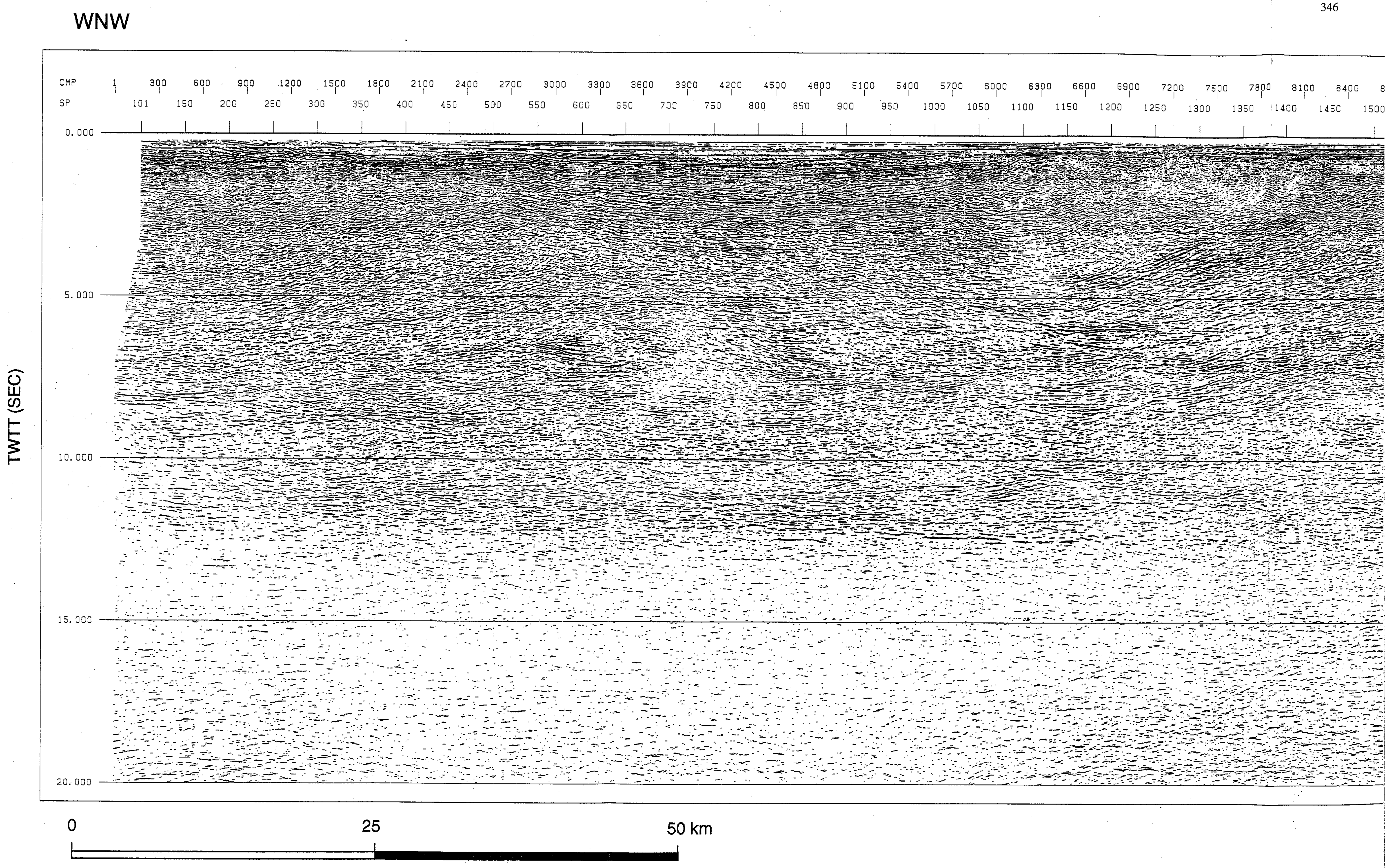

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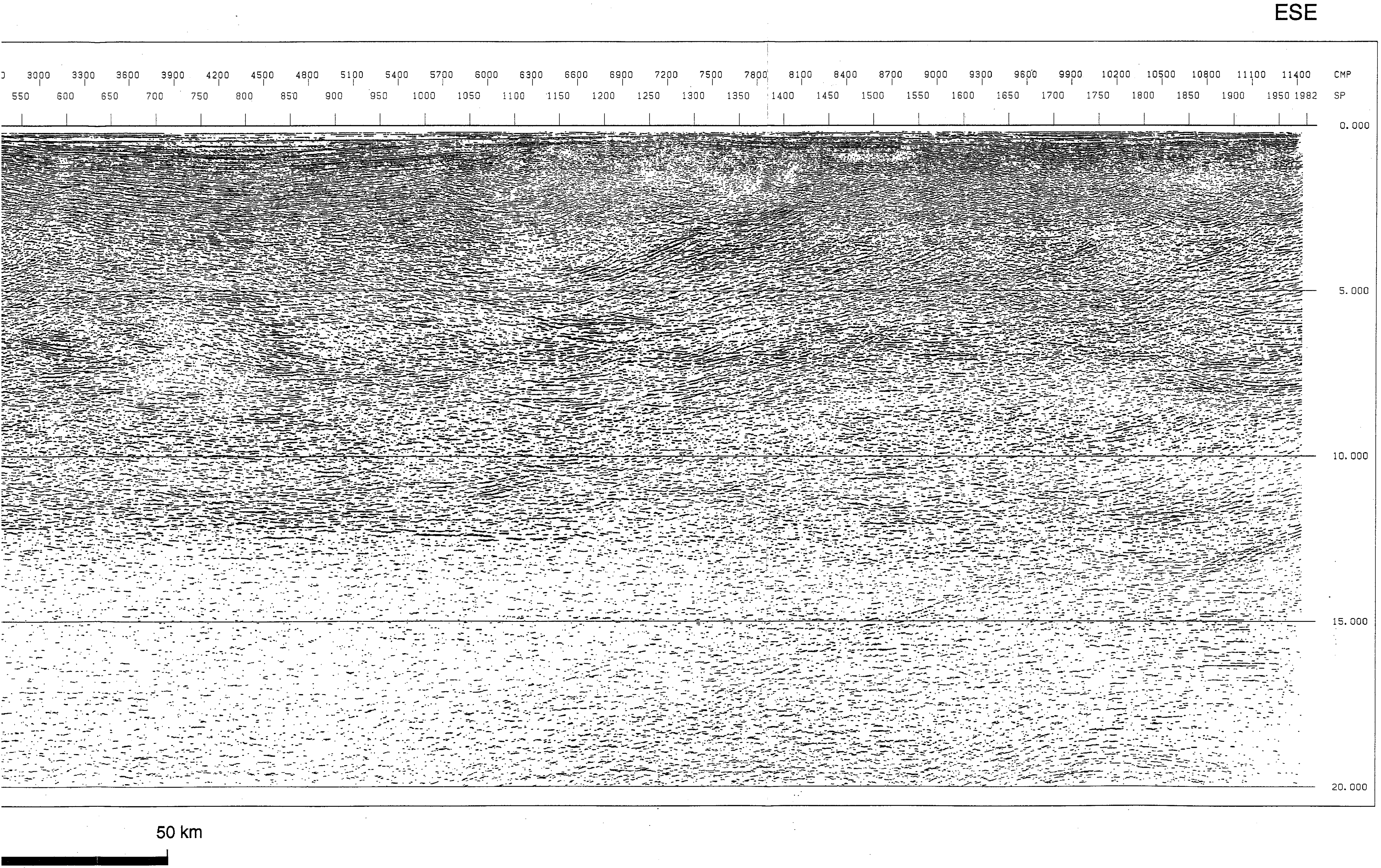

Figure 4.- Migrated section of the profile ESCI-N3.3.

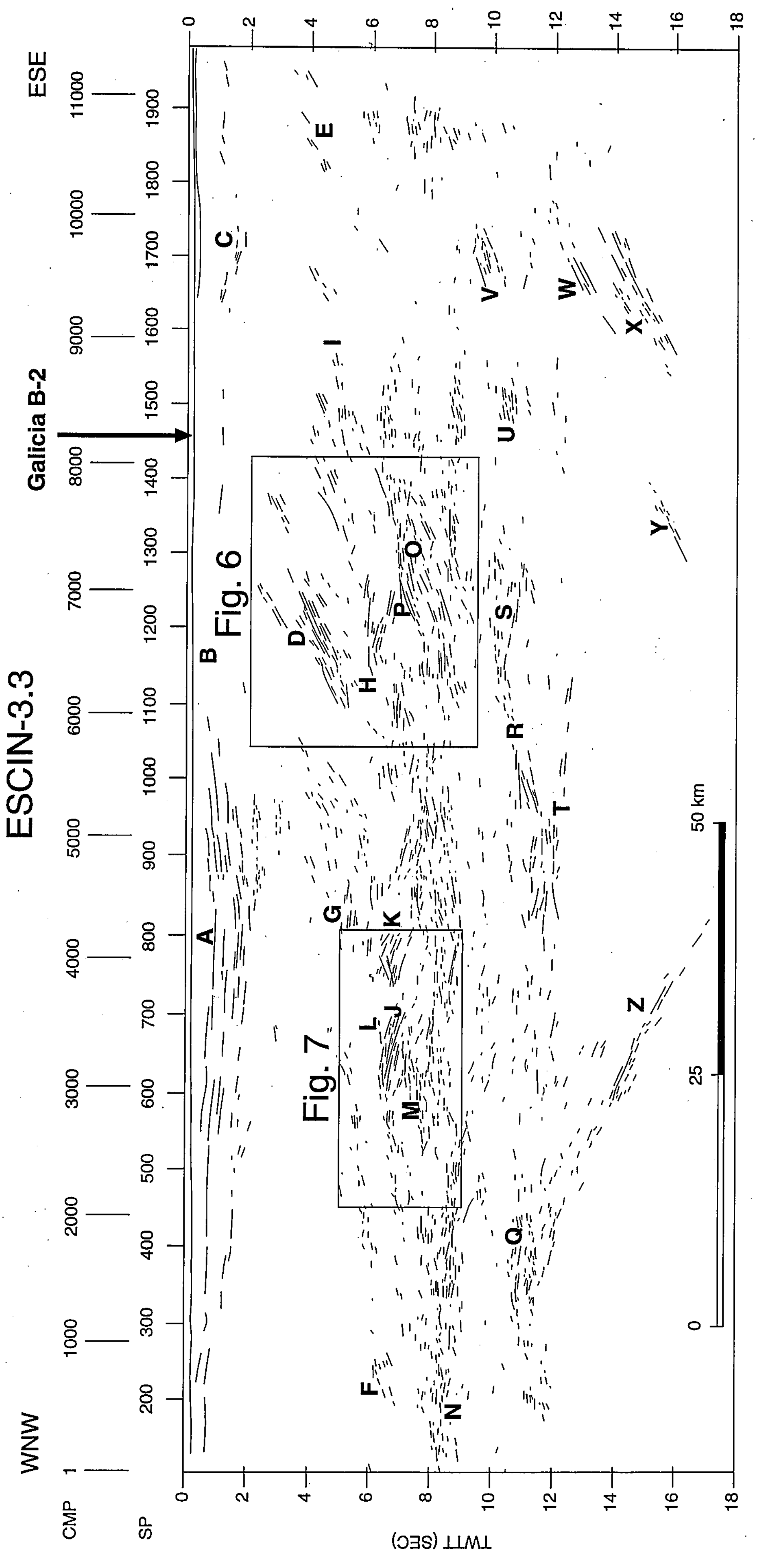

Figure 5.- Line drawing of the stack section. The characters refer to reflections and groups of reflections described in the text. The portions of the profile depicted in Figs. 6 and 7 are shown, as well as the projection onto the profile of the well Galicia B-2.

2). These data would constrain and enhance the interpretation of the near vertical reflection profile. The wide-angle data have been analysed using the arrival times and standard ray-tracing techniques (Spence *et al.*, 1984). The final record sections have been used to constrain the marine profile.

Description of the profile

The final stack and migrated sections are shown in Figs. 3 and 4 respectively, while Fig. 5 depicts a line-drawing of the former. Four roughly horizontal zones will be differentiated according to their reflective characteristics, and described separately: an upper variably reflective zone, an intermediate zone of low reflectivity, a deep banded zone of high reflectivity and a deeper zone with several continuous dipping reflections.

In the western half of the profile, the upper variably reflective zone occupies the first 1 to 2 s, and is characterised by a high reflectivity. The reflections depict a good continuity and vary from subhorizontal near the sea bottom, to weakly dipping at depth, drawing an open synform with its axial surface close to SP 800 (A in Fig. 5). It is followed to the East by a zone with only very superficial reflections and transparent character at depth, between SP 1100 and SP 1300 (B), whose characteristics are those of the intermediate zone of low reflectivity. In the eastern part of the profile, subhorizontal and low-dipping reflections are seen again in the upper 1 to 2 s but their continuity is scarce (C).

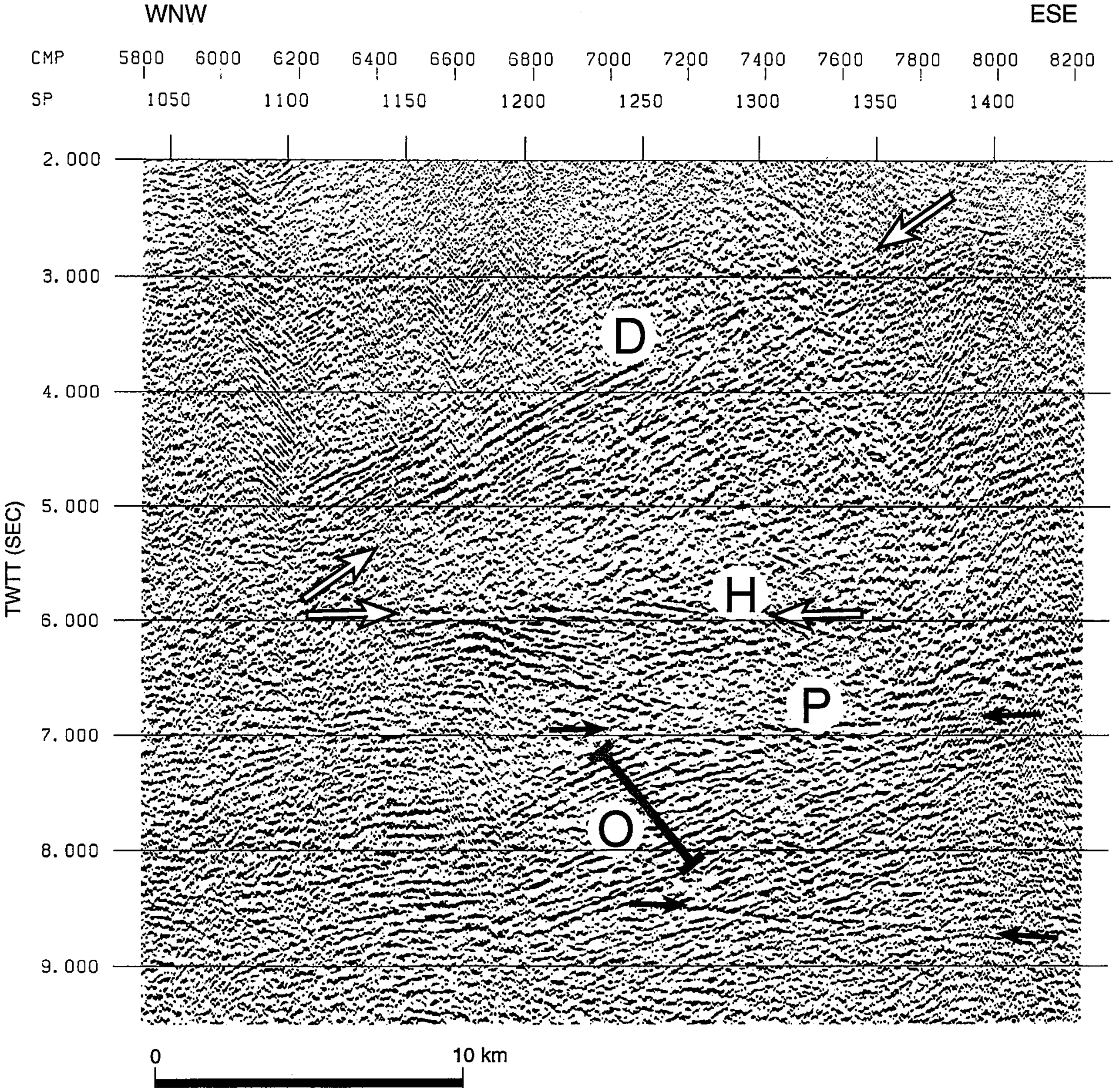

Figure 6.- Detail of the stack section showing the strong west-dipping reflections of the upper crust (D), the horizontal events that underlie them at 6 s (H), and the eastern termination of the intermediate band of high reflectivity (O), truncated in its upper part by an event of the second type of fabric (P). Another event of the second type can be seen near 8.5 s. White arrows indicate proposed Variscan thrusts. Grey bars mark the width of the first type of fabric in the lower part of the basement, probably corresponding to laminated lower crust. Black arrows point to the second type of fabric.

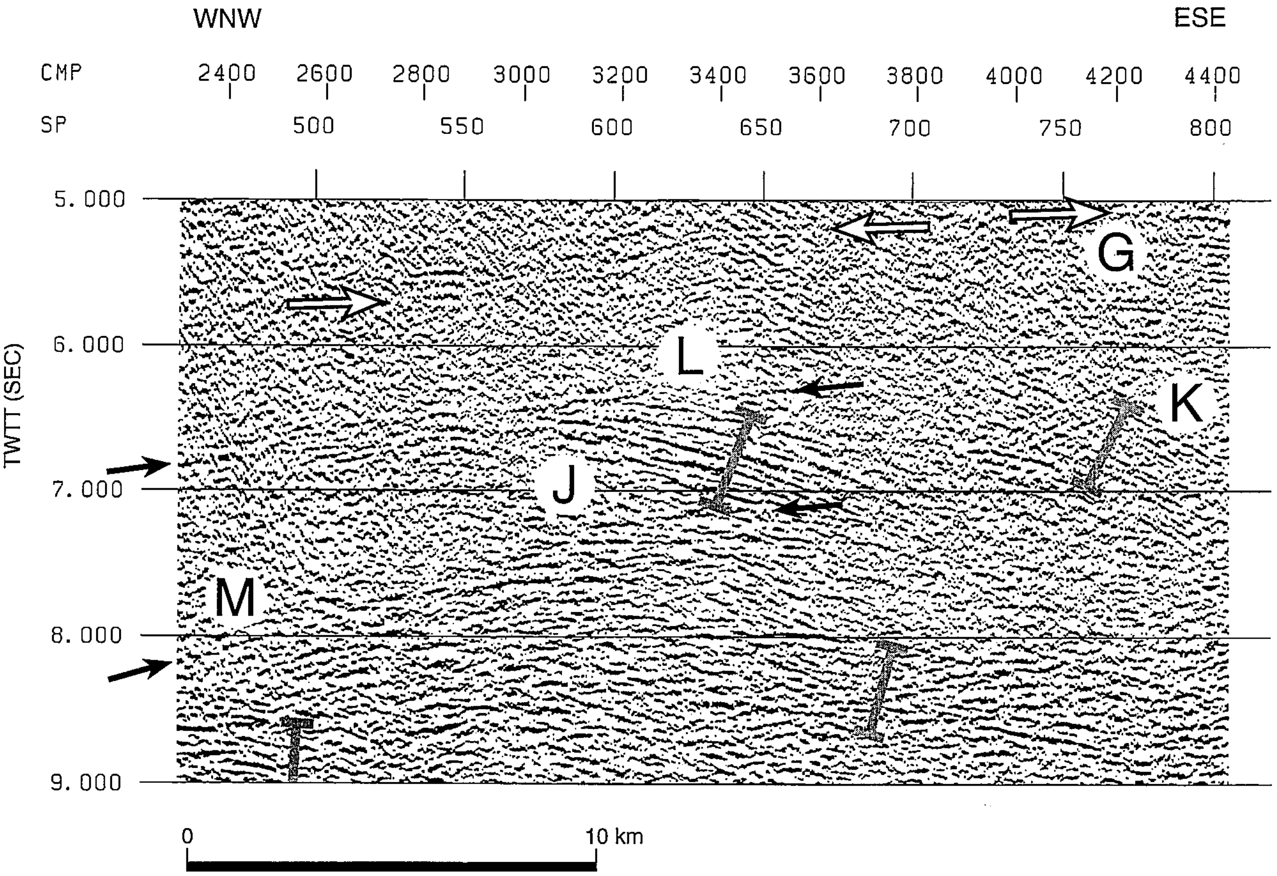

Figure 7.- Detail of the stack section showing reflections of the possible basal detachment of the Westasturian-Leonese Zone (G) and the shallower occurrence of the first (J and K) and second (L and M) types of fabric described in the deep crust. Legend as in Fig. 6.

The intermediate zone of low reflectivity follows downward, until 6.5-7 s. Its upper part is devoid of significant events in most of the profile, though some weak subhorizontal reflections can be seen, mainly in the migrated section, between SP 800 and SP 1150 immediately beneath the sediments. However, between SP 1100 and SP 1400, very pronounced and continuous west-dipping reflections are seen (D), mostly below the transparent zone (B). The band with the highest reflectivity has a width of almost 1 s and runs from 2.5 to 5 s (Figs. 5 and 6). Some weak and short west-dipping events can be seen also around 4 s in the eastern part of the line (E). Beneath 4-5 s, a set of discontinuous reflections form a band that deepens from 5 s, in the East, to 7 s in the West. They dip weakly westward between SP 200 (F) and SP 650 and eastward around SP 800 (G). In the eastern part, they are subhorizontal and can be followed from SP 1125 (H) to SP 1550 (I), underlying and bounding the west-dipping reflections (Figs. 5 and 6).

Following downward, there is a banded zone of high reflectivity that reaches 12 s and where two different seismic fabrics can be identified. The first is characterised by strong, parallel reflections, horizontal to weakly-inclined both to East and West, often curved, which may attain a width of 1 to 1.5 s. This highly reflective fabric appears in three subhorizontal bands. The second type of fabric consists of weak, subhorizontal reflections, individual or grouped in thin bands which crosscut the former fabric in several points.

Fig. 7 depicts the shallower of the highly reflective bands (6.3-7.2 s), which is limited to two separate groups of east-dipping reflections between SPs 550-700 (J) and SPs 740-800 (K) respectively. The top and bottom of the western group (J) is truncated by low-dipping events of the second type of fabric (L and M).

The intermediate band runs between 8 and 9 s from the western edge of the profile (N) to SP 800, from where it ascends one second until SP 1400 (O), where it is truncated by an event (P) of the second type (Fig. 6).

The lower highly reflective band occurs between 10.5 and 12 s, and can be followed from the West (Q) to SP 1150 (R). Again, some reflections of the second type seem to affect it (S and T). This band might be prolonged, ascending to the East, by small discontinuous groups of reflections (U, V), but this continuation is problematic, due to the low quality of the signal and the appearance of dipping events and diffraction hyperbolae in the eastern part of the line (not depicted in Fig. 5).

In deeper parts of the line, beneath the lower banded zone of high reflectivity, there are a few continuous dipping reflections. Several west-dipping events (W, X, Y) can be seen between 12 and 16 s in the eastern part (Figs. 3 and 5). In the western part, a distinct, slightly convex east-dipping event is seen between 11 and 17 s (Z).

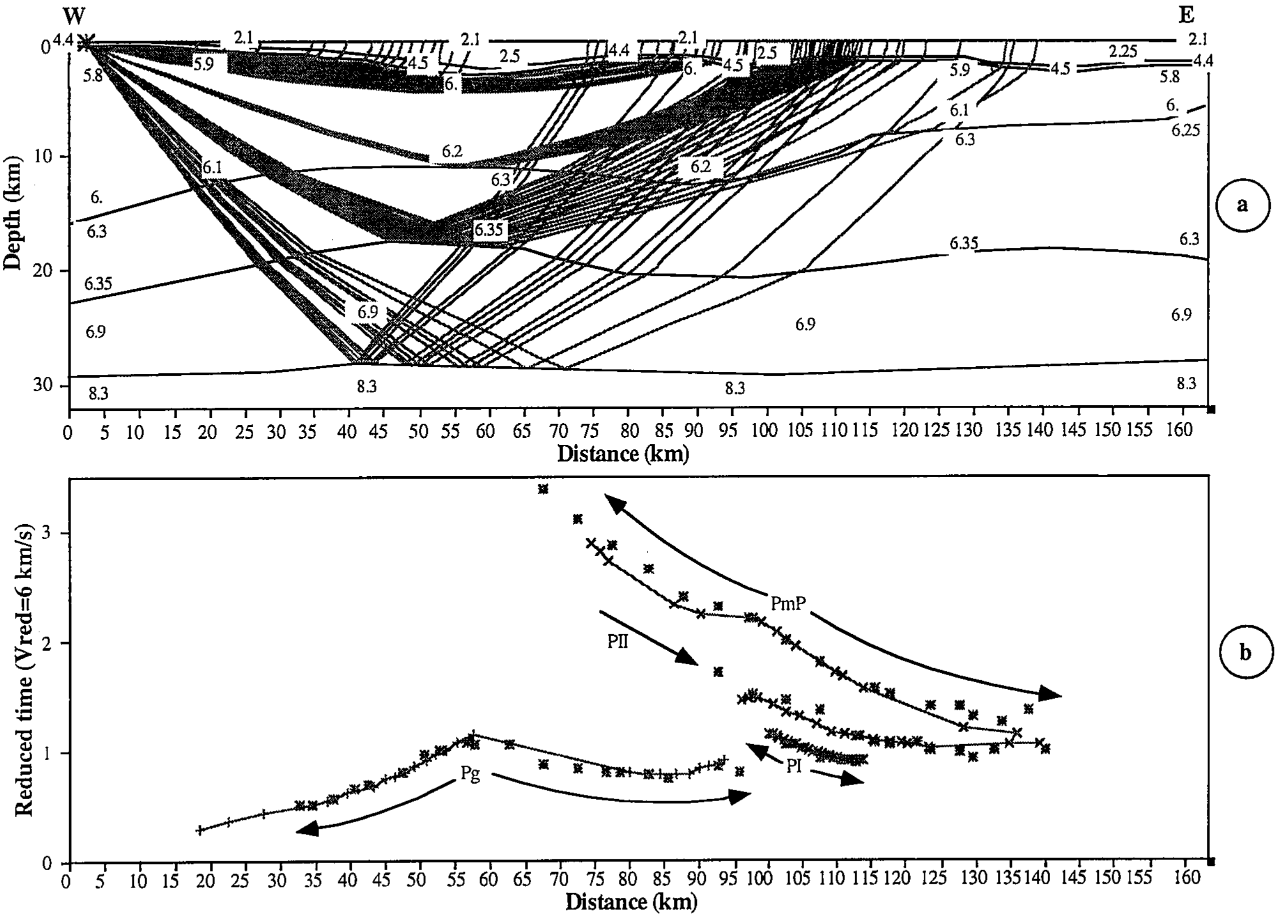

Figure 8.- a) Ray tracing and seismic model for station 15 (see location in Fig. 2). P-wave velocities are marked in km/s. b) Observed (squares) and theoretical (crosses) arrival times with the correlated phases. See text for explanation.

Interpretation and discussion

Sedimentary basins

The upper reflections have imaged two sedimentary basins (A and C in Fig. 5) separated by a transparent zone between SP 1100 and 1300 (B). From the wide-angle data, first clear P_g arrivals (waves essentially travelling across the upper part of the basement) recorded at station 17 can be correlated to a velocity of 6 km/s. This value corresponds to the velocity in the basement, suggesting that the sediments are very thin in a part of the profile. Using ray-tracing techniques, this part fits well the transparent zone (B), which suggests that it actually represents a basement high separating the two sedimentary basins.

The lower boundary of the basins is not clear, because of the existence of multiples and the lack of a clear reflection from the top of the basement. The ray-tracing model indicates a maximum thickness of 3 km for the western basin and a little less (2.5 km) for the eastern one (Fig. 8). The continuity of the reflections is good in the western basin and poor in the eastern one, suggesting that the latter is structurally more complicated. In any case, the strike of the profile, nearly parallel to the continental margin, hinders the study of the geometry and evolution of the basins.

The age of the sediments may range from Mesozoic to recent but, according to Lamboy & Dupeuble (1975) and the well Galicia B-2 (Querol, 1987), drilled in front of Luarca, most of them seem to be Mesozoic.

Basement

Deeper levels of the profile give information concerning the Variscan basement. For the discussion, we will refer to the subdivisions made in the description for the time range between 1-2 and 12 s.

The intermediate zone of low reflectivity, between 1-2 and 7 s, should depict the structures seen on land. In the western half of the line, the range of depths between 2 and 5 s is transparent, implying that the Cabo Ortegal Complex and the "Ollo de Sapo" anticlinorium have not been imaged. Conversely, the west-dipping reflections in its eastern half (D and weaker ones to the East, see Fig. 5) give information concerning the Westasturian-Leonese Zone. The best reflections are seen below the postulated basement high (B), which suggests that the sedimentary basins mask to some extent the structure of the upper basement. On land, this zone corresponds to the Navia and Alto Sil Domain, structurally characterised by a pile of west-dipping overturned folds and thrust sheets (Fig. 2). Though the precise identification of particular structures in the profile is not possible, the west-dipping reflections are attributed to the thrusts and the limbs of the overturned folds.

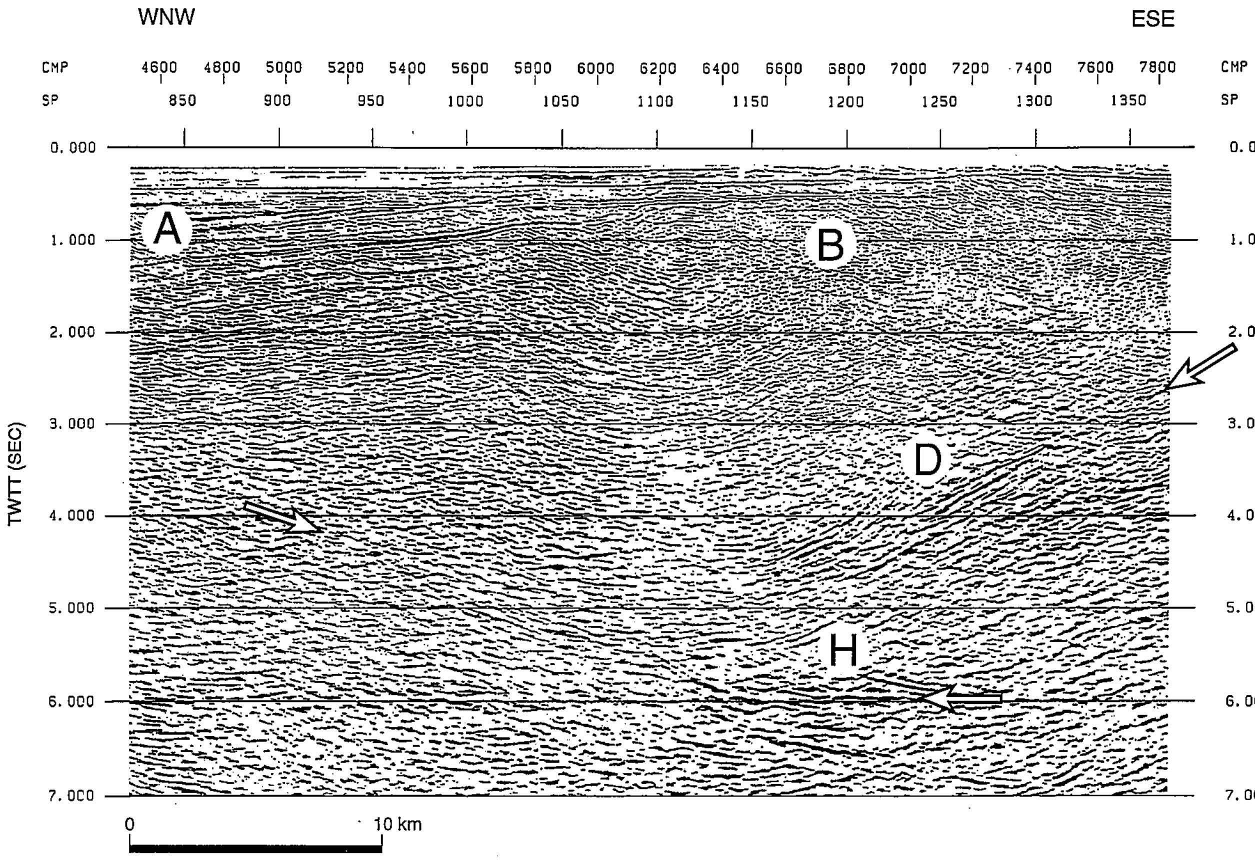

Figure 9.- Detail of the migrated section in the region where the strong west-dipping reflections (D) of the upper part of the basement approach deeper subhorizontal events (H) and seem to curve, merging with the continuation of the latter to the west. Legend as in Fig. 6. See location in Fig. 10.

The west-dipping reflections (D-E) disappear at a depth of 5-6 s, where they are substituted by subhorizontal reflections (H-I). In the migrated profile (Figs. 4 and 9), both groups of reflections seem to merge asymptotically, suggesting that the events between 5 and 7 s image a low-dipping detachment to which the thrusts merge. To the East, the detachment might ascend up to 4 s near the eastern edge of the line. To the West, it seems to continue, dipping slightly westward and reaching a depth of 7 s (Fig. 10). This detachment may represent the sole thrust of the Westasturian-Leonese Zone, which, given its size, would be a first-order tectonic structure. From what can be seen in the profile, mainly in the migrated section (Figs. 4 and 10), it would continue below the Central Iberian Zone, approaching the Moho discontinuity in the western edge of the profile.

It is not clear if the Mondoñedo nappe has been imaged. Because of possible variations in the geometry of the open folds affecting it and of the existence of normal faults in the margin, the nappe may have been either completely eroded prior to the deposit of the Mesozoic sediments, or partially preserved beneath the western sedimentary basin. The hinge zone of the open synform where the Mondoñedo nappe outcrops on the coast (Fig. 2) coincides with a series of shallow subhorizontal reflections between SP 800 and SP 1150 (Fig. 10, migrated section), which may correspond to the lower part of the Mondoñedo nappe, partially preserved underlying the Mesozoic sediments.

The banded zone of high reflectivity depicts a variable upper boundary: 6.3 s between SP 550 and SP 800, and 7-8 s in most of the line. The lower boundary has a fairly constant depth of 12 s. The highly reflective fabric is typical of the lower crust of many continental areas and, in particular, of the Variscan crust of Europe (Meissner, 1986). Moreover, from the arrivals registered on land, two phases, P_I and P_{II} (Fig. 8), can be related to wide-angle reflections in the basement. According to the models, the second corresponds to reflections in an interface characterised by a velocity change from 6.35 to 6.9 km/s and situated at a depth ranging between 17 and 22 km. A dome-like structure in the western half, coincides with the uppermost of the three reflective bands (J-K in Figs. 5 and 7). Consequently, we believe that this part of the profile has imaged the lower crust.

It can be discussed whether or not we are dealing with a banded lower crust attaining locally a width of circa 6 s (between 6.3 and 12 s) or with repetitions of a thinner lower crust. Concerning the shallower occurrence of the lower crust, the dome-like structure obtained in the wide-angle models (Fig. 8) and the shape of the possible basal detachment of the Westasturian-Leonese Zone, weakly convex upward (Fig. 10, migrated section), may be related to the antiform responsible for the Xistral tectonic window. This structure has been attributed to the formation of an antiformal stack below the Mondoñedo basal thrust (Pérez-Estaún *et al.*, 1991). Aller *et al.* (1994) interpreted the so-called "eastern Galicia

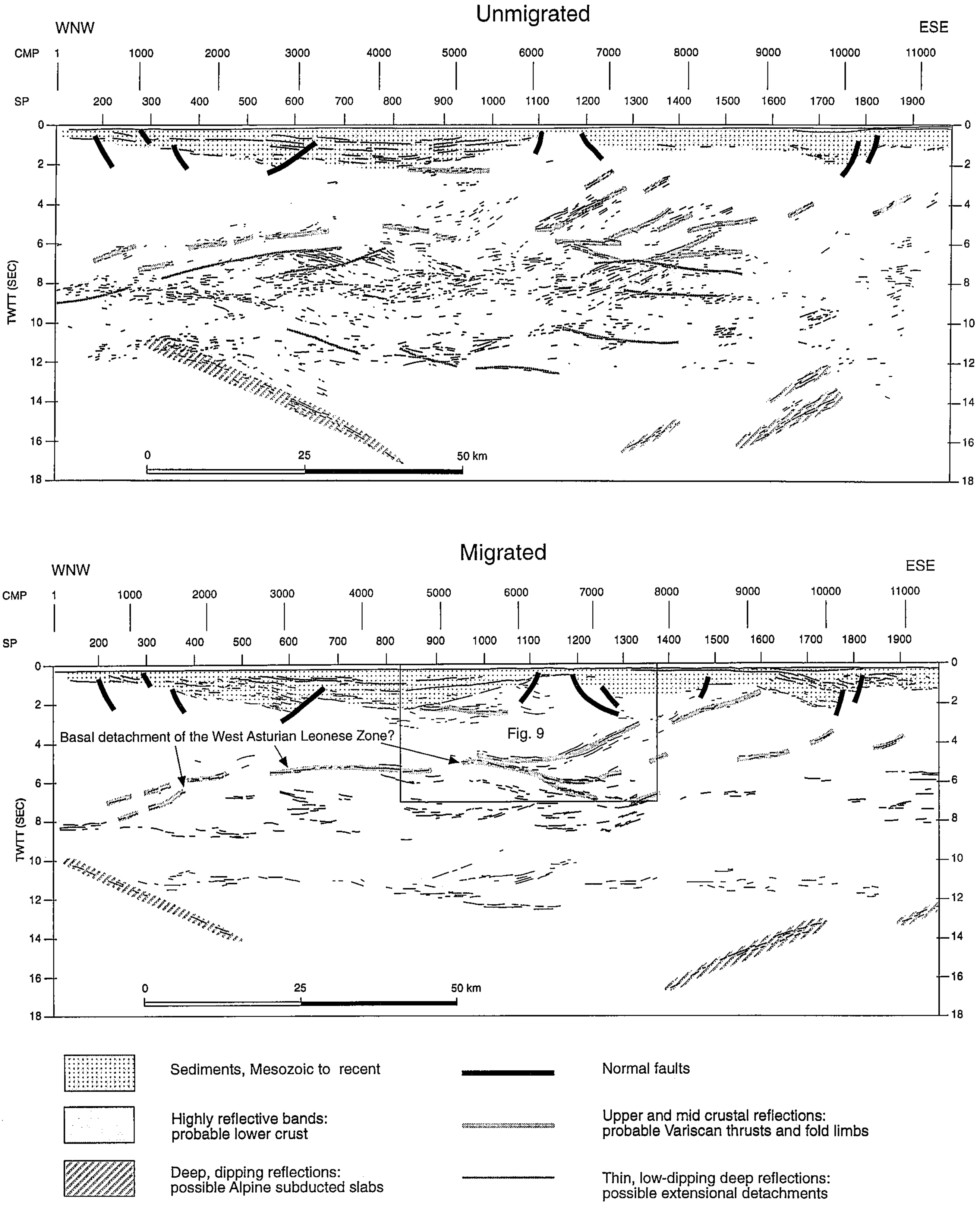

Figure 10.- Interpreted line drawings of the unmigrated and migrated sections. The highly reflective bands and several of the cross-cutting weak subhorizontal reflections may be seen in the migrated section, but have not been outlined because, in general, the seismic image is less clear and part of the information has been lost. The portion of the profile depicted in Fig. 9 is shown in the migrated section.

magnetic anomaly", which closely follows this antiform, as caused by a middle or lower crustal body a few km thick, emplaced at high crustal levels by means of a Variscan thrust fault. Its minimum depth would vary from 2.5 km near the coast, to 10 km more to the South. If this body, probably containing mafic/ultramafic rocks, continues to the North, it should have been surveyed by the profile. For the position it occupies and the strength of the reflections, the most obvious candidate is the uppermost of the reflective bands (J-K in Figs. 5 and 7). This correlation would support a Variscan repetition of the lower crust in this part of the profile.

Looking to the lower reflective band, the seismic land-stations have registered wide-angle reflections generated by an interface 29 km depth, with a strong velocity contrast from 6.9 to 8.3 km/s. The correlation of this phase (P_mP, interpreted as a wide-angle reflection in the Moho) indicates the presence of a strong first-order discontinuity (Fig. 8) that corresponds to a depth of 9 s in the seismic reflection profile, that is, the bottom of the intermediate reflective band. The lower reflective band has the same seismic characteristics as the intermediate, and is tentatively interpreted also as the lower crust. The existence of a band with mantle velocities between the intermediate and lower reflective bands suggests the duplication of a thin lower crust.

The highly reflective bands appear truncated by weak subhorizontal reflections that look like low-dipping faults or detachments. However, the first type of fabric does not appear repeated on both sides of the presumed faults. For instance (see Figs. 6 and 7), groups of reflections of the first type (O and J) cannot be followed above the events of the second type (P and L). This is what can be expected from a normal fault with a direction of movement at high angle to the plane of the profile, because normal faults are subtractive. Conversely, if the faults were reverse, a repetition of the reflective bands would be visible on both sides, independently of the movement direction, due to their additive character. These features point to extensional accidents, that could be related either to the reequilibration of the thickened Variscan crust in late to post-orogenic stages, or to the crustal thinning during the opening of the Bay of Biscay in the Mesozoic. Because these structures seem to overprint the highly reflective bands, the age of the lower crustal duplication should be Variscan in both cases.

Deep dipping events

The dipping reflections appearing between 11 and 17 s near both edges of the profile, could represent side echoes coming from shallow faults with azimuths subparallel to the coast and slightly oblique to the seismic profile, as the ones identified by Lamboy & Dupeuble (1975). However, the ENIEPSA LC77 profiles transverse several of these faults in an slightly oblique way, and never produce reflections comparable in intensity and continuity to the events under discussion. Consequently, it is possible that these dipping events actually represent deep reflectors, and it is suggested that they may represent images of subducted slabs, probably related with the Tertiary convergence. In particular, the western dipping event (Z in Fig. 5) is inclined toward the ESE and, in the profile ESCI-N3.2 (see description in this volume), similar reflections at comparable depths are inclined to the WSW. Taken together, these reflections can be considered to represent apparent dips of an inclined surface roughly oriented E-W and dipping to the South, possibly the subducted oceanic crust of the Bay of Biscay (Fig. 1).

Conclusions

The analysis of the near vertical reflections of the ESCI-N3.3 profile, combined with that of refractions and wide-angle reflections registered on land, has permitted the identification of two sedimentary Mesozoic-Cenozoic basins separated by a transparent zone which coincides with a basement high.

In the upper part of the basement, west-dipping reflections in the eastern half of the profile are related to the overturned folds and thrusts of the Navia and Alto Sil Domain. These structures seem to merge at mid crustal depths with subhorizontal seismic events that are interpreted as the basal detachment of the Westasturian-Leonese Zone. This crustal-scale thrust dips gently to the West and seems to continue under the Xistral tectonic window, the “Ollo de Sapo” anticlinorium and the Cabo Ortegal Complex, structures that have not been imaged, probably due to their structural complexity.

Highly reflective bands characterise the lower crust. The shallowest of them is of limited extent and, given its location, in the prolongation of the eastern Galicia magnetic anomaly, it probably represents a lower crustal slice emplaced at mid-crustal level by a Variscan thrust. The intermediate band is underlain by a zone with mantelic velocities, which defines a Moho around 29 km depth. The lower reflective band is similar to the intermediate, and is tentatively interpreted as a duplication of the lower crust, probably of Variscan age. Low-dipping weak reflections truncate all these reflective bands. Their apparently subtractive character points to extensional accidents, which could be related either to the late or post-orogenic reequilibration of the Variscan crust, or to the opening of the Bay of Biscay.

Finally, deep dipping reflections in the eastern and western parts of the profile, possibly image subducted slabs related to the Alpine convergence of Iberia and Eurasia.

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