OCEAN DRILLING PROGRAM

LEG 173 SCIENTIFIC PROSPECTUS

RETURN TO IBERIA

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This Scientific Prospectus is based on pre-cruise JOIDES panel discussions. The operational plans within reflect JOIDES Planning Committee and thematic panel priorities. During the course of the cruise, actual site operations may indicate to the Co-Chief Scientists and the Operations Superintendent that it would be scientifically or operationally advantageous to amend the plan detailed in this prospectus. It should be understood that any proposed changes to the plan presented here are contingent upon approval of the Director of the Ocean Drilling Program in consultation with the Planning Committee and the Pollution Prevention and Safety Panel.

ABSTRACT

The Galicia Bank and Iberia Abyssal Plain segments of the west Iberia margin were drilled during Ocean Drilling Program Legs 103 and 149 and have been extensively studied geophysically. Leg 149 determined landward and oceanward limits to the ocean-continent transition (OCT) of the crust off western Iberia by drilling an east-west transect of holes. However, only one of these holes penetrated basement between these limits. This site, Site 900, cored 56 m of fine- to coarse-grained gabbro that had experienced synrift dynamic re-crystallization under granulite facies conditions at 136.4±0.3 Ma, according to $^{40}Ar/^{39}Ar$ dating. Geophysical data clearly show that the OCT has magnetic and seismic velocity properties that are in some sense transitional between continental and oceanic crust. Multichannel seismic reflection profiles, one of which has been recently reprocessed, strongly indicate that, although the eastern (landward) part of the OCT is dissected by deeply penetrating normal faults and low-angle detachments, these die out westward (oceanward) into a region of smoother basement that lacks significant intrabasement reflectors and is of uncertain origin. Leg 173 will drill a small number of holes to basement, on basement highs mainly within the OCT, to complete the Leg 149 transect. These holes will characterize the OCT, test models of lithospheric (crustal) extension, determine the extent of synrift magmatism, and examine the nature of the oldest oceanic crust.

INTRODUCTION

In the Iberian Abyssal Plain Ocean Drilling Program (ODP) Leg 149 defined landward and oceanward limits to the crustal ocean-continent transition (OCT), where the transition zone is defined as the region between a margin-parallel peridotite ridge marking the landward edge of ocean crust and the most seaward tilted fault block of continental crust. However, only one hole (Hole 900A) penetrated basement in the 130-km-wide region between these limits. Leg 173 (Fig. 1) is a sequel to Leg 149, and it will enable (1) drilling and coring of a well-imaged major detachment fault (an analogue to the S-reflector), (2) recovery of more rift-related igneous material (e.g., gabbro) and its host rock (mantle), continental crust or slow spreading oceanic crust, (3) testing of the nature of the topographic high between Site 900 and the most landward known serpentinite basement outcrop, and finally (4) sampling of the oldest oceanic crust. These observations, together with the improved quality and quantity of seismic images, will allow us to address the modes of breakup of the lithosphere, the timing and nature of melt generation from the mantle during the final stages of rifting and, the nature and age of early-formed “normal” oceanic crust. The planned drilling will also add to our knowledge of the early sedimentary history of the rifted margin.

BACKGROUND

Rifted margins contain the principal record of continental rifting and the onset of seafloor spreading, both of which are first-order plate tectonic processes. Such margins exhibit a wide spectrum of characteristics, probably in response to different combinations of asthenospheric temperature, lithospheric rheology, strain rate, stress, and pre-existing heterogeneities. The rifting process, through the indirect effects of concurrent subaerial volcanism as well as greater sedimentation and heat flow, can also have important environmental and resource implications. Drilling commonly affords the only means of directly characterizing the nature, age, and emplacement conditions of igneous, metamorphic, and/or sedimentary rocks formed, deposited, or tectonically exposed during margin formation. Nonvolcanic margins provide opportunities to investigate and understand the tectonic aspects of rifting for two reasons. First, normal faults and shear zones that penetrate deep into the crust and uppermost mantle are sometimes evident on seismic profiles and, as has been demonstrated on the west Iberia margin, allow rocks from deeper lithospheric levels to be exposed at the top of acoustic basement. Second, voluminous intrusives/extrusives, which can obscure crustal tectonics, are limited in volume and commonly appear to be absent. Pairs of conjugate rifted margins often exhibit some asymmetry in structural style. This asymmetry may be related to the mode of lithospheric rifting, e.g., pure or simple shear.

The west Iberia margin is an excellent example of a nonvolcanic rifted margin. The Galicia Bank and Iberia Abyssal Plain segments of the margin were cored during ODP Legs 103 and 149, and have been studied extensively by geophysical methods.

Iberia separated from the Newfoundland margin of the Grand Banks in the Early Cretaceous, after prolonged rifting that began in the late Triassic and is well documented on both sides of the Atlantic (Wilson et al., 1989; Welsink et al., 1989). The subsequent plate tectonic and seafloor-spreading history of this part of the North Atlantic is mostly well constrained by seafloor spreading magnetic anomalies. It demonstrates that Iberia and North America moved apart along roughly east-west fracture zones (e.g., Klitgord and Schouten, 1986).

Throughout its post-rift history the west Iberia margin has remained an essentially undisturbed rifted margin that has experienced only minor compression in the north in Eocene time (Pyrenean phase, short lived subduction of Bay of Biscay crust under northern Spain) and in the south and center in the middle Miocene (Rif-Betic phase, gentle folding of abyssal plain sediments).

Offshore, the west Iberia continental margin has been studied extensively by geophysical techniques and, to a lesser extent by geological sampling (e.g., Beslier et al., 1993; Boillot, Winterer, Meyer, et al., 1987, 1988; Hoffman and Reston, 1992; Sawyer, Whitmarsh, Klaus, et al., 1994; Whitmarsh et al., 1990, 1993; Whitmarsh and Miles, 1995; Whitmarsh et al., 1996; Whitmarsh, Sawyer, Klaus, and Masson, 1996). The margin exhibits tilted continental fault blocks that often, but not always (Reston, 1996), seem to lack a wedge of synrift sediments (Wilson et al., 1996). There is an apparent lack of synrift volcanism, and synrift volcanism is equally absent on shore. Tilted fault blocks and a lack of volcanism are both characteristics of a nonvolcanic rifted margin.

The first drilling of the OCT off the west Iberia margin was carried out by ODP Leg 103 in 1985 (Boillot, Winterer, Meyer, et al., 1988); this leg drilled a short transect of holes west of Galicia Bank (Sites 637-641, Fig. 1). In 1991 the recommendations of the North Atlantic Rifted Margin Detailed Planning Group were accepted by JOIDES Planning Committee, which programmed two drilling legs in the North Atlantic during 1993. One of these, Leg 149, drilled a transect of holes into acoustic basement across the OCT in the southern Iberia Abyssal Plain (Sawyer, Whitmarsh, Klaus, et al., 1994; Whitmarsh, Sawyer, Klaus, and Masson, 1996; Sites 897-901, Fig. 1).

Results of Leg 149

Leg 149 drilled a west-to-east transect of five sites. Three sites (Sites 897, 899, and 900) reached acoustic basement (Figs. 1 and 2). A fourth site (Site 901) enabled a firm prediction to be made that the underlying basement is continental crust. The sites were chosen in the context of a conceptual model of the location of the OCT previously defined by gravity, magnetic, and seismic velocity modeling and by seismic reflection profiles. The results obtained during this leg broadly confirmed this model but also produced some surprises.

The results of Leg 149 proved the existence of a peridotite ridge at the inferred landward edge of the oceanic crust formed by seafloor spreading. They also showed that between this ridge and Site 901, which is situated on a fault block of almost unequivocal continental crust, there exists a 130-km-wide region that is probably underlain mostly by a heterogeneous transitional crust. One indication of the transitional nature of this crust may be the MORB-to-transition like gabbro at Site 900 (Seifert et al., 1996; Cornen et al., 1996). Other indications are the transitional to alkaline mafic clasts in mass wasting deposits at Sites 897 and 899 (Cornen et al., 1996; Seifert and Brunotte, 1996). The magnetic and seismic reflection character and velocity structure of the crust provide additional evidence. Whether the Site 900 gabbro formed by pre- or synrift partial melting, the original metamorphic grade and the $^{40}Ar/^{39}Ar$ age of the dynamically recrystallized plagioclase in the cores (Cornen et al., 1996; Feraud et al., 1996) imply that the gabbro was exhumed by important synrift shearing that accompanied lithospheric extension. Although Site 899 sampled a serpentinite breccia and an underlying serpentinized peridotite mass-flow deposit, magnetic evidence suggests that the basement of this site may be atypical of the rest of the Iberia Abyssal Plain OCT. Therefore, it may not be correct to infer continuity of peridotite basement between Sites 897 and 899. Leg 149 succeeded in defining the western (oceanward) boundary of the OCT and also limited the eastern boundary, but only sampled a single site between these limits. Models that explain these observations are presented below. To test these models, drilling is planned to focus on the nature and evolution of the basement itself within this zone and on the significance of intrabasement seismic reflectors identified there.

Review of the Galicia Bank and Iberia Abyssal Plain Transects

The transects of Legs 103 and 149 and their associated research contributed to the understanding of a number of features of the rifted west Iberia margin. These are lithospheric detachment faults, block faulting of the crust, the emplacement and exposure of mantle rocks, minor synrift magmatism, and the characterization of the OCT. The two margin segments, about 200 km apart, exhibit both similarities and differences.

The Galicia Bank margin has

- a narrow OCT (~30 km),
- an unusually clear S seismic reflector interpreted as a tectonic contact between crust and mantle or as a subhorizontal detachment fault,
- clear crustal fault blocks and extensive margin-parallel peridotite outcrops (possibly accentuated by post-rift uplift), and

- possible synrift magmatism (Boillot et al., 1989; Schärer et al., 1995).

The southern Iberia Abyssal Plain (IAP) margin has

- an unusually wide OCT (up to 130 km),
- clear crustal fault blocks,
- peridotite basement (certainly exposed along a narrow ridge, on an isolated high and possibly within a region of smooth basement) and,
- at present, tentative evidence of synrift magmatism.

In the southern IAP, there is apparently no obvious deep and extensive sub-horizontal reflector like S, although several shorter intrabasement reflectors, onto which higher-angle normal faults sole out, have been recognized. The results of Leg 149 highlighted the need for more basement drilling, principally within the OCT, in order to better constrain the modes of lithospheric breakup and to understand the rift-to-drift tectonic and magmatic processes at this excellent example of a non-volcanic rifted margin. Further, independent geophysical work since Leg 149 led to revised tectonic and magmatic models for the rifting and initial seafloor spreading at this margin which can now be tested by further drilling to basement.

Problems that need further investigation and can be resolved by drilling along the southern IAP transect include:

- Characterization of the OCT (the petrology, original level and tectono-metamorphic evolution in the lithosphere, and age of the basement rocks). Where is the continental crust? What is the extent, if any, of a region of serpentinized peridotite within the OCT?
- Characterization of a low-angle detachment fault by drilling down to, and through, the intrabasement reflector and the shear zone.
- Spatial relationships between the mantle rocks, the synrift gabbros and the lower and upper continental crust.
- Understanding the modes of continental breakup and testing pure-shear and simple-shear lithospheric (crustal) extension models.

- Determining the age, nature, extent, and depth of emplacement of synrift magmatic material.
- Determining the nature of early-formed oceanic crust.

Southern Iberia Abyssal Plain OCT Models

Several preliminary tectonic and magmatic models for lithospheric rifting of the west Iberia margin have been produced (Brun and Beslier, 1996; Whitmarsh and Miles, 1995; Krawczyk et al., 1996; Pickup et al., in press; Whitmarsh and Sawyer, 1996), based on (1) earlier geophysical observations, (2) the Leg 149 results, (3) an interpretation of a new magnetic anomaly chart (Fig. 3), (4) the latest time-migrated seismic reflection profiles in the southern Iberia Abyssal Plain (only one is included, Fig. 4) and, (5) analogical models. The models differ in the degree of extrapolation from the boreholes that they employ, in the significance attributed to the peridotite ridge and, in whether the east-west distribution of different basement rocks within the OCT is considered to be systematic or just random. Moreover, some models deal both with modes of lithospheric rifting and OCT formation while others relate to the formation of the OCT alone. Such variety of approaches was valid after Leg 149 because of the small number of drill sites that reached basement.

The above data provide evidence for the ascent of mantle material and the probable underplating of gabbro under the rift zone, possibly just after continental breakup, and for detachment tectonics west of Site 901, at least as far as Site 900.

Two tectonic models propose that extension of the lithosphere occurred along large scale shear zones/detachment faults along which the granulite facies gabbro found at Site 900, and even peridotite (at least to the west in the broad northwest to southeast basement low, east of Site 898), was exhumed. Subsequent coeval asthenospheric upwelling led to adiabatic decompression melting and intrusion/underplating of gabbro near the base of the crust. Partial melting and intrusion occurred during extensional shear deformation in the lithosphere and the subsequent block faulting which led to final breakup. Both models predict the exposure of progressively deeper lithospheric levels to the west of Site 901 and possible synrift intrusion into the lower crust or uppermost mantle west of Site 901. They also recognize that the geometry of tectonic features, interpreted to exist on seismic profiles, includes the result of intense late stage deformation.

The models differ in the geometry of the shear zones/detachment faults. One model proposes a single detachment fault crosscutting the whole lithosphere, on which brittle faults in the upper crust sole out at depth, which is later dissected by further block faulting (Fig.5; Krawczyk et al., 1996). The other proposes the development of two conjugate and coeval normal shear zones, one in the lower continental crust and one in the mantle, which led to extreme thinning or even the disappearance of the lower crust (Brum and Beslier, 1996; Fig. 6).

Two other models have also been proposed (Whitmarsh and Sawyer, 1996). One hypothesis (Sawyer, 1994) is that the OCT between Site 901 and the peridotite ridge was produced by ultra slow seafloor spreading. This can explain the basement exposures of gabbro and peridotite, and the MORB-like character of the gabbro. It is difficult for this model to explain the lack of basalts in the basement cores and the presence of linear margin-parallel magnetic anomolies in the OCT. The other hypothesis (Whitmarsh and Miles, 1995) envisages the progressive tectonic and magnetic disruption of continental crust. It can explain the presence of intruded/underplated MORB-like gabbro but the lack of continental crust in the Leg 149 cores is unexpected.

Additional drilling during this leg will determine whether the above models are correct by testing the detachment hypothesis, by investigating the nature and evolution of the basement in the transition zone, and by seeking evidence of synrift magmatism.

SCIENTIFIC OBJECTIVES

As outlined above, Leg 149 largely succeeded in determining the oceanward and landward bounds of the OCT in the southern Iberia Abyssal Plain. The principal problem now is to investigate the nature of the basement within the OCT itself, to relate it to the general problems of modes of lithospheric extension and rift-to-drift processes, and to test aspects of the models for these tectonic and igneous processes. Leg 173 will attempt to achieve the following objectives:

- Sample acoustic basement, principally within the OCT, to characterize the tectonic and magmatic processes that dominate the transition from continental to oceanic crust in space and time (see Sites 901, IBERIA07A, IBERIA08A/8B, IBERIA09A/9B, IBERIA10A).
- Determine the role of detachment tectonics in the evolution of the margin. This will be done by drilling through a seismic reflector, interpreted as a major tectonic contact or detachment, on the east side of the high on which Site 900 has already been drilled. This new site (two alternative sites, IBERIA09A/9B have been proposed) will also enable determination of the kinematics of deformation and tectono-metamorphic evolution of deep lithospheric levels during a rifting episode and will help to assess the lateral extent of the Site 900 mafic rocks. Another site (IBERIA07A) will be drilled on the westernmost basement high associated with a westward-dipping normal fault, to test the prediction that simple-shear, as a thinning mechanism of the lithosphere, led to the exposure of low-level continental crust (or even uppermost mantle) at this point of the OCT .
- Determine the role and extent of synrift magmatism in the OCT crust, which is inferred to exist from the new magnetic anomaly chart and other data. Use isotope data to determine the petrogenetic origin and dates of original crystallization and subsequent metamorphism of igneous rocks (see Sites 901,

IBERIA07A, IBERIA08A/8B, IBERIA09A/9B) and to characterize synrift underplated material (Site IBERIA09A/9B.

- Sample acoustic basement beneath Site 901 or Sites IBERIA08A/8B to confirm predictions of the existence of continental crust, determine the approximate level in the crust from which it came, thereby setting an unequivocal landward limit to the OCT, and to define geometrical relationships between deep and shallow lithospheric levels (see Sites 901, IBERIA08A/8B).
- Sample the early-formed oceanic crust, as this would complete the whole transect from continental to oceanic crust. Its presence is inferred only by geophysical observations. Samples from this site (Site IBERIA10A) are expected to provide definitive evidence of the oceanic nature of the crust immediately (20 km) west of the peridotite ridge and may enable the seafloor-spreading model to be verified. They will also yield the, possibly unusual, chemistry of the thin crust formed by the earliest magma-starved seafloor spreading and provide valuable petrological and geochemical information about initial melt production (c.f. Site 900 gabbro) following continental break up at a nonvolcanic margin (see Site IBERIA10A).

DRILLING STRATEGY

The principal overall objective of this leg is to complete the transect of sites begun during Leg 149, that sampled basement from continental to oceanic crust. At all sites (except Sites 901 and IBERIA08B) the sediments will be drilled to within about 100 m of acoustic basement before coring commences, because the sediments were already extensively cored during Leg 149. The rotary core barrel (RCB) will be used at all sites. Drilling is anticipated to penetrate several tens of meters into basement. Site IBERIA09A or Site IBERIA09B will require a basement penetration of about 400 m or 600 m respectively.

Here, we plan to use a reentry cone and to case most, or all, of the sedimentary section. A pilot hole will be drilled into the top of basement and then logged. Further basement coring will proceed in a separate hole after casing has been set. The basement section of this hole will also be logged on completion.

No downhole measurements are planned; heatflow measurements were already made during Leg 149.

The ship is expected to occupy each site using Global Positioning System coordinates alone without the need for a pre-site survey since good multichannel seismics already exists over and around the sites.

There will probably be time on Leg 173 to drill only three or four sites (Table 1). The highest priority sites are Site IBERIA09A and Site IBERIA09B but only one of these sites will be drilled. The final choice will depend on additional processing (pre-stack depth migration) of new seismic lines in the area. However, the chosen site will be drilled second because the 18 hr transit from Lisbon does not allow the drill crew enough time to prepare the reentry cone and associated hardware. Site IBERIA08B will be drilled first. In addition we plan to drill Sites IBERIA07A and IBERIA10A if time allows.

LOGGING PLAN

Downhole measurements will provide an important contribution to the main objectives of Leg 173 because core recovery in the deepest sections and in basement is likely to be low.

The tectonic and petrologic objectives of this rifted-margin study should particularly benefit from logging data. Two standard logs (Triple Combo (resistivity/porosity/density/natural gamma) and Formation Microscanner (FMS/sonic/natural gamma-ray tools)) will be available onboard; they will be run at the standard speed at each site. The basement intervals may be logged several times with the FMS.

The main operational goal of the leg is to drill the basement. Determining the orientation of the structural planes, the fractures, and the faults in the basement should be achievable by interpreting the FMS images. The continuous FMS record will allow us to map the structural features in the basement and to precisely determine their azimuth and dips.

Two independent studies will attempt to predict the lithology of the borehole wall rocks from the log and core information using statistical and neural network techniques.

Core-log integration will be an important goal of this leg because of the likely poor recovery at great depth. Physical logging data, such as natural gamma ray and density, may be used to correlate core and log data. Moreover the FMS images will be used in collaboration with a CoreScan shipboard system, designed to image the surface of uncut whole round cores, to relate features seen on the FMS images to the cores, and to obtain the correct in situ azimuthal orientation of the cores and the structures within them. Therefore, this leg may provide an excellent opportunity to use core and log data integration as a means to reconstruct continuous, detailed records of lithologic variations and of structural features in the basement.

PROPOSED SITES AND SITE PRIORITIES

Site IBERIA07A

This site lies between Sites 900 and 899 where coring reached basement during Leg 149, on the crest of a 7-km-wide north-south basement high crossed by three E-W lines and one N-S line. The high appears to be a fault block bounded to the west by an oceanward-dipping normal fault and underlain by a sub-horizontal reflector (detachment fault?), 1.5 s below the crest of the high, that intersects the top of basement south of the site. The basement cores will serve to discriminate among the variety of models postulated for the development of the OCT.

Site IBERIA08A

The N-S crossing of this site, plus a further E-W crossing of the broad high on which it lies, reveal that the high has a trend somewhat west of north and shoals quite rapidly northward; the high could conceivably represent the southward continuation of the Vasco da Gama Seamount south of the Iberia Abyssal Plain. The objective of the site is to determine the westward edge of continental crust and to establish the petro-structural evolution of the continental crust and the spatial relationships between upper lithospheric levels (continental crust) and deeper levels (gabbros of Site 900).

Site IBERIA08B

This site lies on a tilted fault block of probable continental crust that is capped by tilted transparent syn- or prerift sediments. The plan is to drill to the top of the transparent layer and then to core down to the underlying basement. The objectives of the site are the same as those at Site IBERIA08A.

Sites IBERIA09A and IBERIA09B

The seismic data indicate that the high on which this site is situated has an elliptical plan view slightly elongated in a N-S direction. The principal objective of the site is to drill down through possible upper crust or early synrift or prerift sediments to a strong extensive intrabasement reflector (H), interpreted to be an extensional synrift tectonic feature (detachment fault?). The H reflector outcrops a short distance to the west of the sites in the vicinity of Site 900. We expect the gabbro cored there to underlie H. Two other nearby seismic lines that also image H are currently being pre-stack depth migrated.

Site IBERIA10A

This site lies over an elongated margin-parallel basement ridge that lies about 15 km east of the crest of the J magnetic anomaly and 20 km west of the peridotite ridge. Here, attempts to model the magnetic anomalies by seafloor spreading predict the presence of ca. 130 Ma oceanic crust. The objective of the site is to sample the early-formed oceanic crust. Samples from this site are expected to provide definitive evidence of the oceanic nature of the crust immediately west of the peridotite ridge and may enable the seafloor-spreading model to be verified. They will also yield the, possibly unusual, chemistry of the thin crust formed by the earliest magma-starved seafloor spreading and provide valuable petrological information about initial melt production following continental break up at a nonvolcanic margin.

Site 901

This site, already drilled and cored during Leg 149, lies over a tilted fault block capped by a layer of tilted transparent shallow-water sediments of Late Jurassic (Tithonian) age. It exhibits an almost identical geometry on seismic profiles to Site IBERIA08B and the scientific objectives are the same. Because Site IBERIA08B lies west of the major, deeply penetrating north-northeast fault bounding Site 901 this latter site has a lower priority.

The following priorities have been assigned to the sites.

Priority 1

Site IBERIA07A, the most oceanward site within the OCT, will sample basement on a topographic high, which is apparently bounded to the west by a normal fault and underlain by a strong sub-horizontal reflector. This will test the simple-shear extension model for the upper lithosphere and may even reveal an upper mantle exposure. Sites IBERIA09A/9B (either 9A or 9B, but not both, will be drilled) will transect the H seismic reflector, and thereby test the simple-shear lithospheric extension model, and assess the lateral extent of the possibly synrift gabbro basement rocks sampled at Site 900. Sites IBERIA08A/IBERIA08B/901 (one site only) will be drilled to confirm the continental nature of the basement and its approximate original level in the crust, to thereby limit the landward edge of the OCT. In addition, all of the above sites will potentially provide evidence to assess the contribution and lateral extent of synrift magmatism.

Priority 2

Site IBERIA10A will be drilled to demonstrate the existence, age, and chemical nature of the early-formed oceanic crust 20 km oceanward of the peridotite ridge.

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Table 1. Proposed Site Information and Drilling Strategy

Primary Sites

Site	Latitude	Longitude	Water depth (mbsl)	Penet-ration (mbsf)	Transit (days)	Drilling (days)	Logging (days)	Total days
Transit from Lisbon, Portugal, to Site IBERIA08B (171nmi@10.5kt)					0.7			0.7
IBERIA08B	40°43.50′N	11°18.0′W	4725	750		7.0	1.0	8.0
Transit from Site IBERIA08B to IBERIA09A (14nmi @10.5kt)					0.1			0.1
IBERIA09A	40°40.94′N	11°35.60′W	5040	1150		21.1	2.0	23.1
Transit from Site IBERIA09A to IBERIA07A (9nmi @10.5kt)					0.1			0.1
IBERIA07A	40°43.00′N	11°46.70′W	5150	970		6.8	1.2	8.0
Transit from Site IBERIA07A to IBERIA10A (44nmi @10.5kt)					0.2			0.2
IBERIA10A	40°47.80′N	12°43.40′W	5500	700		5.4	1.1	6.5
Transit from Site IBERIA10A to Halifax, Canada (2283nmi@10kt)					9.3			9.3
Total					10.4	40.3	5.3	56.0

Alternate Sites

IBERIA08A	40°40.90′N	11°15.30′W	4830	1550		18.1	1.0	19.1
901	40°40.48′N	11°03.59′W	4720	830		6.2	1.1	7.3
IBERIA09B	40°40.94′N	11°35.08′W	5040	1600		31.0	2.3	33.3

FIGURE CAPTIONS

Figure 1. Bathymetric chart of the west Iberia margin; contours at 200, 500, 1000, 1500 m, etc. Existing DSDP/ODP sites are shown by black dots. Inset is an expanded plot of the boxed area at 40˚40′N showing old (circles) and proposed (triangles) drill sites and tracks of seismic reflection profiles used to create the composite cross-section in Figure 2.

Figure 2. Composite seismic time section created from the track segments of, from west to east, the *Sonne*, *JOIDES Resolution*, and *Lusigal* profiles shown in Figure 1. The irregular surface is the top of the acoustic basement. Basement was sampled at Sites 897, 899, and 900 during Leg 149. The nature of basement (oceanic, transitional, extended continental) is indicated; at Site 901 it is inferred. Proposed Sites IBERIA07A, IBERIA08A/B, IBERIA09A/B, and IBERIA10A are also indicated. IBERIA07A lies slightly to the north of this profile.

Figure 3. Part of a new reduced-to-the-pole magnetic anomaly chart of the whole west Iberia margin produced in collaboration with the Atlantic Geoscience Centre, Dartmouth, Nova Scotia, Canada (Miles et al., 1996). The chart was made from a 5-km-gridded data set and is contoured at 25 nT. The main chart is based on over 400,000 sea-surface observations which were corrected to remove the effects of secular variation, high geomagnetic activity, spurious tracks, and systematic cross-over errors. Greater confidence in the quality of the resulting dataset allowed the use of the small contour interval. Leg 149 drilled to basement in this area (white dots); proposed sites are shown by squares. The data were reduced to the pole to clarify many features. Major linear trends in the anomalies are picked out by bold lines. The chart clearly shows the strong positive J anomaly which appears just west of 13˚W and south of 41˚30′N. Between Site 897 and the continental shelf (~9˚15′W) and north of 41˚N other less strong positive anomalies are associated with the shallow regions of Galicia Bank. South of ~41˚N the chart can be divided into three distinct zones (bounded by the two broad N-S black bands) based on the character of the anomalies.

Figure 4. East-west migrated multichannel seismic reflection profile *Lusigal*-12 through Sites IBERIA08A, IBERIA09A/B, 900, and 901 (Fig. 1). The lower profile is an interpretation of basement reflections seen in the upper profile. Synrift I sediments are marked by close diagonal ruling; synrift II sediments are marked by coarse ruling. H is a detachment fault controlling extension during synrift I phase; L is a listric fault active during the synrift II phase. Pre-rift units are probably present in fault block FB, but are not identified. The magnetic anomaly profile (top) was computed from the data set used to produce the magnetic anomaly chart in Figure 3.

Figure 5. Cartoon incorporating available drill core and geophysical evidence into a single integrated model for the evolution of the southern Iberia Abyssal Plain margin (Krawczyk et al., 1996). As high level extension was accommodated along a detachment fault, upwelling of the asthenosphere in response to “pure shear” extension at depth caused melting and intrusion of lower crust into the transition zone. Intrusion probably continued during subsequent block-faulting which dissected the lower plate to the detachment fault. Drilling during Leg 173 will test this model by investigating the nature of crust in the transition zone and testing the detachment hypothesis.

Figure 6. Sketches *a* to *d* describe the progressive stretching of a four-layer brittle-ductile continental lithosphere leading to mantle exhumation at a rifted margin (Brun and Beslier, 1996). The lowermost sketch is a schematic interpretative geologic cross-section of the Iberia Abyssal Plain based on the model in the rest of the figure.

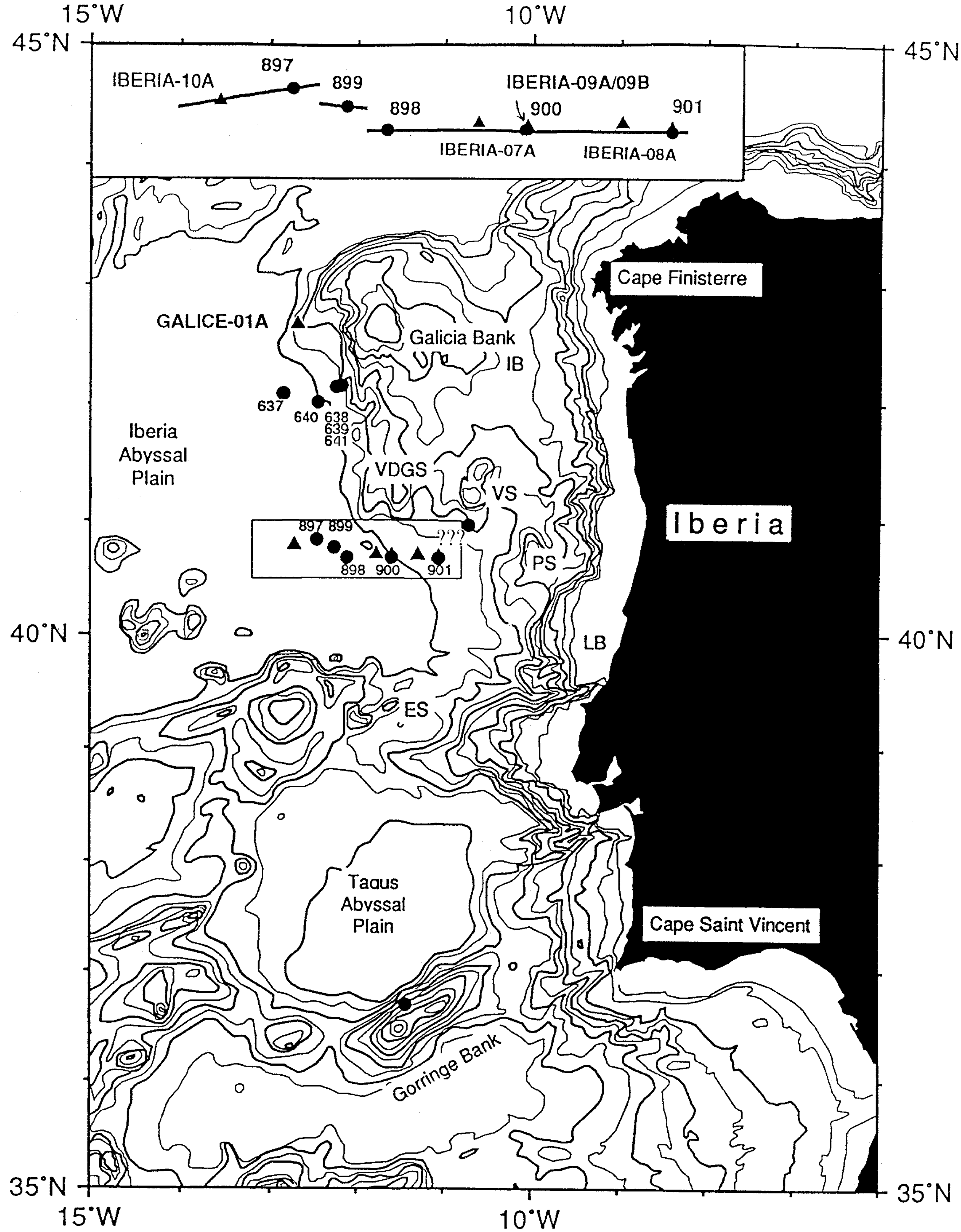
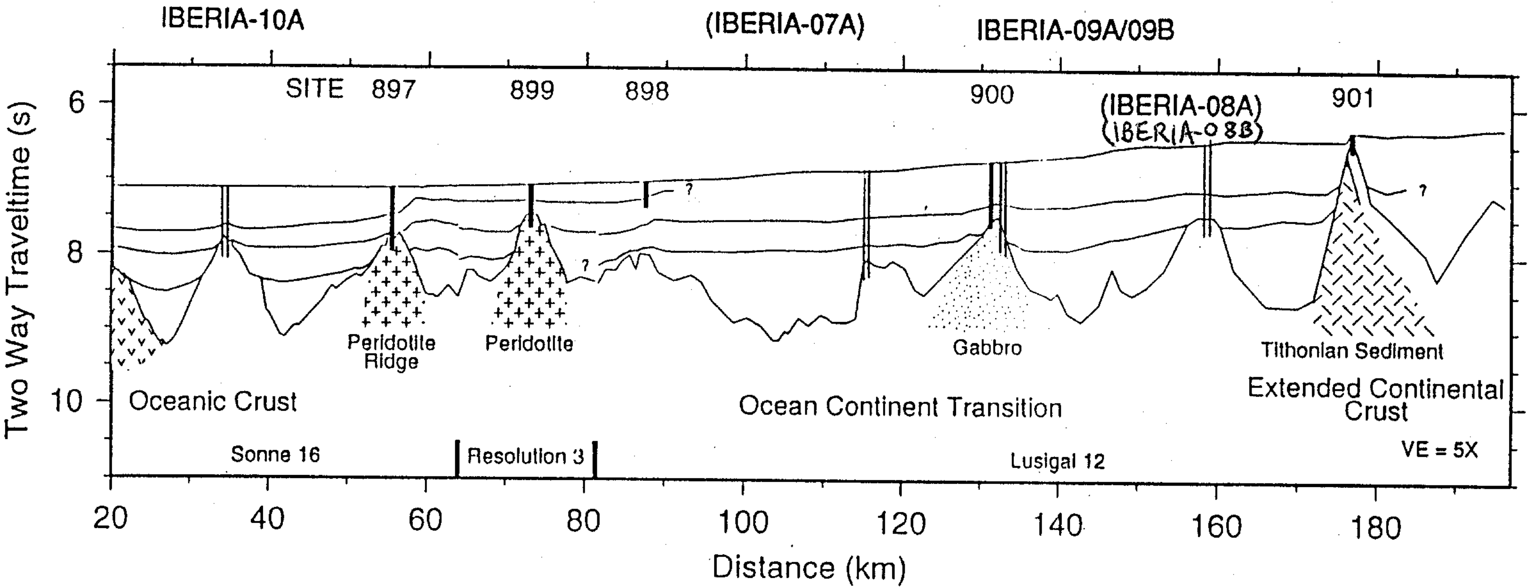
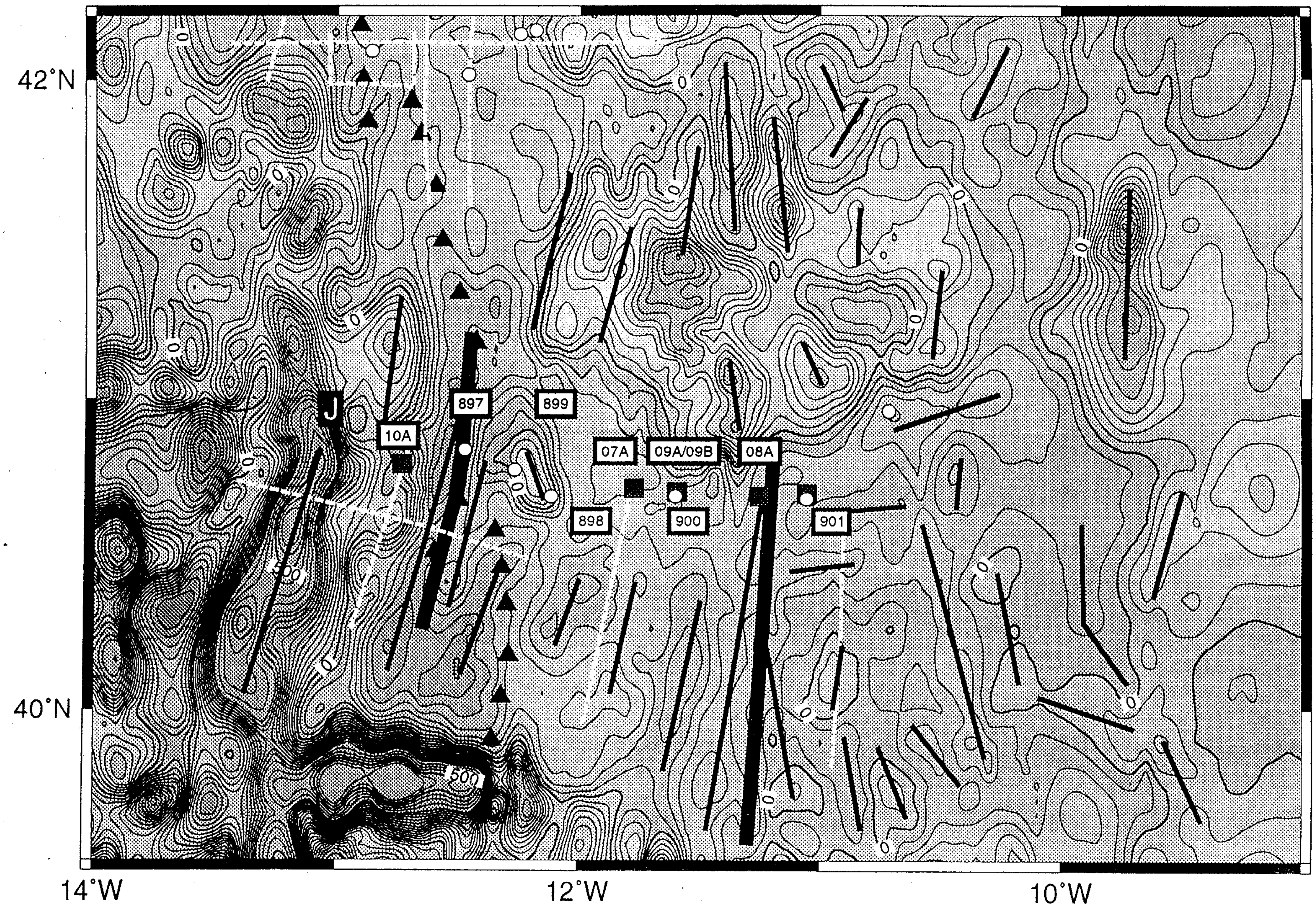

15°W
10°W
45°N
40°N
35°N
IBERIA-10A
897
899
898
IBERIA-09A/09B
900
901
IBERIA-07A
IBERIA-08A
Cape Finisterre
GALICE-01A
Galicia Bank
IB
637
640
638
639
641
Iberia
Abyssal
Plain
VDGS
VS
Iberia
PS
LB
ES
Tagus
Abyssal
Plain
Cape Saint Vincent
Gorringe Bank

Figure 1

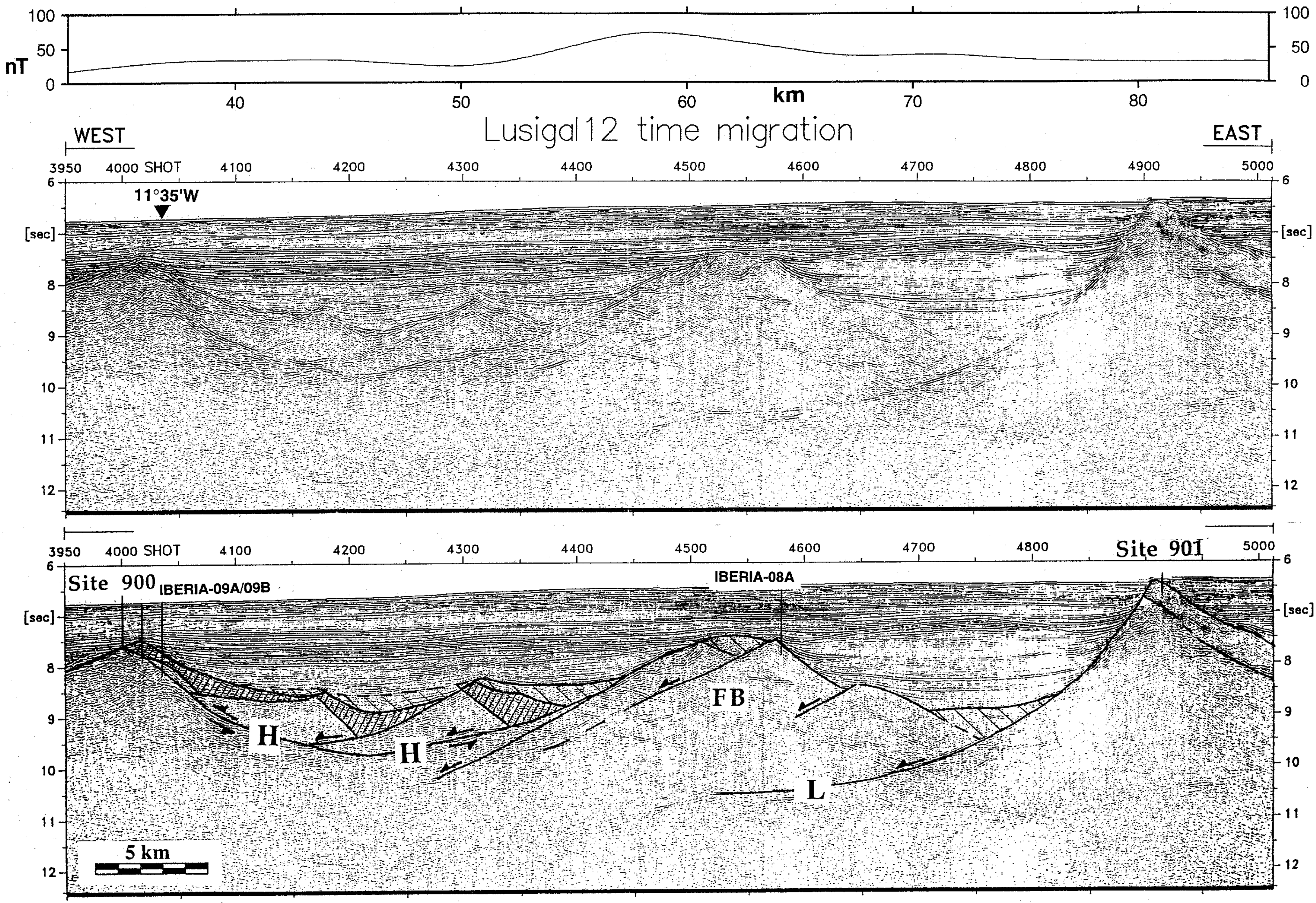


IBERIA-10A
(IBERIA-07A)
IBERIA-09A/09B
SITE 897
899
898
900
(IBERIA-08A)
(IBERIA-08B)
901
?
?
?
Peridotite Ridge
Peridotite
Gabbro
Tithonian Sediment
Oceanic Crust
Ocean Continent Transition
Extended Continental Crust
Sonne 16
Resolution 3
Lusigal 12
VE = 5X
Two Way Traveltime (s)
6
8
10
20
40
60
80
100
120
140
160
180
Distance (km)

Figure 2



42°N
40°N
14°W
12°W
10°W
J
897
899
10A
07A
09A/09B
08A
898
900
901
500
0



nT
100
50
0
40
50
60
70
80
km
Lusigal12 time migration
WEST
EAST
3950
4000 SHOT
4100
4200
4300
4400
4500
4600
4700
4800
4900
5000
11°35'W
[sec]
6
8
9
10
11
12
Site 900
IBERIA-09A/09B
IBERIA-08A
Site 901
H
H
FB
L
5 km

Figure 4

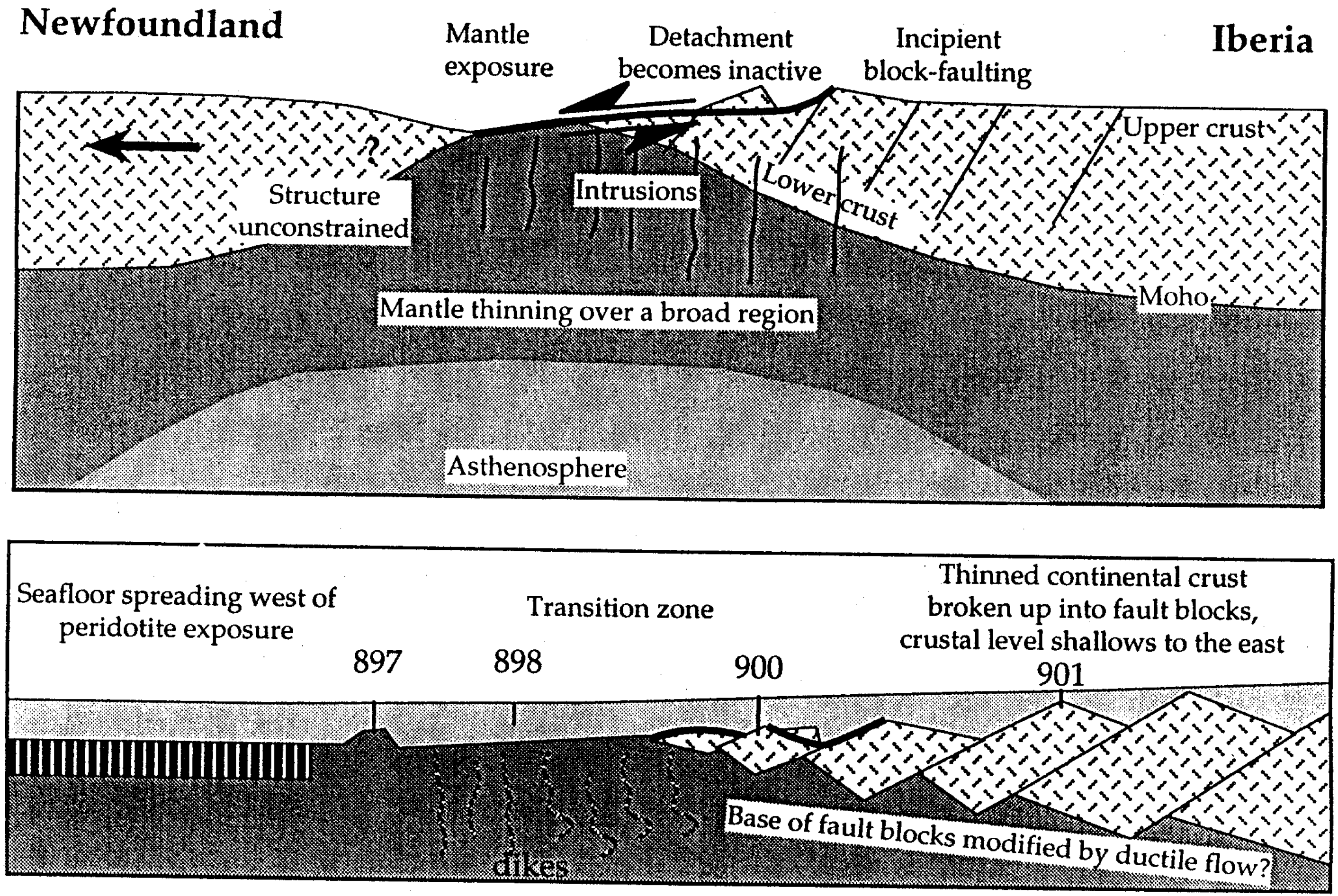
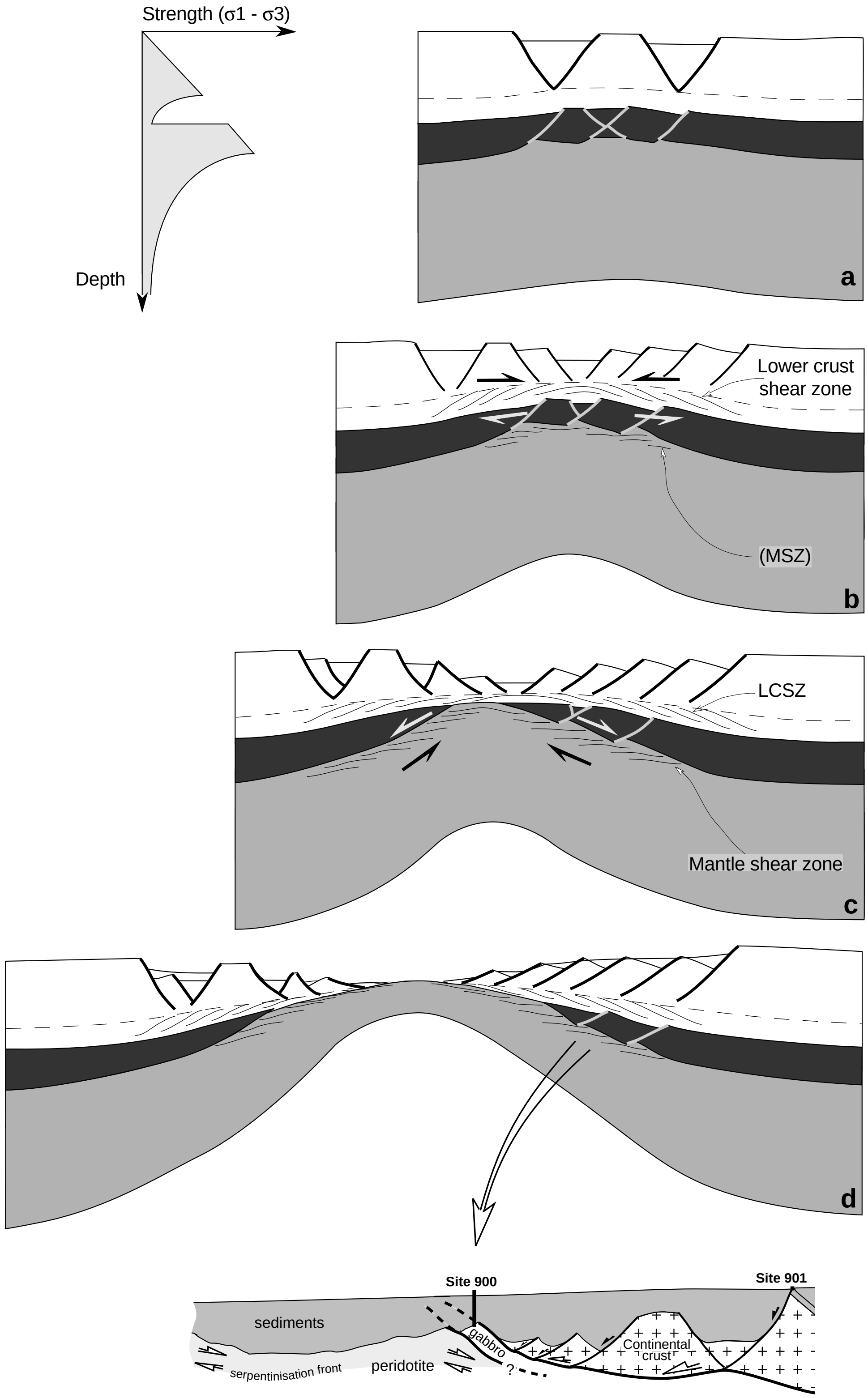

Newfoundland
Mantle exposure
Detachment becomes inactive
Incipient block-faulting
Iberia
?
Upper crust
Structure unconstrained
Intrusions
Lower crust
Moho
Mantle thinning over a broad region
Asthenosphere
Seafloor spreading west of peridotite exposure
Transition zone
Thinned continental crust broken up into fault blocks, crustal level shallows to the east
897
898
900
901
dikes
Base of fault blocks modified by ductile flow?

Figure 5

Figure 6


Strength (σ1 - σ3)
Depth
a
Lower crust
shear zone
(MSZ)
b
LCSZ
Mantle shear zone
c
d
Site 900
Site 901
sediments
gabbro
Continental
crust
serpentinisation front
peridotite
?

Site: IBERIA07A

Priority:1

Position: 40˚42'N, 11˚48'W

Water Depth: 5150 m

Sediment Thickness: 920 m

Total Penetration: 1020 m

Seismic Coverage: *Sonne*-75 Line 2, CDP730; Line CAM 134

Objectives:

1) Sample acoustic basement high in the OCT between Sites 899 and 900, to characterize the tectonic and magmatic processes that dominate the transition from continental to oceanic crust.

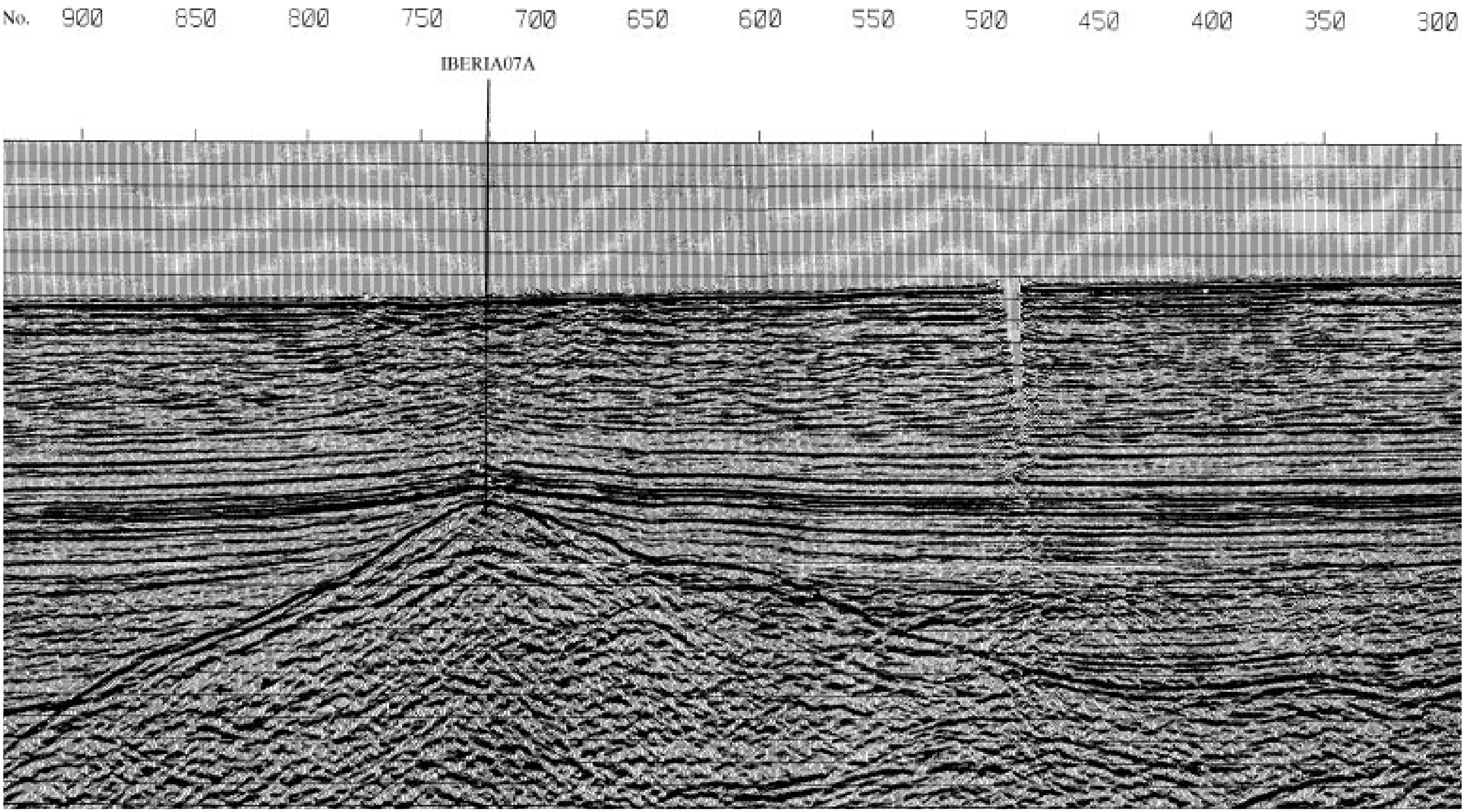
2) Test the prediction that simple shear as a thinning mechanism of the lithosphere led to the exposure of low level continental crust at this point in the OCT.

3) Determine the petrogenetic origin, synrift melting, and metamorphic history of igneous basement.

Drilling Program: Wash down to 100 m above basement and then RCB several tens of meters in basement or to bit destruction.

Logging And Downhole Operations: Triple combo and FMS.

Nature of Rock Anticipated: Nannofossil clay, clay, claystone, siltstone and fine sandstone, ooze, and chalk; mid/lower continental crust or serpentinized peridotite.



Site IBERIA07A

Site: IBERIA08A

Priority:1

Position: 40˚40.90'N, 11˚15.30'W

Water Depth: 4830 m

Sediment Thickness: 1050 m

Total Penetration:1550 m

Seismic Coverage: *Lusigal*-12, SP4580; Line CAM 145

Objectives:

1) Sample acoustic basement high (continental crust overlain by synrift (?) or early postrift sediments)

2) To characterize the tectonic and magmatic processes that dominate the transition from continental to oceanic crust.

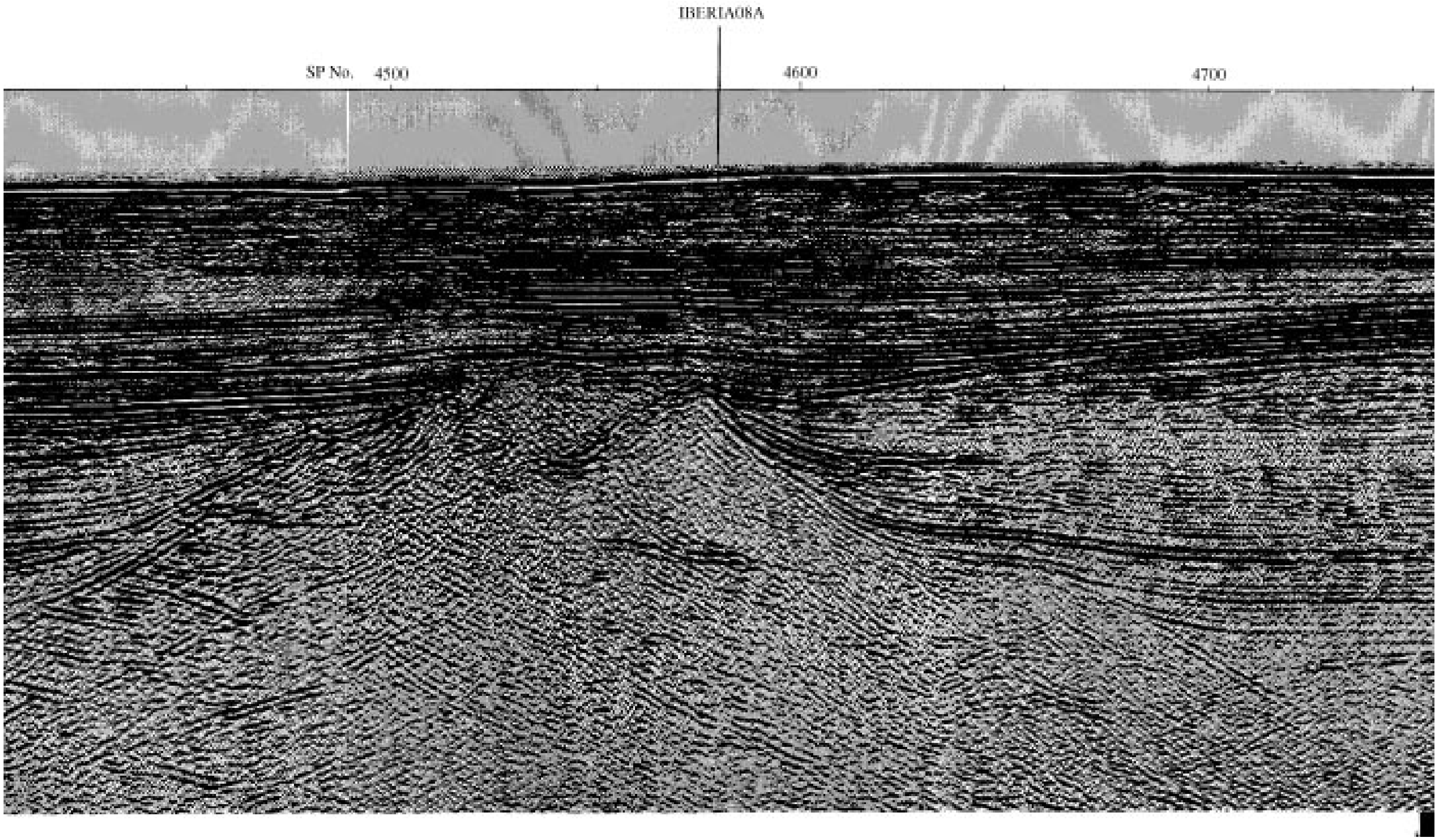
3) Determine the petrogenic origin, synrift melting and metamorphic history of igneous basement. Confirm predictions of continental crust at this site and the approximate level from which it came.

Drilling Program: Wash down to 100 m above basement and then RCB several tens of meters in basement or to bit destruction.

Logging and Downhole Operations: Quad, GLT, FMS

Nature of Rock Anticipated: Nannofossil clay, clay, claystone, siltstone and fine sandstone, ooze, and chalk; mid/lower continental crust possibly overlain by synrift (?) or early postrift sediments.

Site IBERIA08A (*Lusigal*-12)



Site: IBERIA08B

Priority:1

Position: 40˚43.5'N, 11˚18.0'W

Water Depth: 4725 m

Sediment Thickness: 400 m + 300 m (prerift).

Total Penetration: 750 m

Seismic Coverage: *Discovery* Line CAM 144, CDP3140

Objectives:

1) Sample acoustic basement high (continental crust overlain by synrift or prerift sediments).

2) Determine the early sedimentary and subsidence history.

3) Characterize the tectonic and magmatic processes that dominate the transition from continental to oceanic crust.

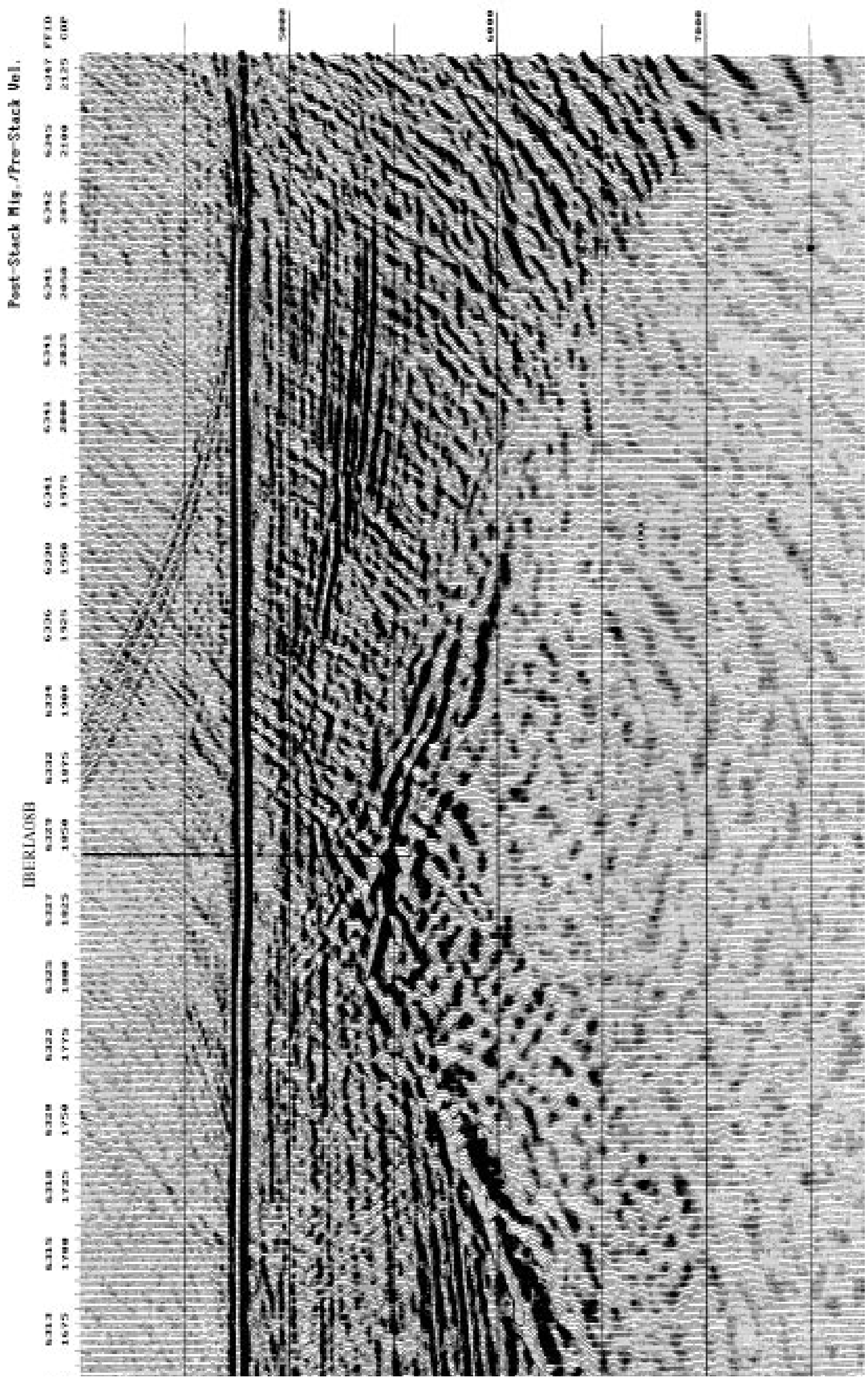
4) Determine the petrogenic origin, synrift melting, and metamorphic historyof igneous basement. Confirm predictions of continental crust at this site and the approximate level from which it came.

Drilling Program: Wash down to transparent layer of syn- or prerift sediments, then RCB through the transparent layer several tens of meters into basement or to bit destruction.

Logging and Downhole Operations: Triple combo, FMS.

Nature of Rock Anticipated: Nannofossil clay, clay, claystone, siltstone and fine sandstone, ooze, and chalk; upper/mid continental crust overlain by tilted syn- or prerift sediments.

Site IBERIA08B (*Discovery* CAM 144)



Site: IBERIA09A

Priority: 1

Position: 40˚40.94'N, 11˚35.60'W

Water Depth: 5040 m

Sediment Thickness: 1100 m (750 + 350 synrift)

Total Penetration: 1150 m

Seismic Coverage: *Lusigal* Line 12, SP4020, *RRS Discovery* Line CAM 136, CDP12890

Objectives:

1) Drill through the detachment fault to determine the role of detachment tectonics in the evolution of the margin.

2) Determine the kinematics of deformation and tectono-metamorphic evolution of the deep lithospheric loads during a rifting episode.

3) Characterize the tectonic and metamorphic processes that dominate the transition from continental to oceanic crust.

4) Determine its petrogenetic origin.

Drilling Program: Drill pilot hole ca. 20 m into basement. Log the hole. Jet-in test, set re-entry cone and casing. Drill 400 m into basement to pass through the H reflector (detachment fault). Log the hole.

Logging and Downhole Operations: Triple combo and FMS.

Nature of Rock Anticipated: Nannofossil clay claystone, siltstone and fine sandstone, ooze, and chalk; continental crust or gabbro.

Site: IBERIA09B

Priority:1

Position: 40˚40.94'N, 11˚35.08'W

Water Depth: 5040 m

Sediment Thickness: 1550 m (950 + 600 synrift)

Total Penetration: 1600 m

Seismic Coverage: *Lusigal* Line 12, SP4035; *Discovery* Line CAM 136, CDP12890

Objectives:

1) Drill through the detachment fault to determine the role of detachment tectonics in the evolution of the margin.

2) Determine the kinematics of deformation and tectonometamorphic evolution of the deep lithospheric loads during a rifting episode.

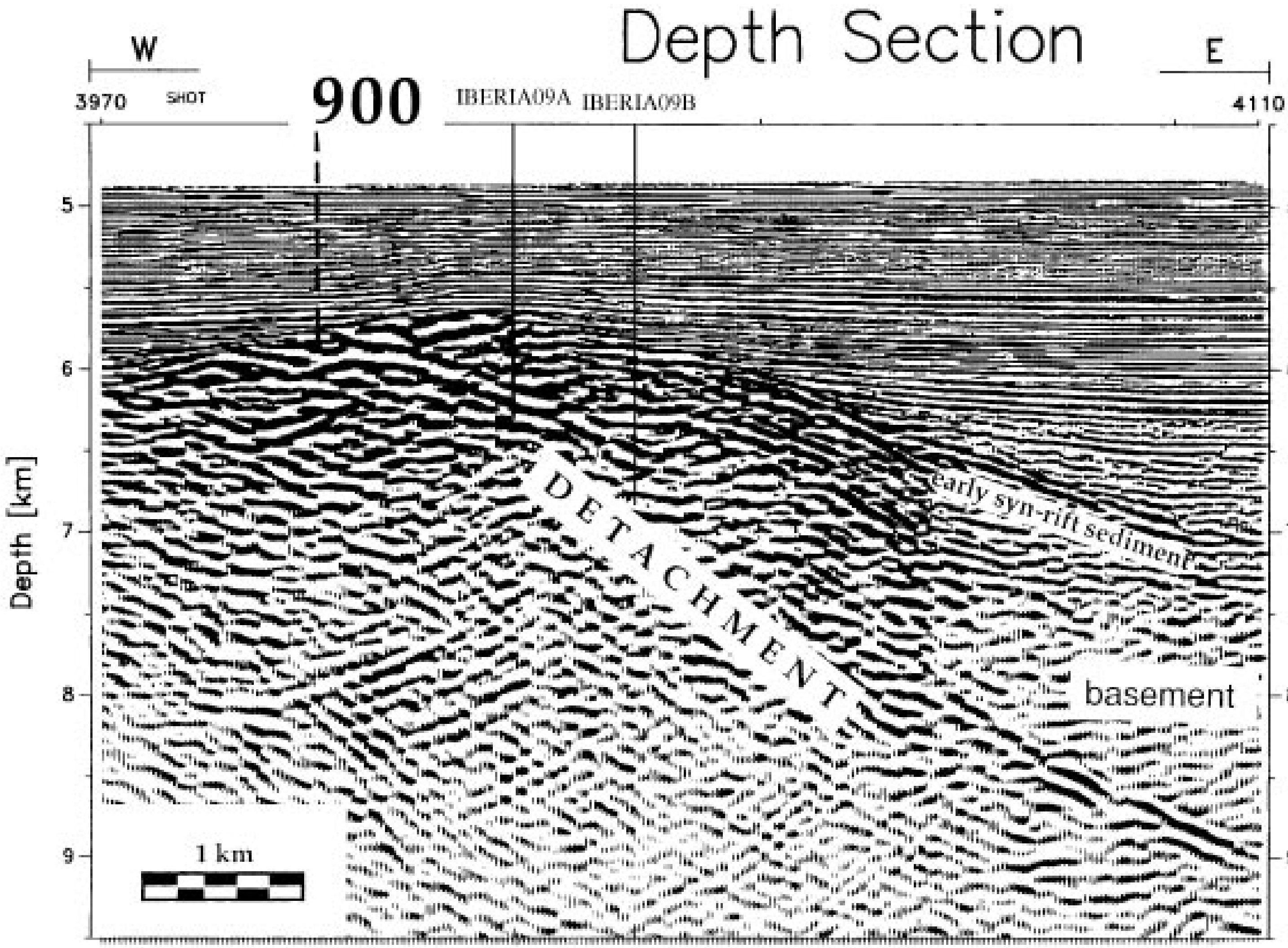
3) Characterize the tectonic and metamorphic processes that dominate the transition from continental to oceanic crust.

4) Determine its petrogenetic origin.

Drilling Program: Drill pilot hole ca. 20 m into basement. Log the hole. Jet-in test, set re-entry cone and casing. Drill 600 m into basement to pass through the H reflector. Log the hole.

Logging and Downhole Operations: Triple combo, FMS.

Nature of Rock Anticipated: Nannofossil clay, clay, claystone, siltstone and fine sandstone, ooze, and chalk; continental crust or gabbro.



Site IBERIA09A/B (*Lusigal*-12)

Site: IBERIA10A

Priority: 2

Position: 40˚47.80'N, 12˚43.40'W

Water Depth: 5500 m

Sediment Thickness: 650 m

Total Penetration: 700 m

Seismic Coverage: *Sonne*-75 Line 16 SP330; *Discovery*-161 day 234 (SCS)

Objectives:

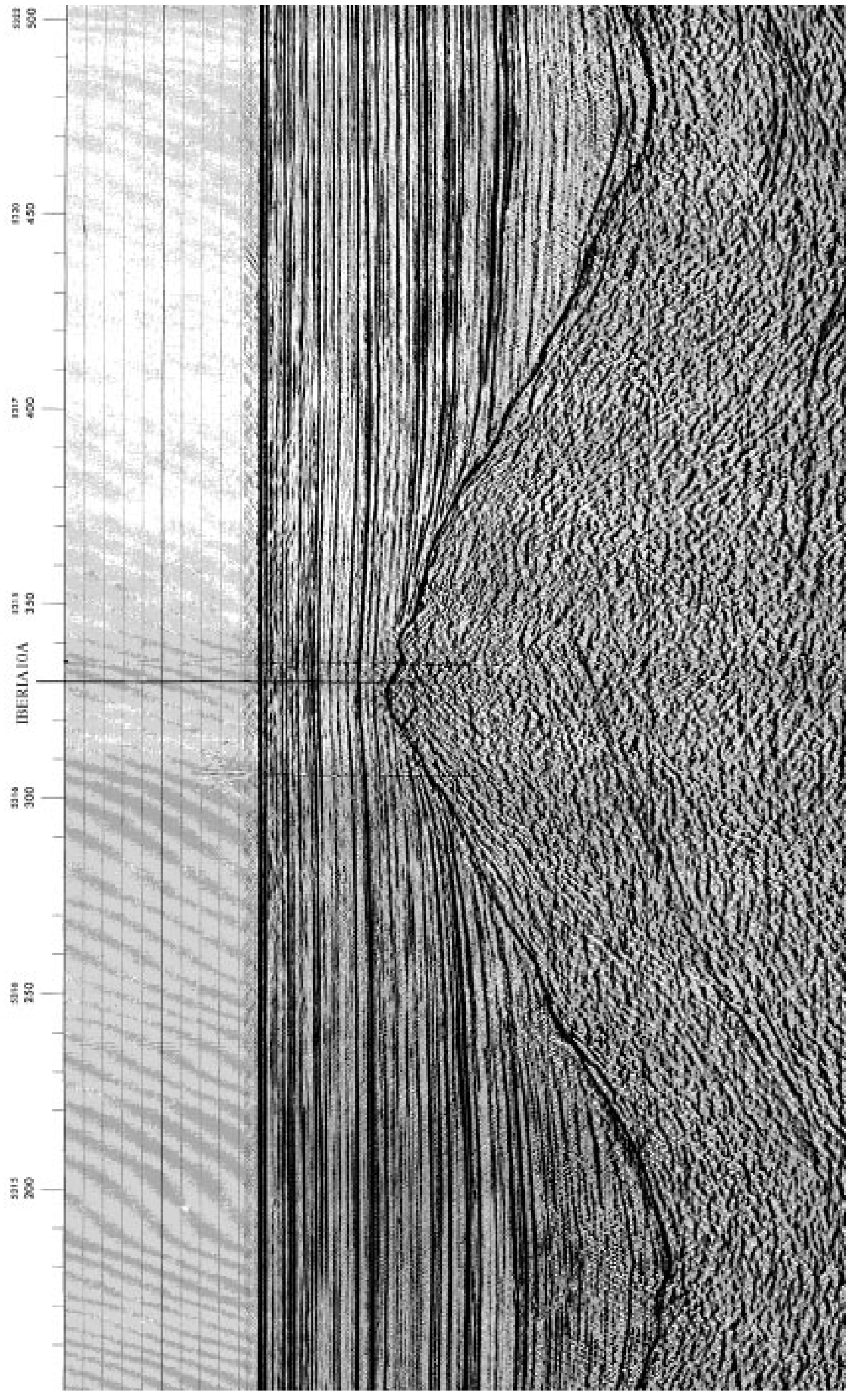
1) Sample oceanic basement west of margin-parallel peridotite ridge to characterize the chemistry and melting of the early formed oceanic crust.

Drilling Program: Wash down to within 100 m of basement and then RCB several tens of meters into basement or to bit destruction.

Logging And Downhole Operations: Triple combo, FMS.

Nature of Rock Anticipated: Nannofossil clay, clay, claystone, fine sand, silt, claystone turbidites, basalt.

Site IBERIA10A (*Sonne*-16)



Site: Site 901

Priority: 1

Position: 40˚40.48'N, 11˚03.59'W

Water Depth: 4720 m

Sediment Thickness: 780 m (post + synrift)

Total Penetration: 830 m

Seismic Coverage: *Lusigal* Line 12 SP4938

Objectives:

1) Continue Site 901 to basement at east end of OCT to sample and date the prerift sediments.

2) Refine lithospheric extension rift model.

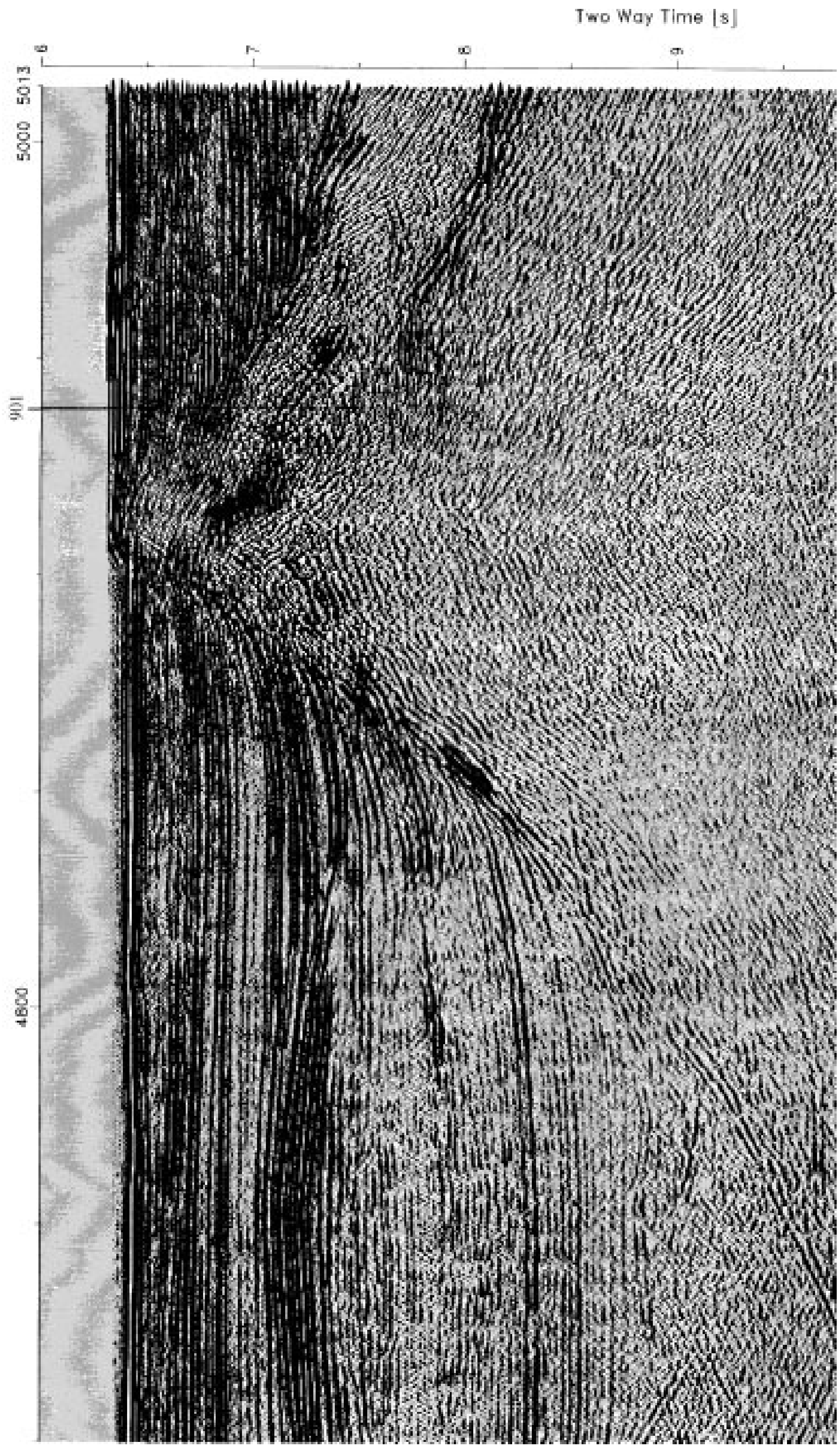
3) Determine early sedimentation and subsidence history, measure heat flow.

Drilling Program: Wash down and RCB to 100 m or to bit destruction.

Logging and Downhole Operations: Triple combo, and FMS.

Nature of Rock Anticipated: Nannofossil clay, silt, sandstone, shallow-water sandstones and carbonates; continental crust.

Site 901 (*Lusigal*-12)



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Leg 173: Return to Iberia

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