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THE ARGO ABYSSAL PLAIN:
A PROPOSAL TO DRILL REFLECTING INTERFACES WITHIN OCEANIC CRUST

BY H.M.J. STAGG & P.A. SYMONDS

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Division of Marine, Petroleum and Sedimentary Resources

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THE ARGO ABYSSAL PLAIN: A PROPOSAL TO DRILL REFLECTING INTERFACES WITHIN OCEANIC CRUST

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DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY

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FOREWORD

This preliminary drilling proposal is put forward to the Ocean Drilling Program to indicate the potential for drilling reflecting interfaces in oceanic crust in the Argo Abyssal Plain off northwestern Australia. The tectonic and/or magmatic origin of such reflectors has become an important research topic over the last few years because of its importance to understanding the accretion processes that occur at spreading ridges. As the quality of reflection seismic data collected over oceanic crust has improved, so has our imaging of the seismic characteristics and reflector geometries of this type of crust. The seismic reflection expression of oceanic crust, and possible origins for the reflectors is probably best presented in the paper by Mutter & Karson (1992). This proposal draws heavily on the discussion in this paper, and has very similar objectives to an ODP proposal (438----) titled " A drilling test of the origin of reflecting interfaces in oceanic crust" by J.C. Mutter & others.

A more detailed discussion of the nature and origin of reflectors within oceanic crust is not included within this proposal; however, it will be incorporated into later versions of the proposal following more detailed study of the reflection characteristics of the Argo Abyssal Plain crust. For more detailed information readers are referred to the above paper and proposal. Our main objective at this time is to reinforce previous discussions on the significance of oceanic crustal reflectivity and its importance to crustal accretion processes, and to highlight the Argo Abyssal Plain as an appropriate and well imaged location at which to study such phenomena by drilling.

The drill sites proposed are close to the maximum capability of total drill pipe deployment for the *JOIDES Resolution*; however, the water depths and sediment thicknesses involved are no greater than for other areas exhibiting good oceanic crustal reflectivity, and in the Argo area the seismic imaging is of extremely high quality. Also, the drilling characteristics of both the sediment and oceanic basement are well known in this area, from the 1988 drilling of ODP Site 765 in 5730 m of water with 1195 m of penetration (948 m of sediment and 247 m of oceanic basement) only a few kilometres from the proposed sites.

The Australian Geological Survey Organisation will be conducting further seismic work in the area in 1995; in particular refraction and wide-angle reflection studies using ocean bottom seismometers. It is possible that further definition of the sites could be carried out at this time.

It is likely that this proposal will be of thematic interest to both the ODP Tectonics and Lithosphere panels.

ABSTRACT

The presence of dipping reflectors and zones of high reflectivity in oceanic crust are being increasingly recognised on modern seismic reflection data. Some workers have related the reflection characteristics of oceanic crust and its associated Moho to spreading rate - slow-spreading crust is proposed to have the richest variety of reflections, but with a poorly imaged Moho, where as fast-spreading crust is suggested to be largely transparent but with a strong reflection Moho. The various reflection characteristics of slow-spreading crust have been associated with both tectonic and/or magmatic origins, but whatever their causes, they are clearly important to understanding the accretion processes that occur at spreading ridges. Although imaging of the seismic characteristics and reflector geometries of oceanic crust has improved dramatically in recent years, without direct information on the nature of the reflecting zones it will not be possible to uniquely constrain their origins and to test competing models.

Recent AGSO deep-seismic data over the Argo Abyssal Plain off northwest Australia provide excellent imaging of both strong crustal reflections and an associated Moho from the world's oldest (Late Jurassic) preserved oceanic crust. This area represents an ideal location at which to test the origin of a variety of oceanic crustal reflectors, and thus could make some major advancements in our understanding of spreading ridge accretion processes. The proposed sites, in conjunction with the nearby Site 765, will provide a unique insight into the nature, origin, variability and deformation of the oceanic crust in the region. Although the drilling will push the capabilities of the *Joides Resolution* to the limit, this is likely to be the case for any sites targeting such objectives within oceanic crust.

The main general objectives of the proposal are to:

1. Test models for the formation (tectonic and/or magmatic) of major crustal reflection features and zones in oceanic crust, and determine their significance to crustal accretion processes at spreading ridges;
2. Determine the cause of the reflectivity of the upper part of oceanic basement and its implications for the composition and physical properties of the crust;
3. Examine the thermal and mechanical evolution of oceanic crust as it ages and moves away from the spreading ridge, and, in particular, the nature and cause of any late-stage reactivation of primary structures.

BACKGROUND

Dipping Reflectors in Oceanic Crust

The presence of structured reflectors and high reflectivity zones within layers 2 and 3 of oceanic crust has been reported in a number of papers (White et al., 1990; Morris et al., 1993; Mutter & Karson, 1992). In an interpretation of these oceanic reflectors, Mutter & Karson (1992) conclude that the reflectivity of oceanic crust could be categorised in two groups:

1. In slow-spreading crust (spreading rates of less than about 35 $mm.a^{-1}$ - Mutter & Karson, 1992), there is no obvious reflection Moho while the main part of the crust exhibits a rich variety of reflecting horizons;

2. In fast-spreading crust, there is typically a strong reflection Moho, while the main part of the crust is essentially transparent to seismic energy.

In seeking reasons for these differences, they concluded that in fast-spreading crust, continuous magma injection was the dominating process, whereas in slow-spreading crust, mechanical extension plays the critical role, although recognising that at any particular instant in time the form of the spreading ridge is controlled by the interplay of volcanic and structural processes. Mutter & Karson (1992) suggest that in slow-spreading crust the reflection characteristics represent extensional deformation by both brittle and ductile mechanisms. Strong continuous bands of reflectors are interpreted as concentrated deformation in brittle-ductile shear zones, whereas pervasive, diffuse reflectivity of low continuity, particularly in the lower crust, is considered to represent distributed bulk coaxial extension in the ductile field (pure shear). Mutter & Karson (1992) interpret reflection bands that cross the entire crust as normal-sense detachment faults that allow for relative displacement of upper and lower crustal sections. They note that such features are imaged on seismic lines in both isochron and flow-line directions, and indicate that the major detachment faults are asymmetric, spoon-shaped features elongated parallel to the spreading axis.

The cause of the reflectivity of such fault zones is itself a very interesting question, as they would not be expected to separate rock of very different composition. Mutter & Karson (1922) advocate a mechanism as proposed by Dick et al., (1991), in which the high reflectivity may be caused by compaction-driven migration of intercumulus melt from a partially crystallised magma body into porous ductile shear zones. These melts alter the gabbros in the shear zones to high-density ferrogabbros, which provide the reflection impedance that allows them to be seismically imaged. However, it seems unlikely that such a mechanism can explain all the reflection characterstics of oceanic crust.

The main questions arising from the above discussion are:

1. What do the various reflection features and zones in oceanic crust represent in terms of crustal accretion processes at spreading centres?
2. What is the cause of the reflectivity in oceanic crust and its implications for the composition and physical properties of the crust?

AGSO Deep-seismic Data from the Argo Abyssal Plain

In 1993 and 1994, the Australian Geological Survey Organisation (AGSO) acquired several deep-seismic lines across the southeastern Argo Abyssal Plain, off northwest Australia. (Figs 1, 2; Stagg & Survey 120 Shipboard Party, 1993; Struckmeyer & Survey 128 Shipboard Party, 1994) in the area that was sampled by ODP Site 765 (Gradstein, Ludden, et al., 1990). These data, parts of which are reproduced here as Figures 3-9, provide the clearest images of oceanic crust reflectors of which we are currently aware. Spreading in the Argo Abyssal Plain commenced in the Late Jurassic (Callovian-Oxfordian) to Early Cretaceous (chrons M26-M16), making it the oldest segment of oceanic crust still preserved in the world's oceans. The spreading half-rate for the early stage of oceanic crust formation here has been computed at 42 $mm.a^{-1}$ (Heirtzler et al., 1978), 46 $mm.a^{-1}$ (Veevers & Li, 1991), 46 $mm.a^{-1}$ (Fullerton et al., 1989), and 37 $mm.a^{-1}$ (Sager et al., 1992), which places it just outside the slow spreading regime defined in Mutter & Karson's (1992) model. Assuming that the Argo crust is more like slow-spreading crust than fast-spreading crust, and that the Mutter & Karson model is applicable, we would expect to observe high reflectivity within the crust, and that a reflection Moho would probably be absent. We would expect to see a higher dip on the reflectors on a flow-line profile as compared to those on an isochron profile.

Examples from two orthogonal seismic profiles over the Argo Abyssal Plain are presented here; these profiles are parallel to the flow direction (NW-SE; line 120-1; Fig. 3) and parallel to the isochrons (ENE-WSW; line 120-2; Fig. 4). Note the location of ODP Site 765 at the intersection of the two profiles (Fig. 5). The profiles show marked differences in seismic reflection character.

The main crustal section in the flow line profile (Fig. 3) is seismically transparent, except for slightly increased reflectivity in the lower crust and a single, prominent reflector that originates beneath a major basement discontinuity and dips southwards at about 30° before dying out in the mid crust at about 9.3 s two-way time (twt). An upward extrapolation of this dipping reflector is associated with an offset of the basement surface in a sense that implies reverse movement along the potential shear zone. Reflection Moho appears as a strong, horizontal band of reflectors at about 10.6 s twt and the upper surface of the crust is moderately rugged. On this profile, the Argo Abyssal Plain appears to have more of the characteristics diagnostic of fast spreading crust.

In contrast, the main crustal section on the isochron profile (Fig. 4) exhibits very high and variable reflectivity. From the relatively smooth upper surface of the crust down to about 9.5 s twt, the crust is fairly transparent, except for planar dipping reflectors that dip both east and west at 30-45°. These dipping reflectors are associated with offsets at the top of the basement (Fig. 6), indicative of reverse shear along them, and also appear to produce offsets at the Moho (Fig. 7). Some movement along these shear zones may have occurred quite late - perhaps into the Aptian - as indicated by uplift of the sedimentary section overlying the hanging wall, and the form of onlapping depositional sequences (Fig. 6). Where reflectors are observed in the shallow crust, they are generally low amplitude and flat-lying. From approximately 9.5-10.6 s twt, the crust is highly reflective with the reflectors generally being of high amplitude but only low to moderate continuity. These reflectors occur in packages that appear to be constrained by the planar dipping ?shear zones, in a similar style to that indicated by Mutter & Karson (1992, fig. 8). This suggests that the dipping shear zones are primary features of the oceanic crust. Some of the dipping ?shear zones offset the basement surface, as previously mentioned, where as others do not extend to the basement surface or appear to terminate against major reflectors dipping in the opposite direction. Also very prominent on the isochron profile, is the reflection Moho at about 10.6 s twt. This reflector shows high continuity (Fig. 7) and can be traced, with only minor disruptions, along this line for more than 80 km.

From these profiles, we can make the following general observations:

1. Although the crust was formed during a period of relatively slow spreading, although at the high end of the slow-spreading range, there is a strong and continuous reflection Moho, in contradiction to the Mutter & Karson (1992) model;

2. The amount and clarity of intra-crustal reflections is much greater in the isochron profile than it is in the flow-line profile - this is intuitively unexpected; and

3. The dip of the strong planar reflectors is somewhat greater on the isochron profile than on the flow profile, which is at odds with the Mutter & Karson (1992) model. These dipping reflectors coincide with offsets at the basement surface and the base of the crust and therefore appear to be shear zones. The ?shear zones appear to be primary features of the oceanic crust, but have also undergone late-stage reactivation, perhaps up to 40 Ma or so after formation of the oceanic crust. The high reflectivity of these shears is difficult to explain in homogeneous rock, and is probably the result of intrusion or alteration along the shear zones.

The new AGSO deep-seismic data provides strong evidence for a deformational origin for the strong, dipping reflectors that extend through the full-crust. The nature and origin of the more subtle and gently-dipping reflector packages is less certain, and it is plausible that either magmatic or ductile deformational processes could be responsible.

Results from ODP Site 765

Ocean Drilling Program Site 765 was drilled in 1988 at the southernmost extremity of the Argo Abyssal Plain at a water depth of approximately 5730 m (Fig. 2). AGSO deep seismic data indicate that the site was in a slight basement depression (Figs 3, 4, and 8) at the apex of a crustal structure formed by east- and west-dipping ?shear zones. Site 765 penetrated approximately 932 m of flat-lying sediments, biostratigraphically dated as of earliest Cretaceous to Pleistocene age, overlying oceanic basement. Drilling of Hole 765D was terminated after drilling 247 m into basement.

The entire volcanic section cored in Holes 765C and 765D comprised pillow basalts (54%), massive basalts (28%), brecciated pillow basalts (8%), autoclastic breccia (6%), and diabase (4%) (Gradstein, Ludden, et al., 1990). The presence of brecciated volcanic rocks is particularly pertinent in view of the interpreted existence of shear zones within the crust.

During Leg 123 a vertical seismic profile was conducted at Site 765 to measure compressional wave velocities and to aid correlation of the drilling results with seismic data. This study identified a weak sub-basement reflection at 8.86 s twt, approximately 600 m into basement, and it has been suggested this may correspond to the contact between pillow basalts and sheet flows (Bolmer et al., 1992). This reflector was difficult to resolve on the normal pre-drill reflection seismic profiles over the site, but is clearly imaged on AGSO seismic lines 120-1 and 120-2 (Figs 3,4, and 8) as a relatively strong, undulating band of reflectors at 8.81-8.86 s twt. This interface corresponds to the sub-horizontal reflector at about 8.86 s twt that is the drilling target at the base of proposed site ARGO01A (Fig. 9). An assumed basement velocity of 4.0 km/s was used by Bolmer et al., (1992) to deduce the 600 m sub-basement depth of this reflector. This is somewhat less than the basement velocity used to estimate the 1000 m of basement penetration required to intersect intra-basement targets at proposed sites ARGO01A and ARGO02A, and suggests that given the Site 765 experience less than 1000 m of basement penetration may be necessary.

As the sites proposed here are within 3 km of Site 765, it is expected that drilling requirements and conditions will essentially be as previously encountered.

PROPOSED DRILLING SITES

In this proposal, we suggest that two holes, ARGO01A and ARGO02A (Fig. 9), be drilled a short distance to the west of Site 765 (Fig. 5), with the aim of drilling through intra-oceanic crustal reflectors to determine their characteristics and cause. The main general objectives of the proposal are to:

1. Test models for the formation (tectonic and/or magmatic) of major crustal reflection features and zones in oceanic crust, and determine their significance to crustal accretion processes at spreading ridges;
2. Determine the cause of the reflectivity of the upper part of oceanic basement and its implications for the composition and physical properties of the crust;
3. Examine the thermal and mechanical evolution of oceanic crust as it ages and moves away from the spreading ridge, and, in particular, the nature and cause any late-stage reactivation of primary structures.

The sites are designed to sample the main styles of oceanic crustal reflectivity - the strong dipping reflectors that extend through the whole crust; the transparent zones; and the zones of relatively flat-lying lower amplitude reflectors. Both holes will intersect the same dipping ?shear zone - one where the associated reflector is strong and one where it is more subtle. The ?shear zone to be sampled exhibits some evidence of minor late-stage reactivation, but much less than at other locations, where the primary fabric of the zone could well have been altered or destroyed.

While both these holes are pushing the drilling capabilities of the *Joides Resolution* to the limit, they are a unique opportunity to add to the information database on the processes affecting the formation and deformation of oceanic crust world-wide. As such the proposal clearly lies within the thematic domains of the JOIDES Lithosphere and Tectonic panels, and is very relevant to scientific problems and objectives defined in their recent white papers. In particular, it relates to LITHP questions concerning oceanic crustal accretion and the interplay between magmatism and tectonism at or near the ridge axis; and the thermal and mechanical evolution of the oceanic lithosphere. It attacks important TECP objectives that are also concerned with the competing effects of magmatic construction and mechanical extension that create the diverse structural fabrics of fast and slow-spreading ridges. Specific TECP goals relate to understanding mid-ocean ridge constructional processes in three dimensions, and testing the models for the origin of seismic reflectors in oceanic crust.

As ODP Site 765 was drilled near the proposed sites, drilling times and conditions can be much better constrained than at a virgin site. Also, a considerable body of information exists for Site 765, including a VSP, which provides good velocity control on the upper crustal section. Together this information will help reduce the uncertainties involved is estimating target depths and hence drilling times from the seismic data.

Drilling 247 m of basement at Hole 765D took about 9 days giving a drilling rate of 27 m per day. At this rate it would take about 26 days to drill 700 m of oceanic basement and about 37 days to drill 1000 m. Recovery was stable at the base of the hole at about 30-40%, and shipboard scientists on Leg 123 suggested that "given the present drilling limits of the *JOIDES Resolution*, a further penetration of 1 to 1.5 km might be possible".

A variety of good quality multichannel seismic data, and some single channel data, exists in the vicinity of the proposed sites (Fig. 5), and the deep-seismic line tying the sites to the through Site 765 is of excellent quality. At the moment there is no crossing seismic line through the proposed sites, but it is possible that such information could be obtained in 1995 during other seismic operations in the area. AGSO is planning to conduct refraction and wide-angle reflection experiments in the area using OBS's in 1995, and the information from this work will provide valuable velocity control within oceanic basement. At this time it may also be possible to collect further crossing deep-seismic data over the proposed sites, as well as higher resolution GI gun array data to further enhance the upper crustal seismic image. Other preparatory activities that could be conducted are additional enhancement of the existing seismic image by further optimisation of the stacking velocity field, particularly within oceanic basement, and the use of techniques such as iterative pre-stack depth migration, and depth conversion using a variety of approaches. However, given the great water depths involved and the consequent insensitivity of the seismic image to stacking velocity etc., it is unlikely that any major quality gains will be obtained. Improved processing of other multi-channel seismic data in the area, particularly line 56/22P3 (Fig. 5), could be attempted.

Specifications of the proposed sites are summarised on the following page:

ARGO01A

Objective: To drill through a dipping reflector a short distance below the surface of oceanic basement, where the reflector is relatively subtle, and continue to depth to penetrate a horizontal reflector approximately 0.35 s twt into basement.

At this site, penetration of the dipping reflector alone requires only a little more basement drilling than has been already achieved at Site 765.

Location: 15° 59.1' S 117° 33.1' E
Water Depth: 5685 m
Total Penetration: 1600-1900 m
Sediment thickness: 900 m
Basement Penetration: 700-1000 m
Seismic Coverage: AGSO line 120-2, SP 510
Rocks Anticipated: Turbidites and oozes overlying oceanic basement.
Pollution Prevention & Safety: ODP Site 765 drilled nearby with no problems.

ARGO02A

Objective: To drill through a high-amplitude dipping band of reflectors within oceanic crust, and the overlying relatively transparent upper section of oceanic basement.

Location: 15° 59.4' S 117° 32.4' E
Water Depth: 5685 m
Total Penetration: 1600-1900 m
Sediment Thickness: 900 m
Basement Penetration: 700-1000 m
Seismic Coverage: AGSO line 120-2, SP 485.
Rocks Anticipated: Turbidites and oozes overlying oceanic basement.
Pollution Prevention & Safety: ODP Site 765 drilled nearby with no problems.

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APPENDIX 1: ODP SITE SUMMARY FORMS

Site summary forms for the proposed sites ARGO01A and ARGO02A are contained on the following pages.

ODP Site Summary Form

Fill out one form for each proposed primary and alternate site and attach to proposal.

Title of Proposal:	The Argo Abyssal Plain: a proposal to drill reflective interfaces within oceanic crust
Site-specific Objective(s) (List of general objectives must be inc. in proposal)	Determine the nature of a significant dipping reflector - a possible crustal shear zone - near the surface of oceanic basement and the cause of moresubtle horizontal reflectors within basement.

Site Name:	ARGO01A
Area:	Southern Argo Abyssal Plain - off northwest Australia
Lat./Long.:	15° 59.1' S 117° 33.1'E
Water Depth:	5685 m
Sediment Thickness:	900 m
Total penetration:	1600 to 1900 m

	Sediments	Basement
Penetration:	900 m	700 to 1000 m
Lithology(ies):	Turbidites and pelagic ooze, ash layers	Basalt and gabbro, possibly brecciated in places

Coring (circle): 1-2-3-APC VPC* XCB MDCB* PCS RCB Re-entry HRGB

Downhole measurements: 1. Schlumberger suite - standard quad combo & P/S wave tools 2. FMS 3. Bore-hole televiewer 4. VSP

Estimate of days on site: 35 - 45?

*Systems currently under development.

Target(s) (see Proposal Submission Guidelines): A B C D E F G H (circle)

Site Survey Information (see Proposal Submission Guidelines for details and requirements):

		Check	Details of available data and data that is still to be collected
01	High res. seismic refl.		
02	Deep penetration seis. refl.	✓	AGSO 16 s record line 120-2 (48-fold; 192 channel)
03	Seismic velocity	✓	
04	Seismic grid	✓	Regional network of MCS lines
05a	Refraction (surface)		To be collected in 1995 using OBSs (refraction & wide-angle reflection)
05b	Refraction (near bottom)		
06	3.5 kHz	✓	
07	Swath bathymetry		
08a	Side-looking sonar (surface)		
08b	Side-looking sonar (bottom)		
09	Photography or video		
10	Heat flow	✓	From Site 765
11a	Magnetics	✓	
11b	Gravity	✓	
12	Sediment cores	✓	Nearby (~3 km) due to Site 765
13	Rock sampling	✓	
14	Water current data		
15	OBS microseismicity		
16	Other		VSP at nearby Site 765

Weather, Ice, Surface Currents: Generally good; potential cyclones December-February

Seabed Hazards: None known

Territorial Jurisdiction: Australia

Proponent Name, Address, Ph., Fax, Email:

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Date: December, 1994

ODP Site Summary Form

Fill out one form for each proposed primary and alternate site and attach to proposal.

Title of Proposal:	The Argo Abyssal Plain: a proposal to drill reflective interfaces within oceanic crust
Site-specific Objective(s) (List of general objectives must be inc. in proposal)	Determine the nature of a significant dipping reflector - a possible crustal shear zone - within oceanic crust and the overlying transparent basement..

Site Name: -	ARGO02A
Area:	Southern Argo Abyssal Plain - off northwest Australia
Lat./Long.:	15° 59.4' S 117° 32.4'E
Water Depth:	5685 m
Sediment Thickness:	900 m
Total penetration:	1600 to 1900 m

	Sediments	Basement
Penetration:	900 m	700 to 1000 m
Lithology(ies):	Turbidites and pelagic ooze, ash layers	Basalt and gabbro, possibly brecciated in places

Coring (circle): 1-2-3-APC VPC* XCB MDCB* PCS RCB Re-entry HRGB

Downhole measurements: 1. Schlumberger suite - standard quad combo & P/S wave tools 2. FMS 3. Bore-hole televiewer 4. VSP

Estimate of days on site: 35 - 45?

*Systems currently under development

Target(s) (see Proposal Submission Guidelines): A B C D E F G H (circle)

Site Survey Information (see Proposal Submission Guidelines for details and requirements):

		Check	Details of available data and data that is still to be collected
01	High res. seismic refl.		
02	Deep penetration seis. refl.	✓	AGSO 16 s record line 120-2 (48-fold; 192 channel)
03	Seismic velocity	✓	
04	Seismic grid	✓	Regional network of MCS lines
05a	Refraction (surface)		To be collected in 1995 using OBSs (refraction & wide-angle reflection)
05b	Refraction (near bottom)		
06	3.5 kHz	✓	
07	Swath bathymetry		
08a	Side-looking sonar (surface)		
08b	Side-looking sonar (bottom)		
09	Photography or video		
10	Heat flow	✓	From Site 765
11a	Magnetics	✓	
11b	Gravity	✓	
12	Sediment cores	✓	Nearby (~3 km) due to Site 765
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14	Water current data		
15	OBS microseismicity		
16	Other		VSP at nearby Site 765

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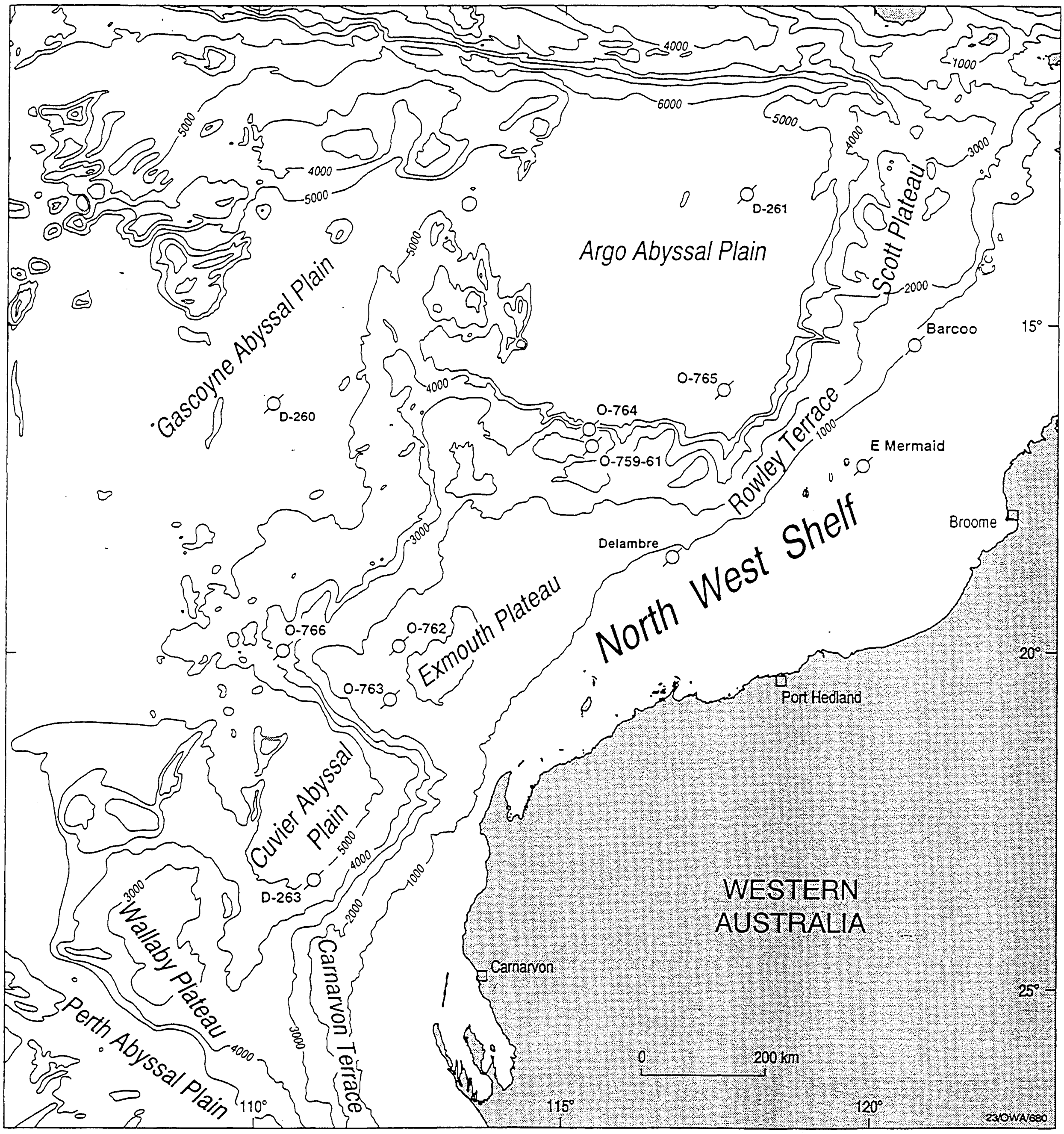

Figure 1: Bathymetric map of the North West Shelf and adjacent ocean basins (after Exon, 1994)

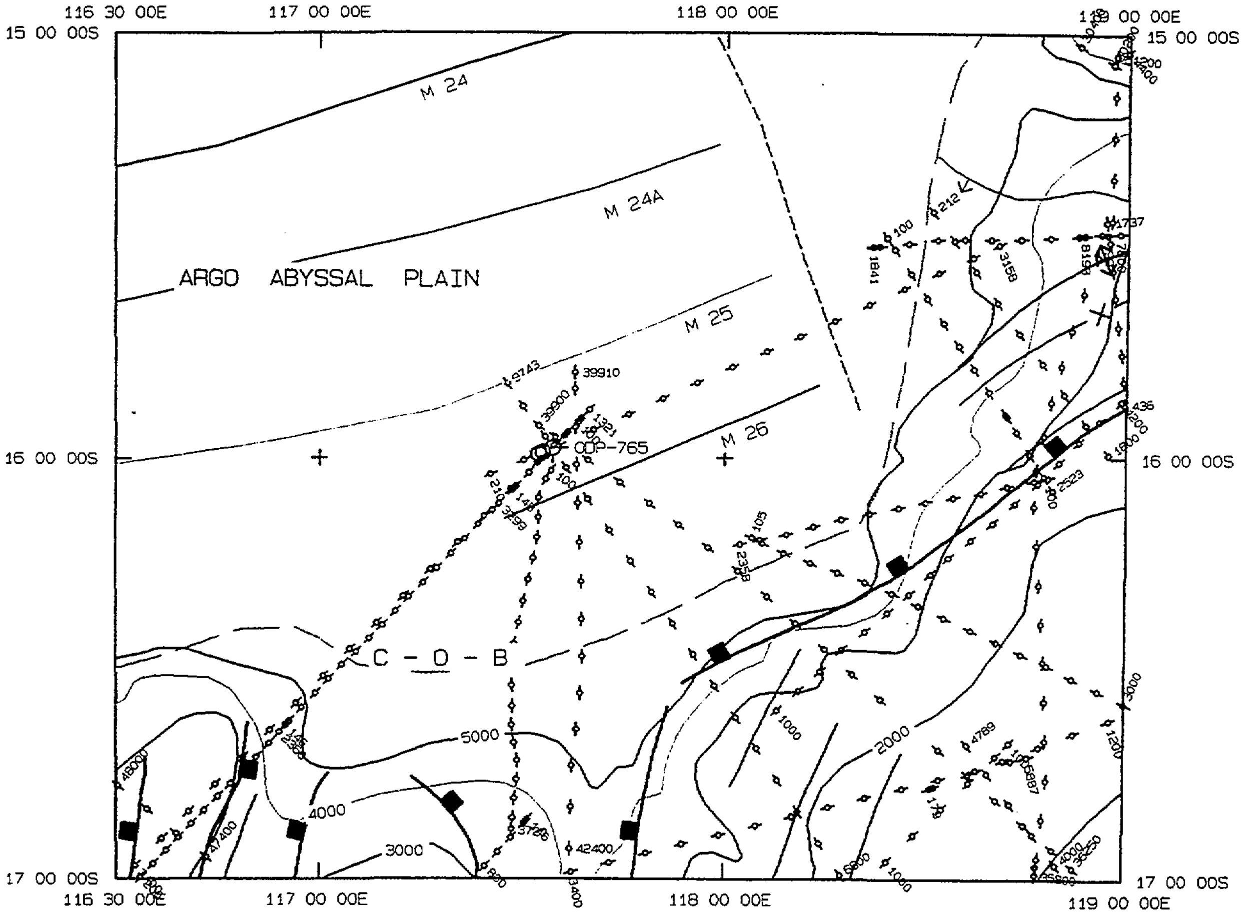

Figure 2: Southern Argo Abyssal Plain, showing multichannel seismic tracks, tectonic elements, bathymetric contours (metres), location of ODP Site 765, and locations of proposed sites ARGO01A and ARGO02A. Sites ARGO01A and ARGO02A are the overlapping circles slightly west of ODP-765. C-O-B is the continent-ocean boundary.

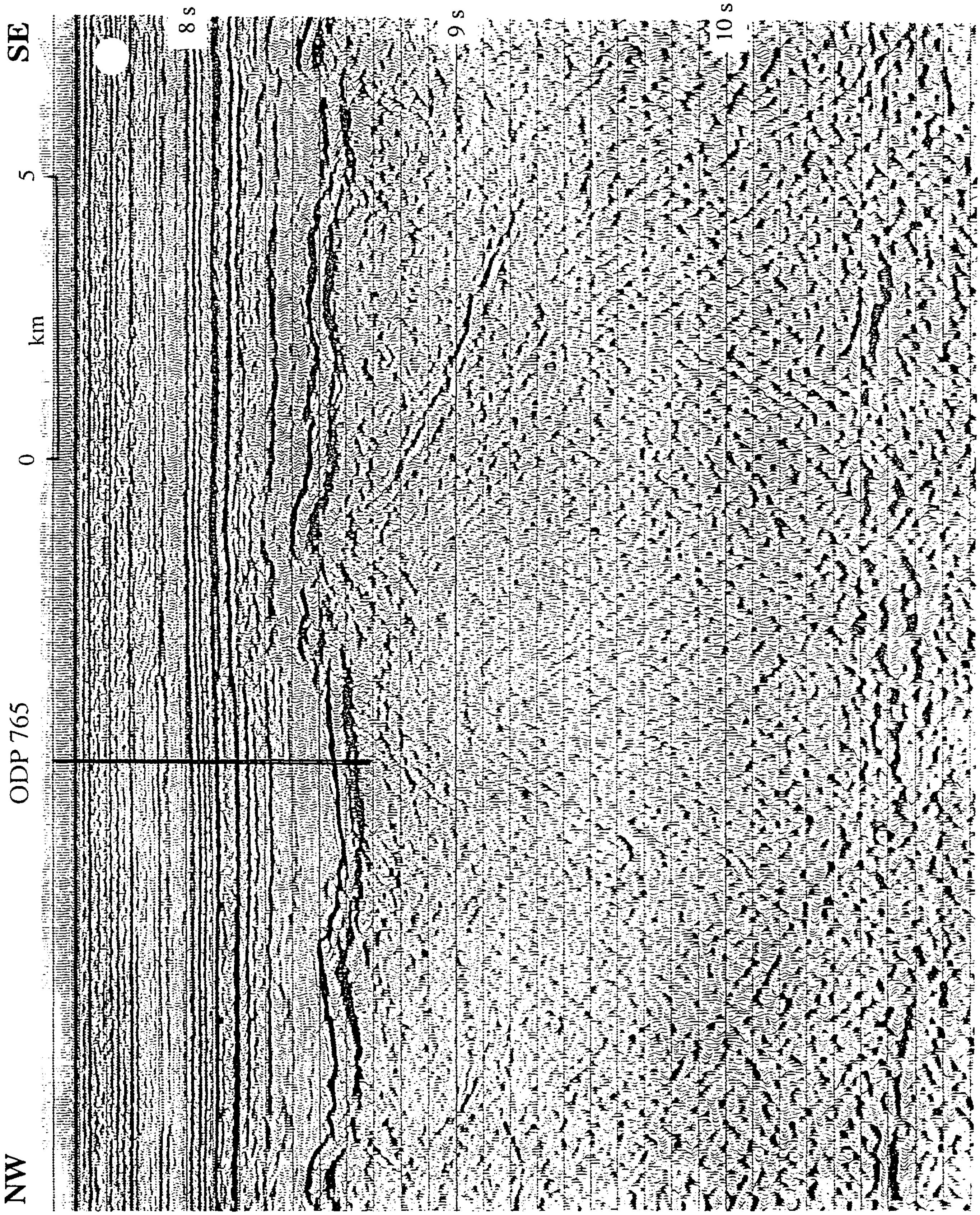

Figure 3: Portion of AGSO seismic line 120-1, parallel to the flow-line on the Argo Abyssal Plain, showing the location of ODP Site 765. Note the dipping intra-basement reflector at around 9 s TWT on the right of the section, and the reflection Moho at 10.5 - 10.6 s TWT.

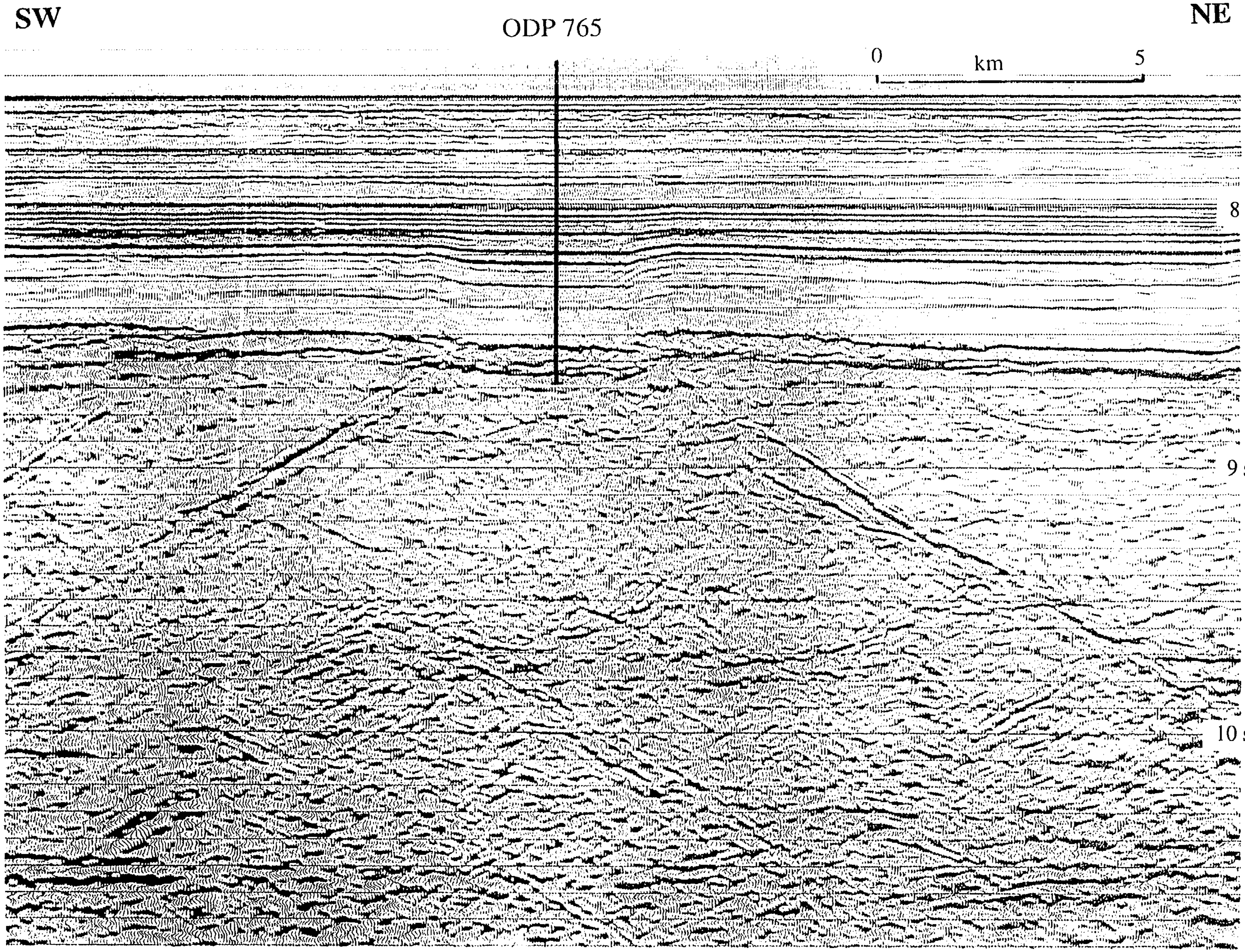

Figure 4: Portion of AGSO seismic line 120-2, parallel to the isochrons in the Argo Abyssal Plain, showing the location of ODP Site 765. Note the intras-basement reflectors at 8.8 - 10.7 s TWT and the reflection Moho at 10.5 s TWT.

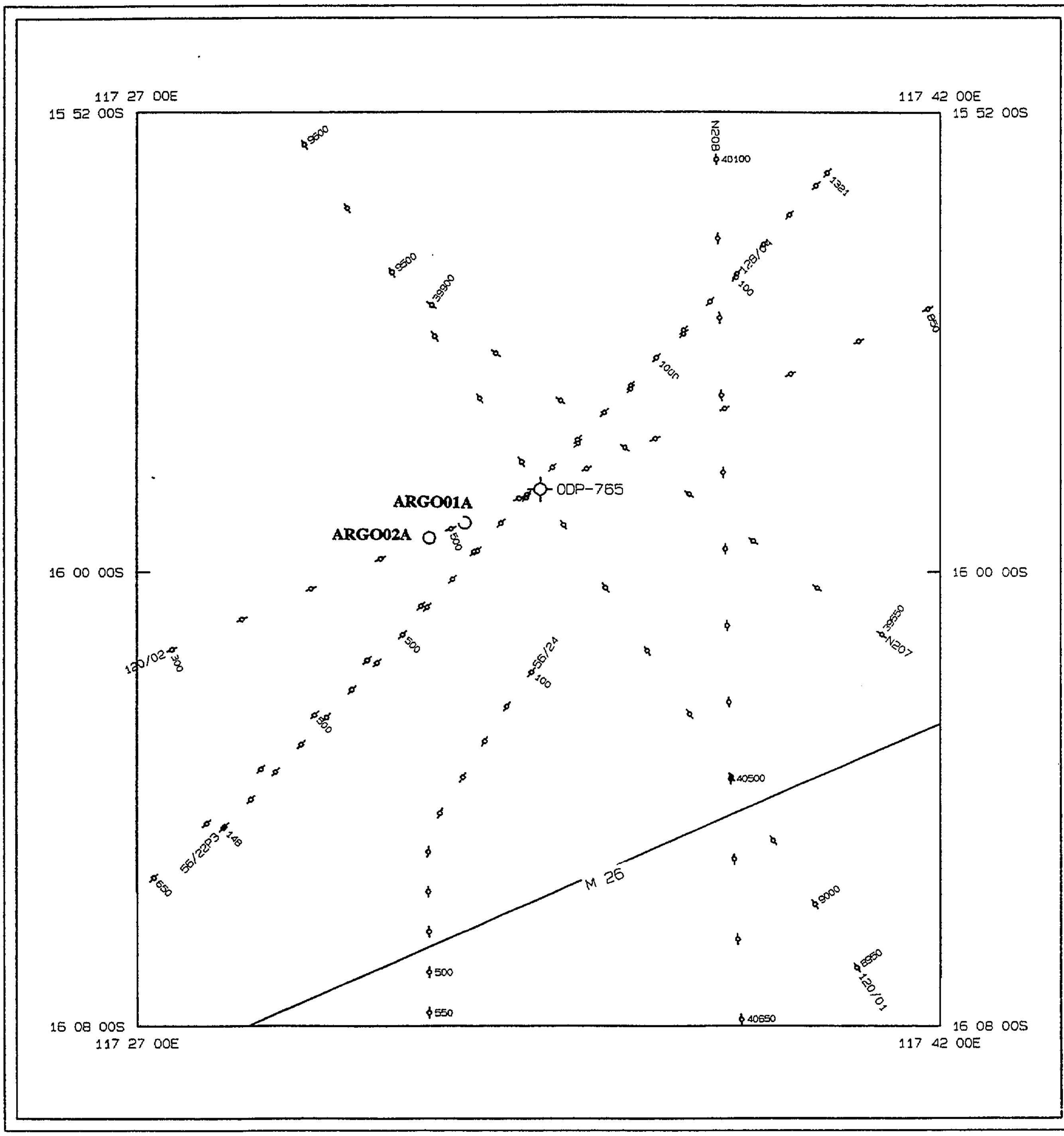

Figure 5: Southern Argo Abyssal Plain, showing multichannel seismic tracks in the immediate vicinity of ODP Site 765 and the locations of proposed sites ARGO01A and ARGO02A.

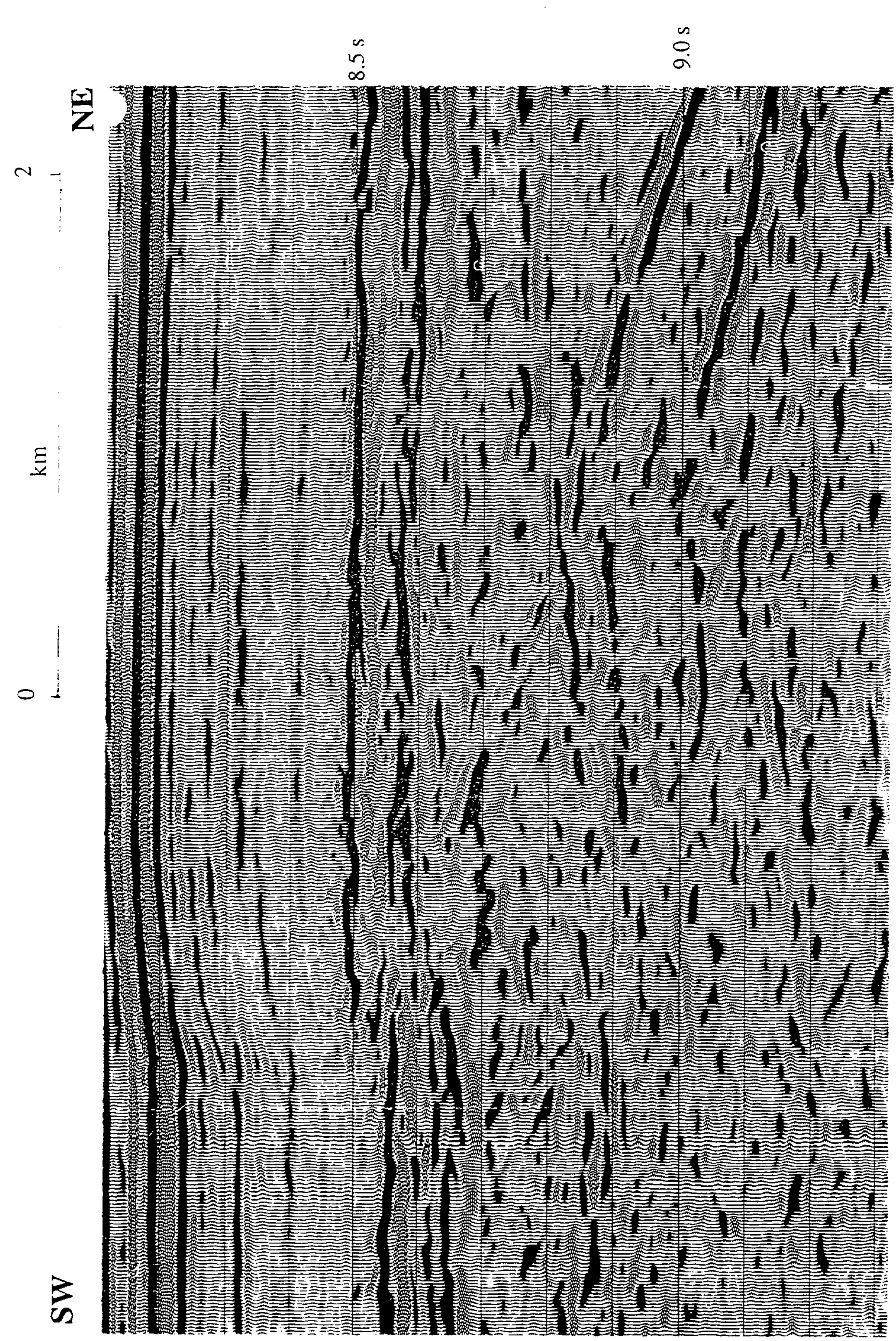

Figure 6: Portion of AGSO seismic line 120-2, showing an east-dipping ?shear zone with reverse movement at the top of oceanic basement at 8.5 - 8.6 s TWT. ODP Site 765 lies just off the western end of this profile.

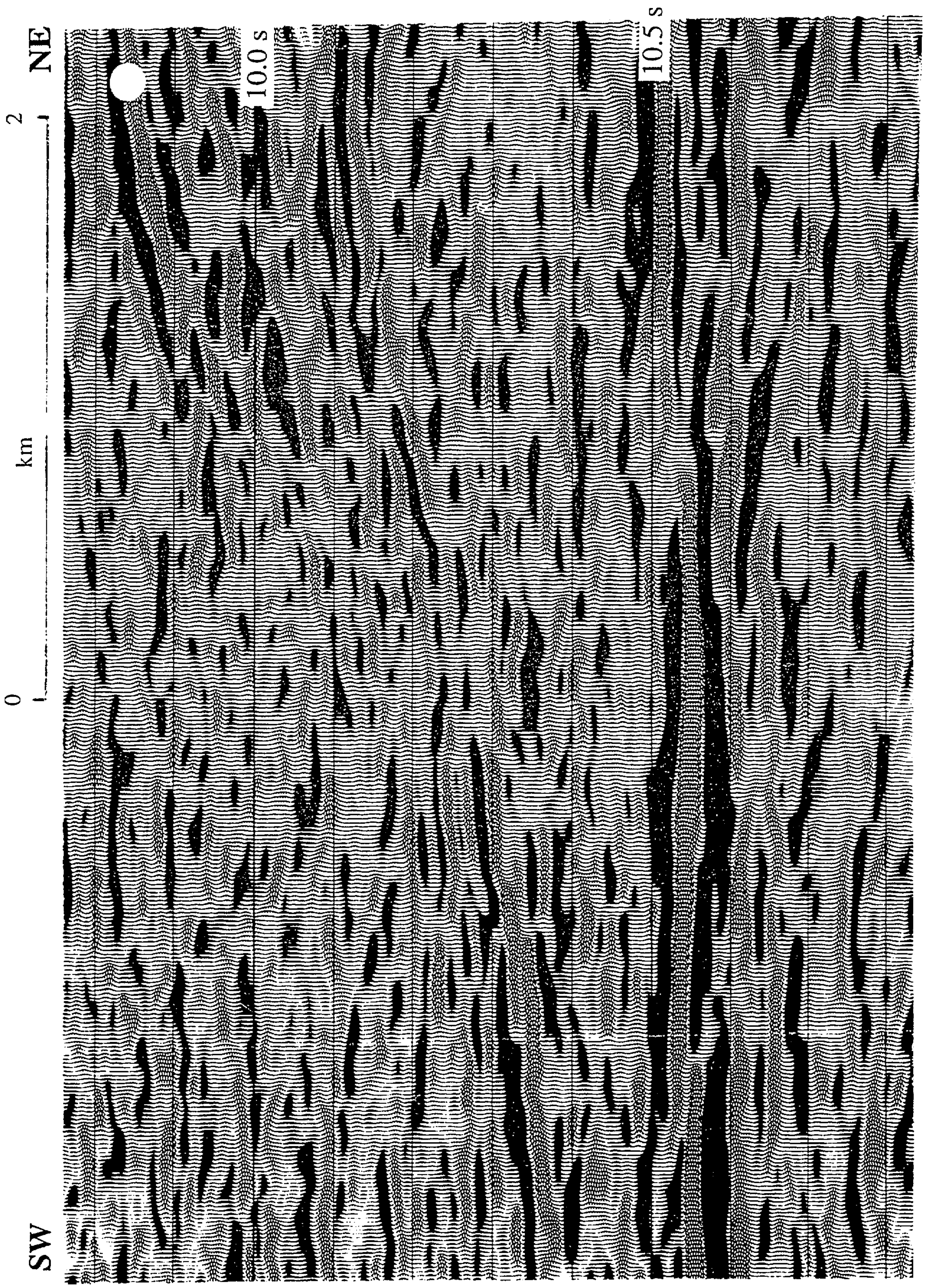

Figure 7: Portion of AGSO seismic line 120-2, showing apparent minor offsets in the reflection Moho. These offsets (~30 msec) are approximately 100 metres.

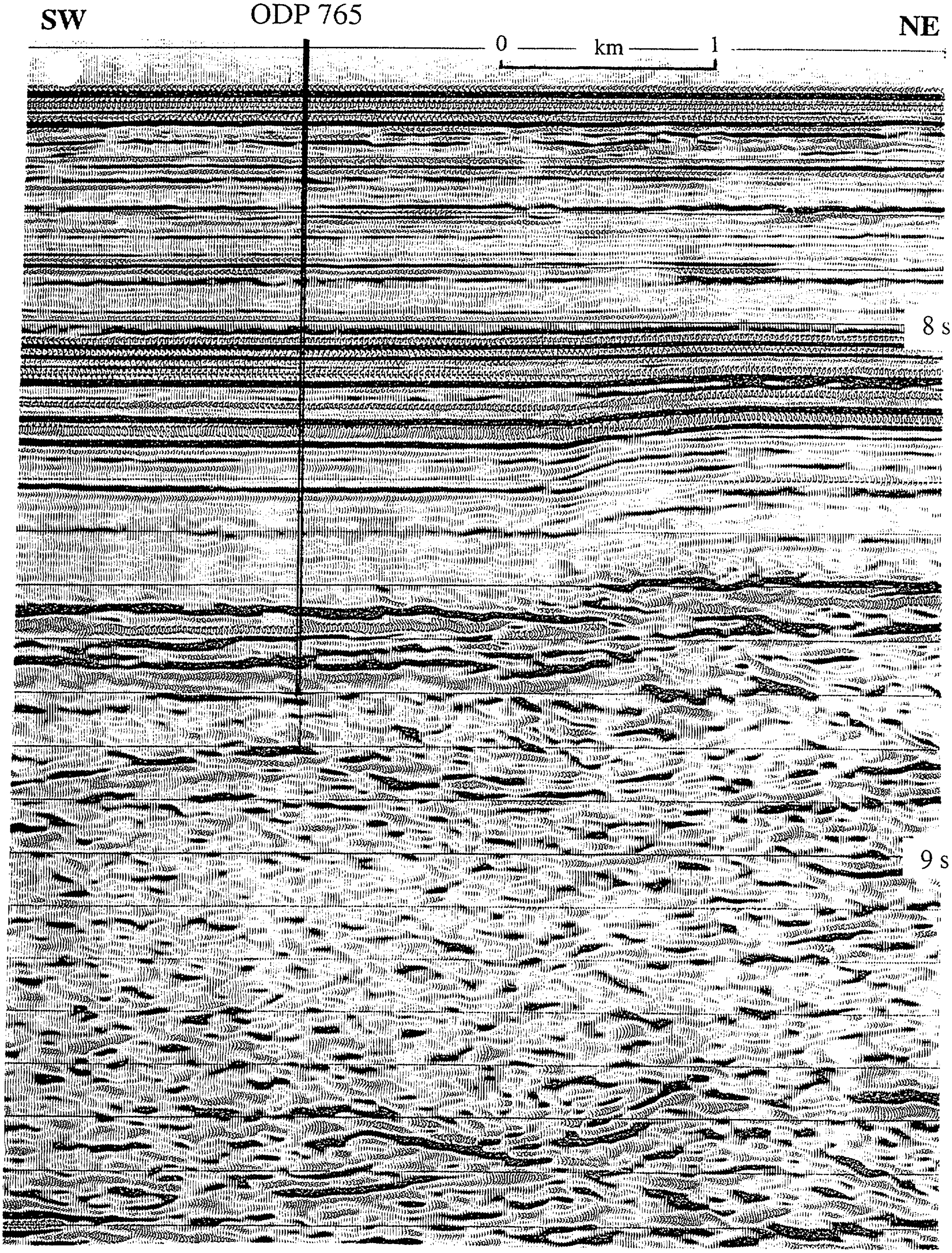

Figure 8: Portion of AGSO seismic line 120-2, showing the location of ODP Site 765. Note the east-dipping shear zone which offsets basement to the east of Site 765.

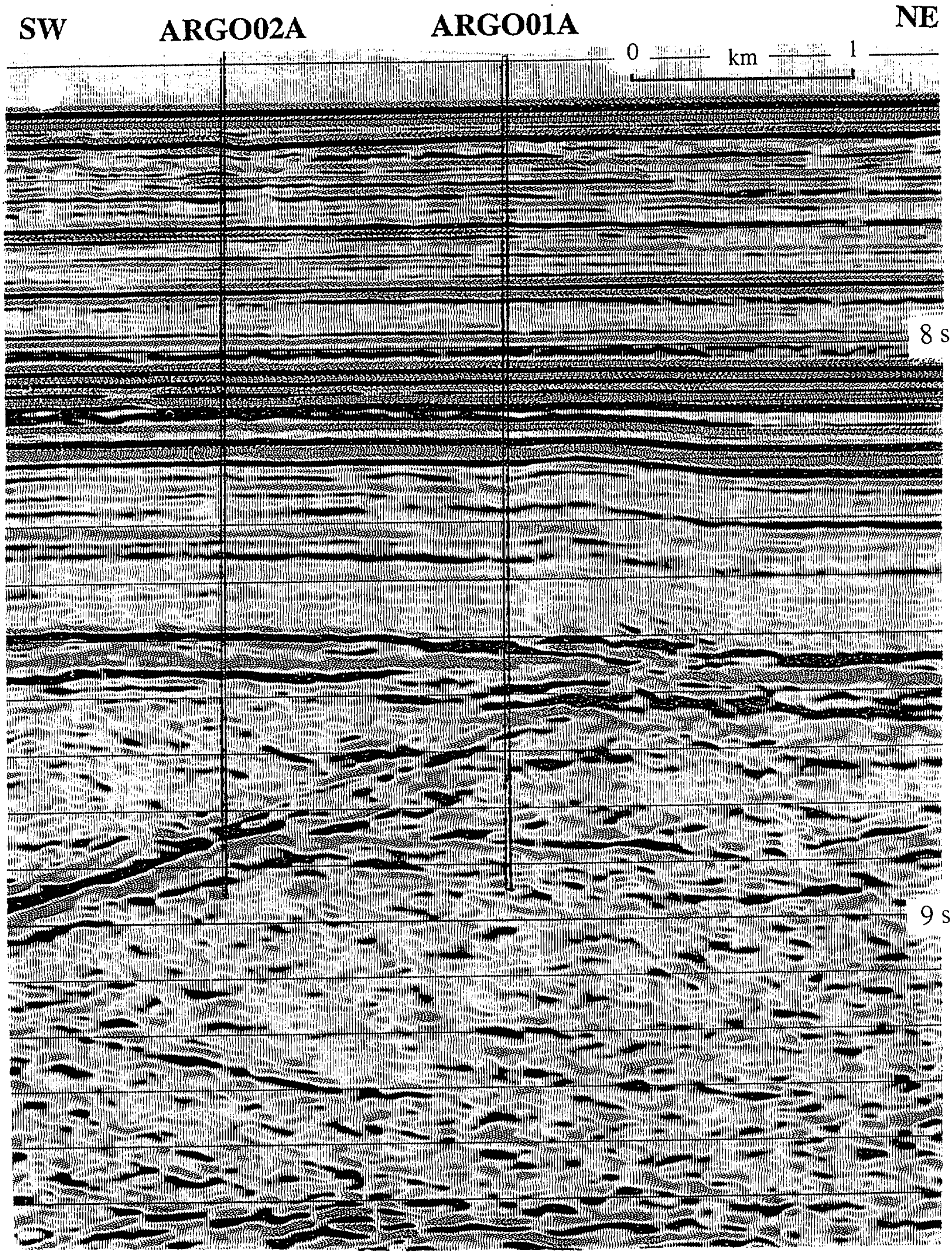

Figure 9: Portion of AGSO seismic line 120-2, showing the proposed locations for sites ARGO01A and ARGO02A. ARGO01A is designed to drill through the west-dipping shear zone just below the top of basement and to intersect the horizontal reflector that splays off the shear zone at about 8.85 s TWT. ARGO02A is designed to intersect the shear zone deeper in the crust where it has a high seismic amplitude.