OCEAN DRILLING PROGRAM

LEG 163 SCIENTIFIC PROSPECTUS

SOUTHEAST GREENLAND MARGIN

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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

Studies of volcanic rifted margins (VRM's) address the highly ranked tectonic and lithospheric objectives of deciphering the nature of continental breakup and rifting and the relationships of the large igneous provinces (LIP's) with mantle plumes. Following from results of Ocean Drilling Program (ODP) Leg 152, Leg 163 will occupy 6 sites along 2 margin transects (the EG63 and EG66 transects) off Southeast Greenland as part of an integrated onshore-offshore study.

Leg 163's objective is to distinguish between different models for plume emplacement and plume structure, and to characterize the weakening, thinning, and rupture of the continental lithosphere during continental breakup associated with mantle plumes. Results of Leg 152 along the EG63 transect suggest that the main part of the anomalous igneous crust along VRM's, the seaward-dipping reflector sequences (SDRS), is created by Icelandic-type oceanic crustal accretion. Recovery of high-Mg picrites suggests that excessively high-temperature asthenosphere was present during breakup (i.e., that breakup is somehow related to mantle plumes). However, the main part of the SDRS at this distance (>500 km) from Iceland seems to have an Normal Mid-Ocean Ridge Basalt (N-MORB) type composition. The EG66 transect will provide long stratigraphic section(s) of the early Paleogene volcanism closer to the Iceland hotspot track (Iceland-Greenland Ridge). This will test whether the incompatible element depleted nature of the Leg 152 and Leg 81 (Hatton Bank) basalts is a primary feature of the ancestral plume, or whether it is an offset-dependent feature, suggestive of a compositional zonation of the plume head. Additional sampling of highly variable lava compositions present within the lowermost part of the SDRS will permit petrochemical description of the first surface expression of the mantle plume. Expanded sampling of the transition from initial, continental lithosphere-contaminated volcanism to more pristine, oceanic type volcanism will better characterize the primary source region for mantle melting. The Leg 152 discovery of highly tectonized continental crust and rift sediments below the feather-edge of the SDRS will be further addressed to document the history, nature, width, and environment of a volcanic margin rift zone and its development into the continent-ocean transition (COT).

INTRODUCTION AND BACKGROUND

The Leg 163 drilling program follows the general guidelines of the North Atlantic Rifted Margin Detailed Planning Group (NARM-DPG) report (Larsen, Sawyer, et al., 1991). The selection of specific sites for Leg 163 and their prioritization are based on new geophysical and geological studies, and, most importantly, on the recent results of ODP Leg 152 off Southeast Greenland (Larsen, Saunders, Clift, et al., 1994a,b; Larsen, Saunders, et al., 1994).

Studies of rifted margins, including volcanic rifted margins, were given a high priority by the ODP Long Range Plan. Recent studies suggest that VRM's are by far the dominant type of rifted margin within the Atlantic, if not globally (c.f., Coffin and Eldholm, 1992; Holbrook and Keleman, 1993). Hence, there seems to be a close connection between formation of this type of LIP and continental breakup.

One of the highest recovery hard-rock legs drilled by ODP (1255 m recovered, 43% recovery), Leg 152 was a major success and has instigated a major complementary geological and geophysical research program of the Southeast Greenland Margin (Larsen et al., in press). Drilling and preliminary analytical work have already established important results. First, recovery of highly picritic lavas suggests that excessively high-temperature asthenosphere plays an important role in continental breakup (Larsen, Saunders, Clift, et al., 1994a,b) and the formation of VRM's, and, hence, that mantle plumes, or other mechanisms for delivering anomalously hot mantle material to the base of the lithosphere, are important in this development. Secondly, drilling through the volcanic cover and through a basal-normal fault into highly deformed pre-rift sediments showed the potential importance of tectonic stretching within the rift zone prior to volcanism. Thirdly, the apparently depleted nature of the volcanism at the EG63 transect indicates a limited presence (or absence) of plume-derived mantle material during breakup at this offset (approx. 550 km) from the Iceland hotspot track (Iceland-Greenland Ridge). Finally, $^{40}Ar/^{39}Ar$ dating of the oldest lavas drilled has provided ages of around 61-62 Ma (Sinton et al., 1994) that are considerably older than expected for the breakup of this margin (56-58 Ma), according to ocean floor magnetic anomalies and the general perception of Northeast Atlantic opening (Talwani and Eldholm, 1977; Larsen, 1988).

Since the NARM-DPG report and the scheduling of Leg 152, about 5000 km of high resolution MCS data across the Southeast Greenland Margin have been acquired (Fig. 1; Larsen, Saunders, et al., 1994) and provide an excellent database for further detailed siting of drill sites. Moreover, a considerable broadening of the Leg 163 study to include analysis of onshore sequences is planned by the recently formed Danish Lithosphere Centre (DLC), working with researchers from six research institutes in the United States of America. Deep MCS and wide-angle profiling across and along the margin, and extensive onshore field geological work on the exposures of breakup-related gabbros, dike swarms, flood basalts, and extensional tectonism, are being carried out (Larsen et al., in press).

SETTING OF THE LEG 163 DRILLING TRANSECTS

The rifted structure of the Southeast Greenland Margin seems to be particularly simple (Larsen and Jakobsdôttir, 1988; Larsen, 1990) in the sense that (i) Tertiary rifting apparently took place in non-rifted cratonic crust, and (ii) transform offsets of the early rift axis south of Iceland, similar to the present-day Reykjanes Ridge, seem to be absent or of minor importance.

The two Leg 163 drilling transects are located at 550 and 200 km, respectively, from the Iceland hotspot track (Fig. 2). The general geological structure along the two transects is basically identical. The landward part of the transects crosses the original line of breakup, and, hence, the COT, and continues seaward into the anomalously thick igneous crust formed during the first few million years of plate separation. The seismic reflection records along the transects show, from land to sea, a thin eroded feather-edge of the thick SDRS overlying continental basement (early rift structures are locally visible). Seaward, the volcanics expand into an SDRS, which is more than 5 km thick. No structures can be mapped by seismic reflection data below the thicker parts of the SDRS (Fig. 3). But this region (15-20 km thick) is believed to be formed of gabbro sills.

SCIENTIFIC OBJECTIVES AND DRILLING STRATEGY

In conjunction with Leg 152 results and other studies, the goal of Leg 163 drilling is to understand (i) the origin, state, and emplacement of hot asthenospheric material below the margin during breakup, and (ii) the deformation of the lithosphere in response to this emplacement, and the interaction between asthenosphere and lithosphere during breakup (Fig. 4). This study includes testing of the different models for plume emplacement and plume structure (c.f, Campbell and Griffiths, 1990; Duncan and Richards, 1991; Hill, 1991; White and McKenzie, 1989; Lawver and Müller, 1994).

The primary objectives and drilling strategy for Leg 163 include

1. The recovery of long stratigraphic section(s) of the early Paleogene volcanism close to the hotspot track (plume tail).

2. Study of the pre-volcanic rifting history, timing, nature, width, and environment of rift zone.

3. Additional sampling and $^{40}Ar/^{39}Ar$ dating of the early volcanism, completing the program begun during Leg 152.

4. Additional sampling of the transition from transient picritic volcanism into N-MORB-type volcanism within the SDRS, completing the program begun during Leg 152.

Unlike the Neogene Iceland plume magmas, Leg 152 picrites and MORB basalts within the main SDRS are all depleted in incompatible elements (Fig. 5). This feature will be further investigated through expanded stratigraphic sampling but, first and foremost, by drilling Paleogene lava sections closer to the assumed plume center. Sampling along this second transect will allow us to examine whether this is a primary feature of the ancestral plume, or whether it is an offset-dependent feature, suggestive of a compositional zonation of the plume head.

In a recently proposed model, Lawver and Müller (1994) presented a third possible explanation for the apparent lack of plume-derived mantle material during breakup of Southeast Greenland, suggesting that the plume center (tail) drifted from a position beneath central Greenland (ca. 62 Ma) to the East Greenland margin about 15-20 m.y. after breakup (ca. 40-35 Ma). This model will be tested by drilling along the EG66 transect and by comparison with results from DSDP Sites 407-409 from the Neogene part of the transect. The latter sites show Icelandic plume type enrichment (Schilling, 1973; Luyendyk, Cann, et al., 1978a,b,c).

If it is proven that a long-lived plume system has drifted east (relative to the overlying lithosphere), and that an extensional stress field, independent of the plume, has caused rifting over the fringes of the approaching plume (cf. Lawver and Müller, 1994), the role of mantle plumes in instigating breakup would seem less direct and more of a (strongly) modifying process to extension and plate separation. If, on the other hand, a plume component has been clearly present close to the Iceland-

Greenland Ridge (IGR) from the start of breakup, it would indicate that the plume stem was centered below, or close to, the rift zone during breakup and, hence, played a first-order role in the process of continental breakup. Leg 163 investigations will also address how the continental crust and lithosphere weaken and extend during breakup by further examining highly deformed pre-rift sediments below the feather-edge of the SDRS (Fig. 6). Drilling will aim to recover stratigraphic sections documenting rift history and rift environment.

The earliest SDRS volcanism was not sampled during Leg 152 because of normal faulting and stratigraphic omission. Recovery of the very early volcanism will be targeted during Leg 163. This early volcanism may show a large compositional diversity, including possible alkaline sequences, which could indicate deep early melting within the plume. The lowermost Leg 152 lavas have yielded surprisingly old $^{40}Ar/^{39}Ar$ ages (62 Ma, Sinton et al., 1994), suggesting an early pulse of plume-generated volcanism prior to the main sequence (Larsen et al., 1994). Also, recovery of deeper basalt core at Site 915 within the feather-edge of the SDRS will expand the stratigraphic coverage of the apparently rapid transition from continentally hosted magmatism (including picritic compositions) to one producing oceanic N-MORB type lavas of apparently uniform tholeiitic composition (Fig. 7).

PROPOSED SITES

Proposed sites EG63-5 and EG63-6, and Site 915 all lie on the southern EG63 transect. Proposed sites EG66-1, EG66-1A, and EG66-2 all lie on the northern EG66 transect.

Proposed site EG63-5

The main objectives of drilling at proposed site EG63-5 are

1. To identify the nature of the landward-dipping reflectors: are these closely spaced dikes in a basement host rock or pre-rift sediments?

2. To identify the general dip and rotation of dikes/host rock or of the pre-rift sediment.

3. Using rock orientation, lithology, and geochemistry, to identify the presence, if any, of multiple dike generations.

4. To correlate the offshore dikes with the onshore dike complex and with the nearby SDRS (if dikes are present).

5. To identify the nature of deformation (dike width and intensity, fault movements along dikes, P/T conditions) if a dike complex is present.

6. If sediments are present, to recover a long section of pre-rift sediments to characterize the early rift history (timing, environment, subsidence, source area, etc.), including diagenetic and metamorphic alteration.

This site lies on the middle shelf at a water depth of 475 m. In this location, the shelf is nearly free of post-rift sediment with only a thin 5-10-m-thick cover of glaciomarine sediments (Figs. 8, 9, and 10). In general, the pre-Quaternary and pre-volcanic rocks in this area (inner shelf) are continental basement rocks, most likely of a granitic to gneissic nature and of Archean to early Proterozoic age. However, toward the breakup zone and the COT below the mid to outer shelf, the basement is deformed through rifting and seaward flexuring below the feather-edge of the SDRS. Results of Leg 152 (Site 917) show that tectonically deformed (subvertical), pre-rift metasediments are present seaward of proposed site EG63-5. The likely types of deformation of the continental crust include injection of closely spaced dikes and seaward rotation of fault blocks by as much as 40°-60°. Thermal alteration of the crust is indicated by Leg 152 data, which show incipient metamorphic brown mica formation in the pre-rift metasediments. However, only a few dikes were observed at Site 917 located seaward of, and stratigraphically higher than, proposed site EG63-5.

The existence of landward-dipping reflectors at proposed site EG63-5 is confirmed by recent seismic data from 1993 (cross line, Fig. 10) from which the strike of the dipping wedge could also be determined. The strike is slightly oblique to the coast and the margin. These reflectors may represent dikes. However, they may also represent the tectonically tilted pre-rift sediments drilled during Leg 152. If a dike complex is present, it will have structurally important implications. However, if sediments are present (the most likely scenario), the site will provide an excellent possibility for a long section of pre-rift sediments from which the early rift phase can be characterized in terms of timing, subsidence, and environment. Also, it would be structurally interesting to recover landward-dipping pre-rift sediments at this location, which is only 6 km landward of Site 917. Because the steeply dipping to subvertical orientation of the Site 917 pre-rift sediments presumably was acquired through seaward rotation, the discovery of landward-dipping pre-rift sediments would suggest a major tectonic discordance between the two closely spaced sites.

We plan to drill proposed site EG63-5 after the drilling of proposed site EG63-6. This will provide new evidence on the nature of the landward-dipping reflectors below the unconformity. If a dike complex is present, its thickness and the relative abundance of dikes will determine the ultimate depth of penetration. If conditions are similar to the coastal exposures, drilling to bit destruction (100-200 m?) will be adequate.

If pre-rift sediments are present below the base of the unconformity, more than 200 m of penetration can be expected to be achieved within the allotted drilling time or, alternatively, less time could be spent on the site.

Proposed site EG63-6

The main objectives of proposed site EG63-6 are:

1. To determine the stratigraphy, composition, nature, and true dip of the volcanics above the breakup unconformity.

2. To determine the nature and age of the breakup unconformity.

3. To determine the nature and deformation of the continental basement (composition of host rock, dike intensity, tectonic rotation) and to compare this with proposed site EG63-5 and Site 917.

4. To determine the dike intensity and dike orientation (if any) within the early SDRS lavas and the geochemical nature of the dikes.

This site lies on the middle shelf at a water depth of 460 m. In this location, the shelf is nearly sediment free with only a 5-10-m-thick cover of glaciomarine sediments (Figs. 8, 9, and 11). The pre-Quaternary rocks are volcanic rocks, most likely basaltic lavas. The volcanic rocks dip approximately 10° seaward and form the very feather-edge of the SDRS. At proposed site EG63-6, the volcanic cover is around 225 to 250 m thick. Thin sediment beds could be present between, and below, the volcanic units. This whole sequence rests on top of the breakup unconformity. At nearby Site 917, only a few thin intra-volcanic sediment horizons were found, and a thin fluviatile sandstone bed was found at the breakup unconformity.

The primary objective at proposed site EG63-6 is the recovery of the oldest part of the volcanic section. A potentially large compositional diversity within these earliest lavas is anticipated. $^{40}Ar/^{39}Ar$ dating of the overlying lavas from Site 917 has yielded an age around 62 Ma (Sinton et al., 1994), suggesting that these lavas belong to the very oldest volcanism within the North Atlantic Basalt Province. At proposed site EG63-6, we may sample initial magmas derived from deep and small-percentage partial melting of a rising plume head (see also proposed site EG66-1).

Site selection was planned to stratigraphically complement, but not overlap, Site 917. If warranted, overlap can be achieved by a slight seaward displacement of the drill site. However, the site should not be moved too far downdip, as this could endanger penetration below the breakup unconformity and will place drilling in a seismically less well-imaged area that may contain tectonic complexities.

Penetrating the breakup unconformity is also a high priority. At Site 917, this was achieved at the intersection of the unconformity with a normal fault. Proposed site EG63-6 provides a more simple target with better seismic imaging, and will permit much improved sampling of the continental crust subcropping below the breakup unconformity. Total thickness from sea bed to the breakup unconformity is estimated to be approximately 250 m. We have planned for 410 m of total penetration in order to sample adequately and log the interval below the unconformity.

Deepening of Site 915

The objective in deepening Site 915 is to expand the stratigraphic coverage within the early oceanic SDRS succession to prove or disprove steady-state plume conditions, study the composition of the asthenospheric magma reservoir, and provide suitable material for radiometric age determinations. Site 915, which was initially drilled during Leg 152, is located at a water depth of 533 m (Figs. 8 and 9). Quaternary (84.8 m) and Eocene sediments (102.3 m) were encountered before reaching a thin heterolithic conglomerate (2.2 m) and finally volcanic basement at 189.3 mbsf (Larsen, Saunders, Clift, et al., 1994a). Basement penetration was limited to 20.1 m because of bit failure, and only two igneous units were recovered.

At nearby Site 917, a 779-m-long section of lavas revealed a transition from a lower continental succession, the Lower and Middle Series, into an upper oceanic succession, the Upper Series (Fig. 7). At its base, the oceanic succession includes highly pricritic lavas, but within Site 917, it shows a trend toward N-MORB type lavas with little MgO variation (Fig. 7). The same type of lavas was recovered from Site 915 and the more seaward Site 918.

According to seismic correlation, drilling approximately 250 m into the basement at Site 915 will enable stratigraphic correlation with Site 917 (Upper Series at Site 917). If the transition into low-MgO variation, N-MORB type basalts is indeed sharp and stable, N-MORB lavas are likely to occur throughout the entire main SDRS. This would be consistent with the recovery of 122 m of N-MORB lavas at the more seaward Site 918 within the main SDRS.

Deepening of Site 915 will increase the stratigraphic coverage within the apparently non-contaminated oceanic succession, which is the most suitable for detailed geochemical characterization of the asthenosphere during breakup. In addition, the ages obtained from the Lower and Middle Series suggest the presence of a considerable hiatus between the continental succession and the oceanic succession. Alternatively, formation of the whole SDRS may cover a much larger time interval (62-53 Ma) compared to the previous estimates (57-53 Ma). Thus, it is important to gather additional material from the oceanic succession, which is suitable for $^{40}Ar/^{39}Ar$ dating, to locate this possible hiatus and to calculate magmatic fluxes.

Proposed site EG66-1A

The objective at proposed site EG66-1A is similar to that at Site 915, namely, to recover a long section of lavas from the early, oceanic SDRS succession to study the composition of the asthenospheric magma reservoir, to prove or disprove steady-state conditions, and to provide suitable material for radiometric age determinations.

Proposed site EG66-1A is located at a water depth of 270 m (Figs. 12 and 13). At the drill site, a thin glacial cover overlies a more than 1-km-thick, seaward-dipping (35°-45°) lava succession, representing the very oldest part of the SDRS. The thickness of the glacial cover varies from 10 to 40 m around the drill site.

The main objective is to retrieve a stratigraphic record of the early part of the Paleogene SDRS at a position close to the IGR. At this offset from the IGR, incompatible element, Icelandic plume-type lavas are known from Neogene oceanic crust. The site will test whether or not such enriched plume-related material can be traced back close to the time of breakup. The implications of such material being present are far reaching with regard to plume emplacement and plume structure.

The stratigraphic position of proposed site EG66-1A is similar to that of Site 915, i.e., approximately 1 km above the base of the SDRS lava succession. By analogy with Site 915, drilling at EG66-1A will allow us to sample a long section of "oceanic" material without continental contamination. We plan 500 m of basement penetration to get a long representative section and possibly intersect a lower continental succession. However, a section of only 150-200 m (likely to be achieved with a single bit) will be acceptable, and excessive time will not be spent to progress beyond that depth. There is also the possibility for offset drilling of two or three shallower single-bit holes to obtain a longer composite section.

Proposed site EG66-1

The main objectives at proposed site EG66-1 are

1. To recover the earliest rift volcanism in a position close to the IGR; the early volcanism may include, in part, highly alkaline rocks related to deep, initial melting within the plume.

2. To provide a firm correlation between seismically observed, offshore crustal flexure zones below the feather-edge of the SDRS and potentially similar structures exposed along the coast, representing major tectonic and magmatic extension of the crust.

Proposed site EG66-1 is located at a water depth of 260 m (Figs. 12, 13, and 14). Thin (~ 0-5 m) Holocene sediment overlies an approximately 200-m-thick succession of the oldest lavas, dipping approximately 40°-45° seaward. The lavas overlie seaward down-flexured basement. By analogy with nearby coastal outcrops, the whole succession is likely to have been intruded by closely spaced dikes, originally at right angles to the lavas, and then subsequently tilted about 45° seaward. The general tectono-stratigraphic position is similar to that at proposed site EG63-6 on the southern transect.

The thin, sparsely present onshore lava succession close to proposed site EG66-1 ranges from nepheline-normative, in part basanitic, alkaline basalts to tholeiitic material. Such strongly alkaline compositions are unknown from the other lower stratigraphic parts of the East Greenland flood basalts. In 1994, an alkaline intrusive complex was found onshore (Larsen et al., in press), and preliminary age determinations from this complex are around 58 Ma. Similar to the earliest alkalic volcanism in the Deccan flood basalt activity (Basu et al., 1993) or Hawaii where alkaline material occurs in the Loihi Seamount, this could be interpreted as representing low-degree melting at great depth, presumably from the approaching plume. Alkaline material may also be present at southern transect EG63; drilling at proposed site EG63-6 will examine this possibility. However, for two reasons, alkaline material is more likely to occur at proposed site EG66-1 or, at least, to be more distinctly developed here. First, it is known from nearby onshore outcrops, and secondly, the location is more plume proximal, and, hence, melting at great depth is more likely to occur here.

Another important goal at this site is to provide control of the structural similarity of this offshore flexure zone with the coastal flexure zone and associated dike swarm. That a flexure zone is present offshore can be seen directly from the seismic data. The key issue to be addressed by drilling is to confirm the presence or absence of the dike complex offshore; the dike complex is a ubiquitous constituent of the onshore coastal flexure zone. If firm correlation between onshore and offshore structures can be made, the onshore studies (including land drilling) will gain much importance in terms of understanding the structure of the continent-ocean transition.

Proposed site EG66-2

The main objectives at proposed site EG66-2 are

1. To recover a Paleogene basement section from approximately 7-m.y.-younger crust than at proposed sites EG66-1 and EG66-1A, to test for the possible increased presence of plume-derived mantle material.

2. To obtain samples of the SDRS that have not been contaminated by continental lithosphere.

This site is located in 1670 m of water (Figs. 15 and 16), near the seaward end of the SDRS on crust of approximately anomaly 22 age (51-52 Ma), i.e., about 7-9 m.y. younger than the initial breakup volcanism (approximately 60-58 Ma). SDRS's are developed to great depth at this position (7-8 km). The large thickness of the extrusive part of the oceanic crust shows that a strong thermal anomaly was present during its formation. The main objective at this site is to recover a long section of the SDRS (200 m is targeted) to test for the possible changes in lava composition from the Paleogene to the Neogene as a result of incorporation of plume-derived mantle material. The site provides an additional sampling point between landward site EG66-1A and seaward DSDP Sites 407, 408, and 409 (Figs. 15 and 16). The implications for plume models of such possible variations are explained elsewhere. If a clear plume signal is present in terms of character and chemistry of the basalts recovered at proposed site EG66-1A, the priority of drilling at proposed site EG66-2 is lowered. We are aware that plume components may be subtle features, and may be identified only in post-cruise studies.

In order to keep other variables as constant as possible, we have sited proposed site EG66-2 in the youngest possible stratigraphic position, where a strong thermal anomaly, comparable to the time of breakup, (i.e., thick SDRS) is still present.

The SDRS at proposed site EG66-2 is covered by a 520-m-thick sequence of Paleogene shelf sediments and Neogene slope sediments.

DRILLING PRIORITIES AND OPERATIONAL PROCEDURES

The six proposed sites for Leg 163 are all first priority sites. However, the drilling strategy for two of the sites (proposed sites EG66-2 and EG63-5) depends on the outcome of drilling results at proposed sites EG66-1 and EG66-1A (for proposed site EG66-2) and at proposed site EG63-6 (for proposed site EG63-5). Also, drilling operations and delays caused by weather or ice may require reduction of the number of sites drilled.

Below, we describe the planned sequence of drilling and the relationship between the proposed sites.

1. Drilling will begin at proposed site EG66-1A after a short transit from Reykjavik. This site may be accomplished as a single, deep hole (520 mbsf) or as a number of closely spaced, shallow offset holes, providing a composite stratigraphic section.

2. The next site to be drilled is proposed site EG66-1. Though less penetration is required (280 mbsf), the strategy of offset holes rather than one deeper hole may be implemented. The site is likely to be started in almost bare rock drilling conditions and may require use of a Hardrock Guide Base.

3. On the basis of the lithologies retrieved, the shipboard XRF analyses of basalts, and other available information (see also proposed site description) from proposed sites EG66-1 and EG66-1A, the scientific need to drill proposed site EG66-2 as planned (reentry site with basement penetration) will be evaluated by the Co-Chiefs in consultation with the shipboard science party and reviewed against the remaining time for drilling sites on the southern EG63 transect.

4. Based on (3) above, a decision will be made whether or not to drill proposed site EG66-2 as a reentry site, or not to drill at all.

5. Proposed site EG63-6 will be the first site drilled on the southern transect. Stratigraphic overlap with existing Site 917 may not be accomplished at this site, and, if time and conditions permit, a shallow offset site seaward of Site EG63-6 may be attempted (after drilling of proposed site EG63-5 and deepening of Site 915) to provide complete stratigraphic sampling. Depending on the nature of the material below the breakup unconformity and the drilling conditions, proposed site EG63-6 may be deepened as a substitute for proposed site EG63-5.

6. Proposed site EG63-5 will be drilled after EG63-6. However, if the material recovered at proposed site EG 63-6 conclusively demonstrates the nature of the seismic images of landward-dipping reflectors below the unconformity, the need for drilling proposed site EG63-5 will be reviewed.

7. Deepening of Site 915 is required to expand the sampling of the Upper Series part of the SDRS. The goal of stratigraphic overlap with Site 917 may be modified because of time constraints, but, at the very least, drilling to bit destruction will be attempted (estimated depth of 350 mbsf).

8. Possible offset hole to proposed site EG63-6. An offset hole as described above may be attempted as the final, optional drilling activity of Leg 163.

All sites have been accepted by the JOIDES Pollution Prevention and Safety Panel (PPSP) to drilling depths in excess of those stated here. Possible alternate and/or offset sites close to proposed sites have been previewed by PPSP. Permission to drill these will be requested from the ship as applicable.

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TABLE 1 - Time Estimates for Leg 163 Sites

Proposed Site	Latitude	Longitude	Water Depth (m)	Penetration (m)	Drilling Operations Time (days)	Logging Time (days)	Logging Type	Time on Site (days)	Transit Time (days)
Transit from Reykjavik to EG 66 area									1.5
EG 66-1	65°44.81'N	34°59.41'W	260	280	3.4	0.9	Gp *, F *	4.3	
EG 66-1A	65°42.08'N	34°52.17'W	270	520 (700)	11.9 (for 700 m)	1.0	Gc, Gp, F	12.9	
EG 66-2	64°57.84'N	33°02.74'W	1670	720	7.8	1.4	Gc, Gp, F	9.2	
Transit from EG 66 area to EG 63 area									0.7
EG 63-5	63°31.83'N	39°55.65'W	475	210	2.7	0.9	Gp *, F *	3.6	
EG 63-6	63°31.35'N	39°54.07'W	460	410	5.3	1.0	Gc, Gp, F	6.3	
Site 915	63°28.29'N	39°46.91'W	533	447	4.0	1.0	Gp	5.0	
[Miscellaneous transits]									[0.5]
Transit from EG 66 area to St. John's									5.0
SUBTOTAL:				**2587**	**35.1**	**6.2**		**41.3**	**7.7**

GRAND TOTAL: 49 days at sea

Gp = quad combo. Gc = geochemical log. F = formation microscanner.

* dependent upon conditions

FIGURES

Figure 9. Interpreted section for the landward end of the ~63°N margin transect, showing location and targets for proposed sites EG63-5 and EG63-6 in relation to Leg 152 drill sites.

Figure 10. Seismic reflection profile crossing proposed site EG63-5 in a north-south direction.

Figure 11. Seismic reflection profile crossing proposed site EG63-6 in a north-south direction. The earliest lavas are clearly imaged.

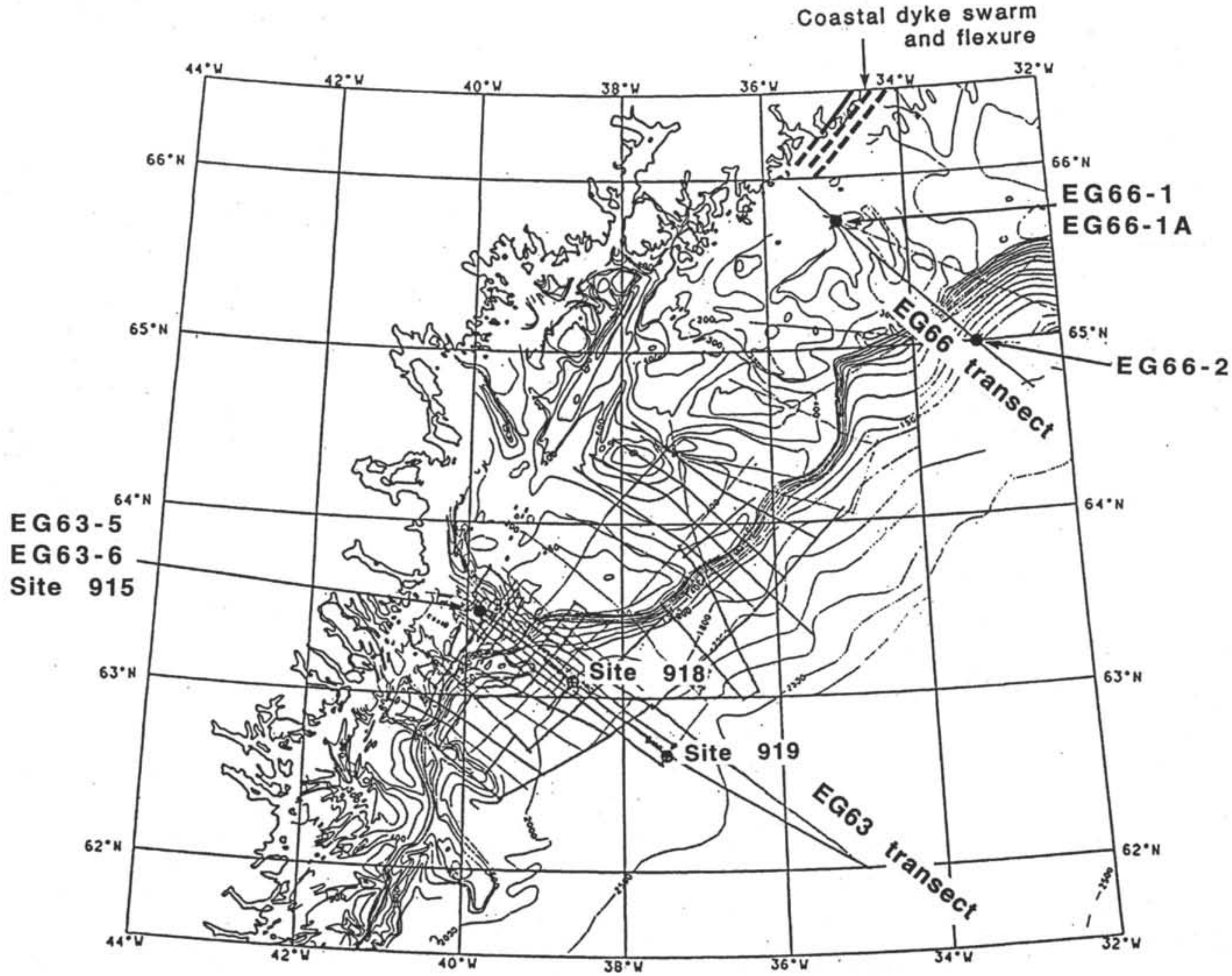
Figure 12. Regional seismic line along northern drilling transect EG66.

Figure 13. Seismic reflection profiles for the landward end of the ~66°N drilling transect, showing locations of Leg 163 proposed sites EG66-1 and EG66-1A. Proposed site EG66-1A is sited to sample material mainly from the oceanic succession. Proposed site EG66-1 is sited to sample the very earliest, and possibly most alkaline, volcanism, the breakup unconformity, and the underlying continental crust. By analogy with coastal outcrops 50 km northward along strike of the flexure zone, it is expected that a similar dike complex is present at proposed site EG66-1.

Figure 14. Seismic reflection profile crossing proposed site EG66-1 in a north-south direction. The breakup unconformity and the oldest lavas are normally faulted. The site has been moved a few hundred meters to avoid the fault zone and maximize stratigraphic coverage.

Figure 15. Seismic reflection profile showing proposed site EG66-2, from the seaward end of the ~66°N drilling transect.

Figure 16. Seismic reflection profile crossing proposed site EG66-2 in a north-south direction.


Coastal dyke swarm
and flexure
44°W
42°W
40°W
38°W
36°W
34°W
32°W
66°N
65°N
64°N
63°N
62°N
EG66-1
EG66-1A
EG66-2
EG66 transect
EG63-5
EG63-6
Site 915
Site 918
Site 919
EG63 transect

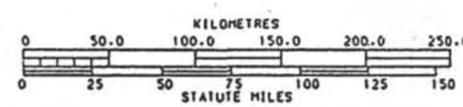

KILOMETRES
0 50.0 100.0 150.0 200.0 250.0
0 25 50 75 100 125 150
STATUTE MILES

Figure 1

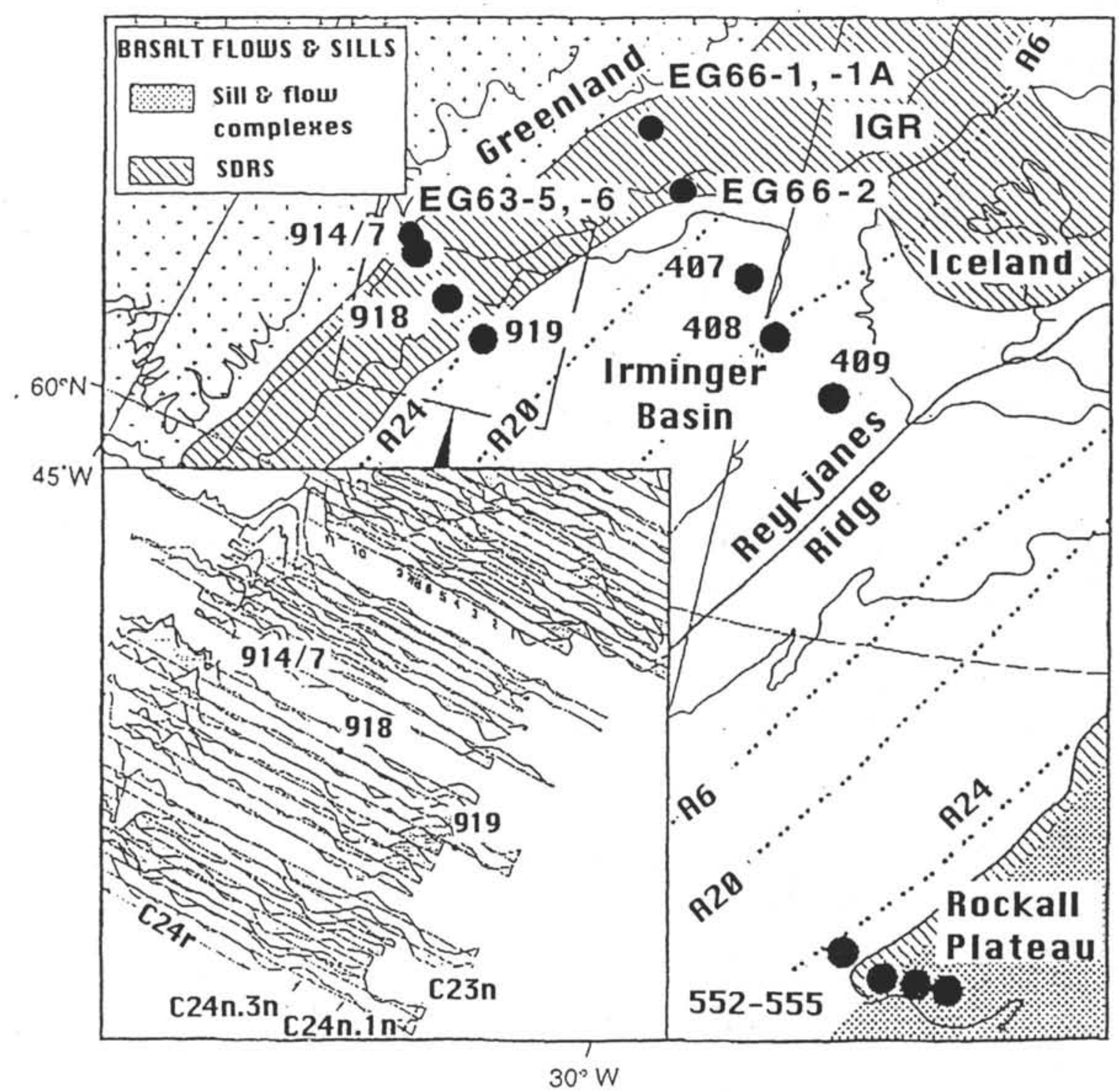
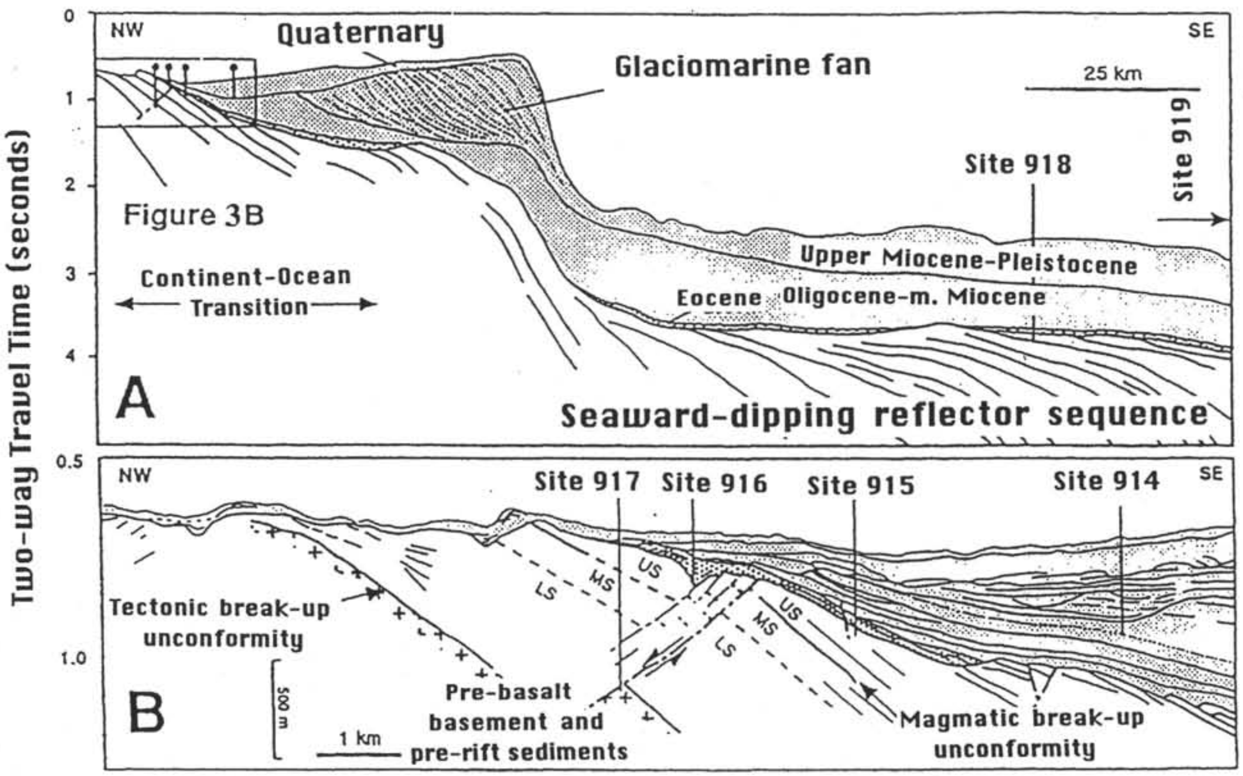

BASALT FLOWS & SILLS
Sill & flow complexes
SDRS
Greenland
EG66-1, -1A
IGR
A6
EG66-2
EG63-5, -6
914/7
Iceland
407
918
919
408
409
Irminger Basin
60°N
45°W
A24
A20
Reykjanes Ridge
914/7
918
919
C24r
C23n
C24n.3n
C24n.1n
A6
A20
A24
Rockall Plateau
552-555
30° W

Figure 2



NW
SE
Quaternary
Glaciomarine fan
25 km
Site 919
Site 918
Figure 3B
Upper Miocene-Pleistocene
Continent-Ocean Transition
Eocene
Oligocene-m. Miocene
A
Seaward-dipping reflector sequence
Two-way Travel Time (seconds)
0
1
2
3
4
0.5
1.0
Site 917
Site 916
Site 915
Site 914
US
MS
LS
Tectonic break-up unconformity
Pre-basalt basement and pre-rift sediments
Magmatic break-up unconformity
B
500 m
1 km

Figure 3

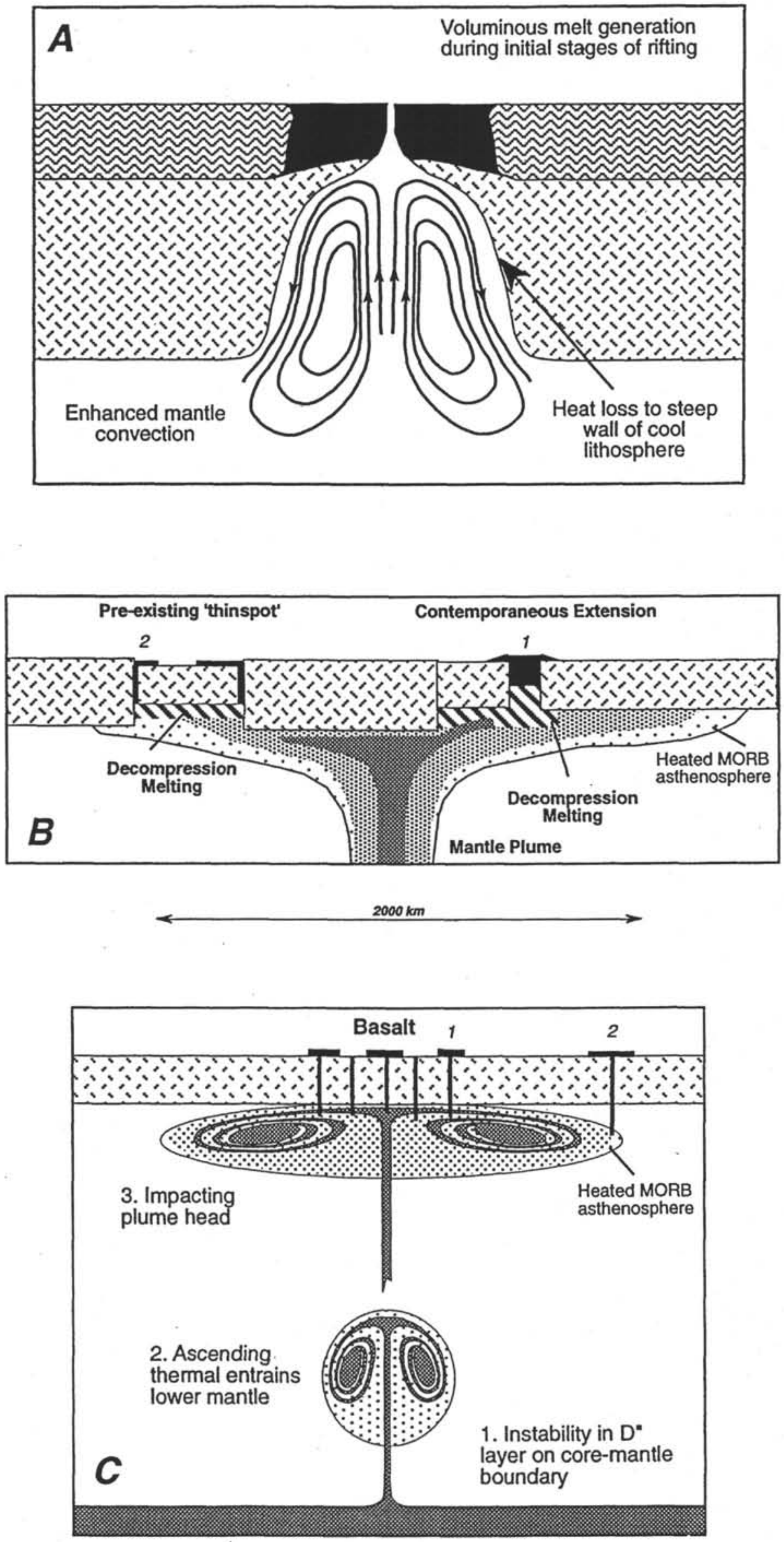

A
Voluminous melt generation during initial stages of rifting
Enhanced mantle convection
Heat loss to steep wall of cool lithosphere
Pre-existing 'thinspot'
Contemporaneous Extension
2
1
Decompression Melting
Heated MORB asthenosphere
Decompression Melting
B
Mantle Plume
2000 km
Basalt
1
2
3. Impacting plume head
Heated MORB asthenosphere
2. Ascending thermal entrains lower mantle
1. Instability in D" layer on core-mantle boundary
C

Figure 4

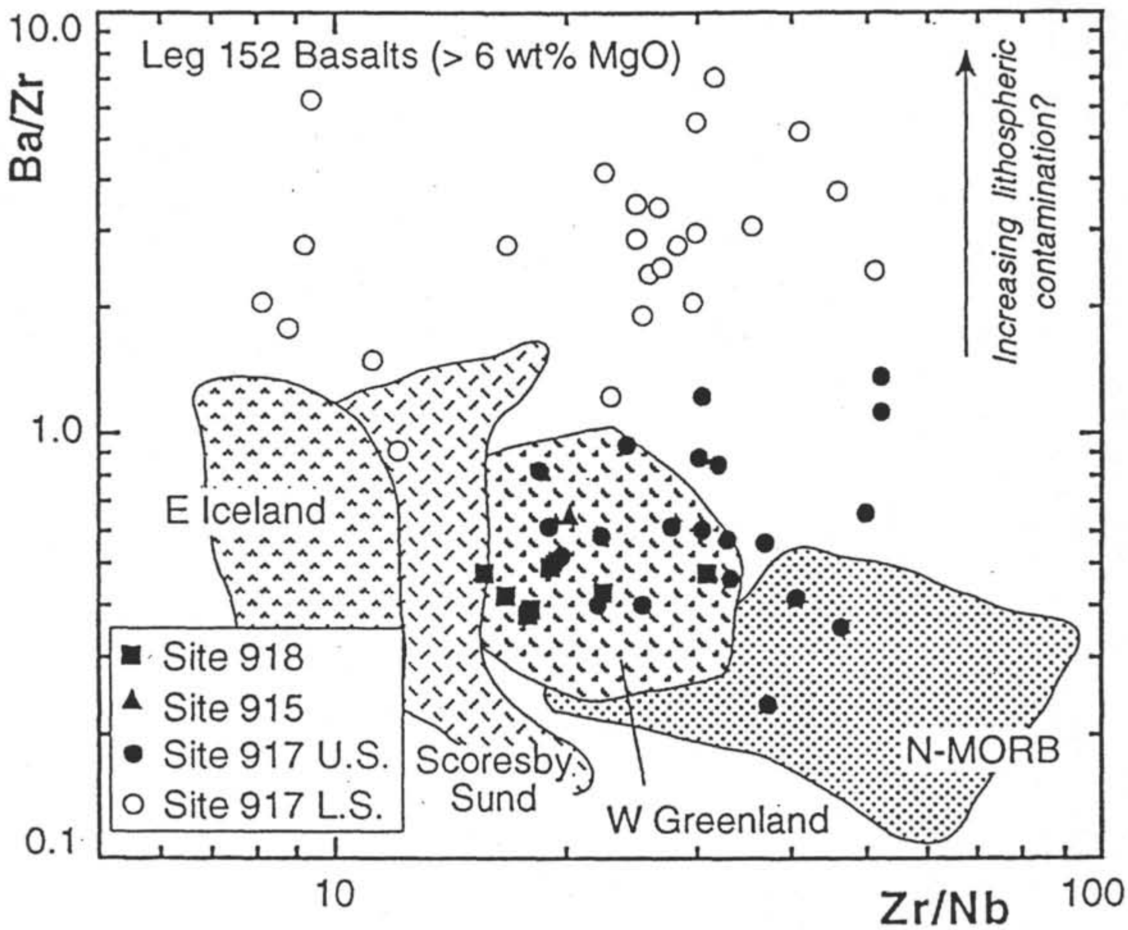

Leg 152 Basalts (> 6 wt% MgO)
Ba/Zr
10.0
1.0
0.1
Zr/Nb
10
100
Increasing lithospheric contamination?
E Iceland
Scoresby Sund
W Greenland
N-MORB
Site 918
Site 915
Site 917 U.S.
Site 917 L.S.

Figure 5

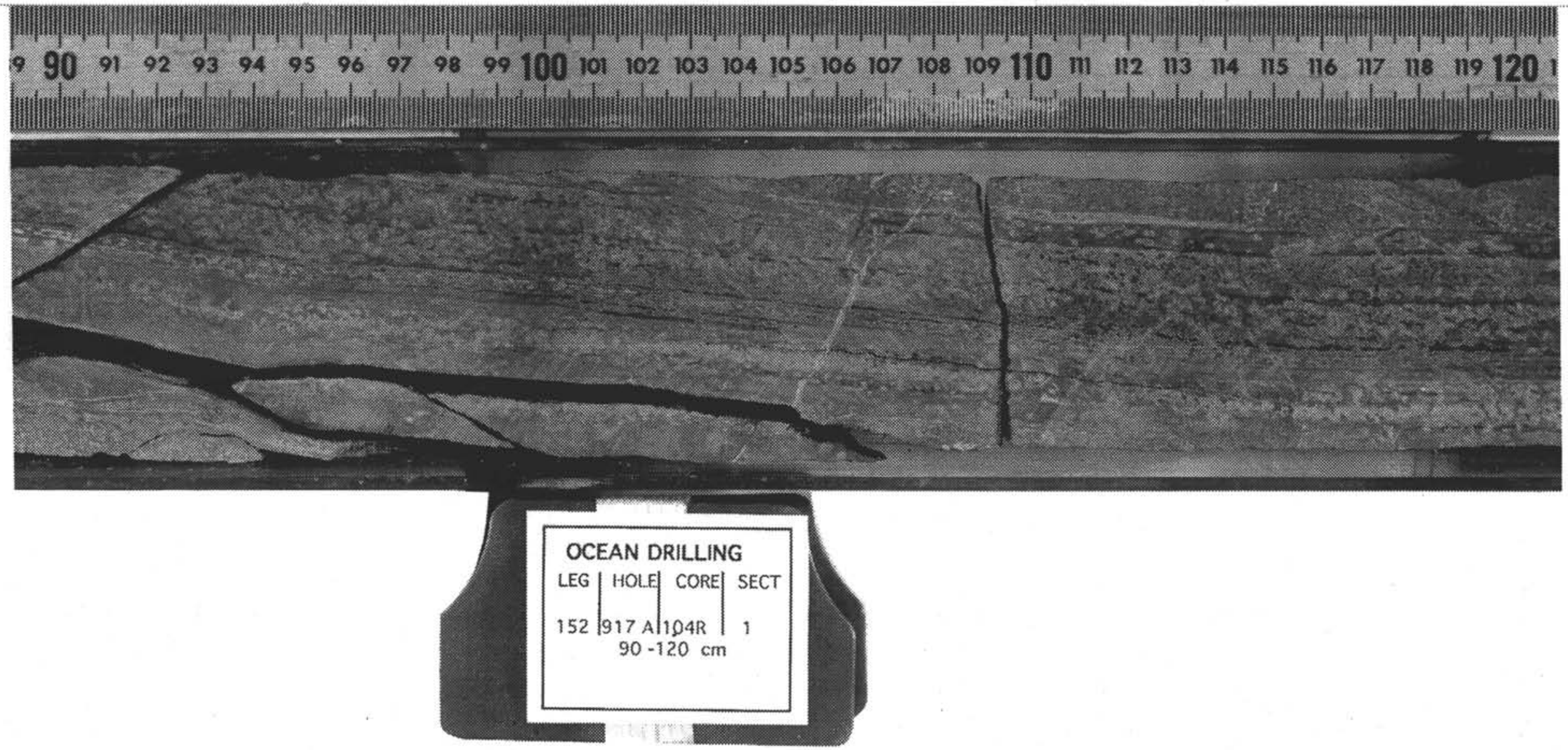

90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120
OCEAN DRILLING
LEG HOLE CORE SECT
152 917 A 104R 1
90 -120 cm

Figure 6

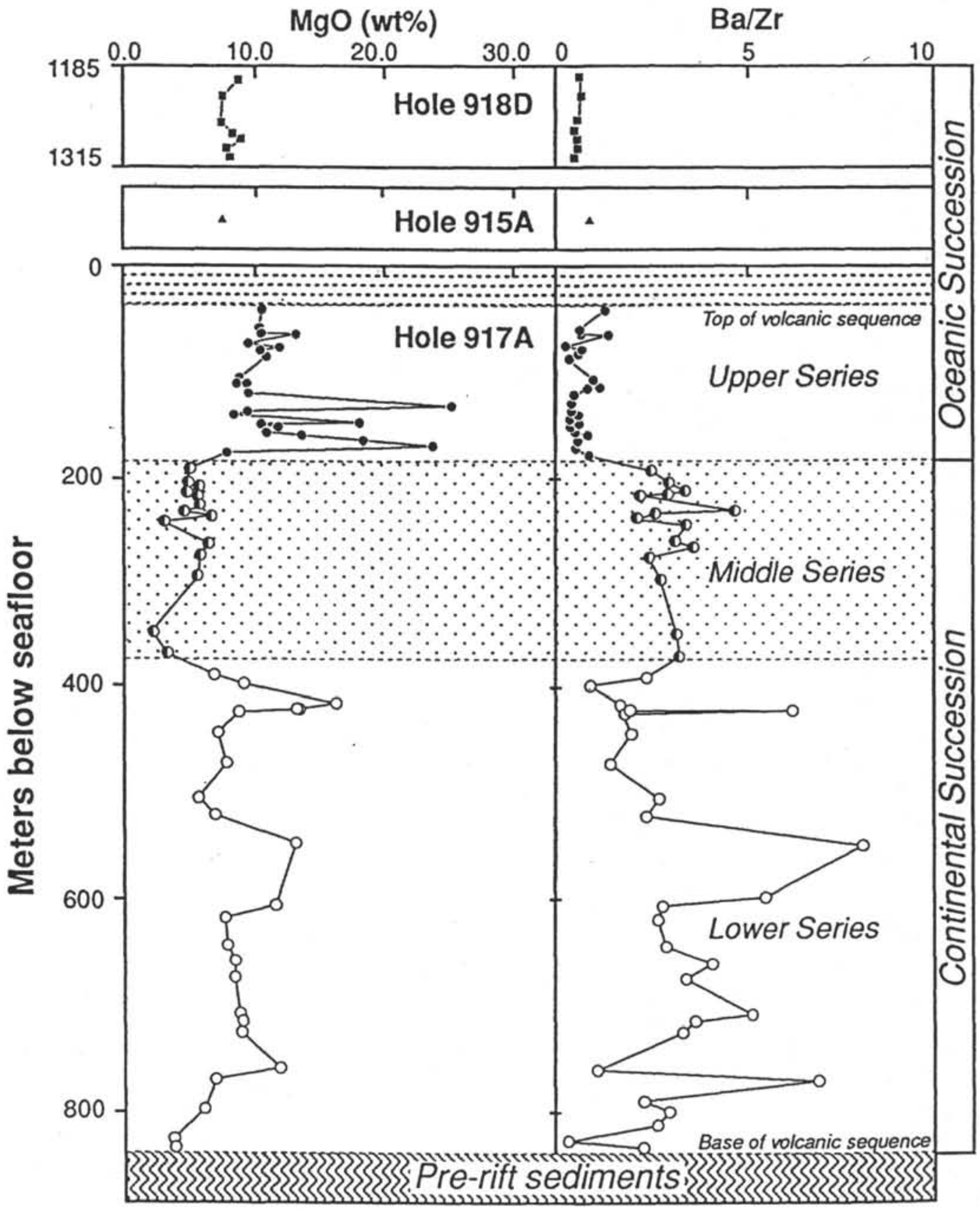

MgO (wt%)
Ba/Zr
0.0
10.0
20.0
30.0
0
5
10
1185
1315
Hole 918D
Hole 915A
0
200
400
600
800
Hole 917A
Top of volcanic sequence
Upper Series
Middle Series
Lower Series
Base of volcanic sequence
Pre-rift sediments
Meters below seafloor
Oceanic Succession
Continental Succession

Figure 7

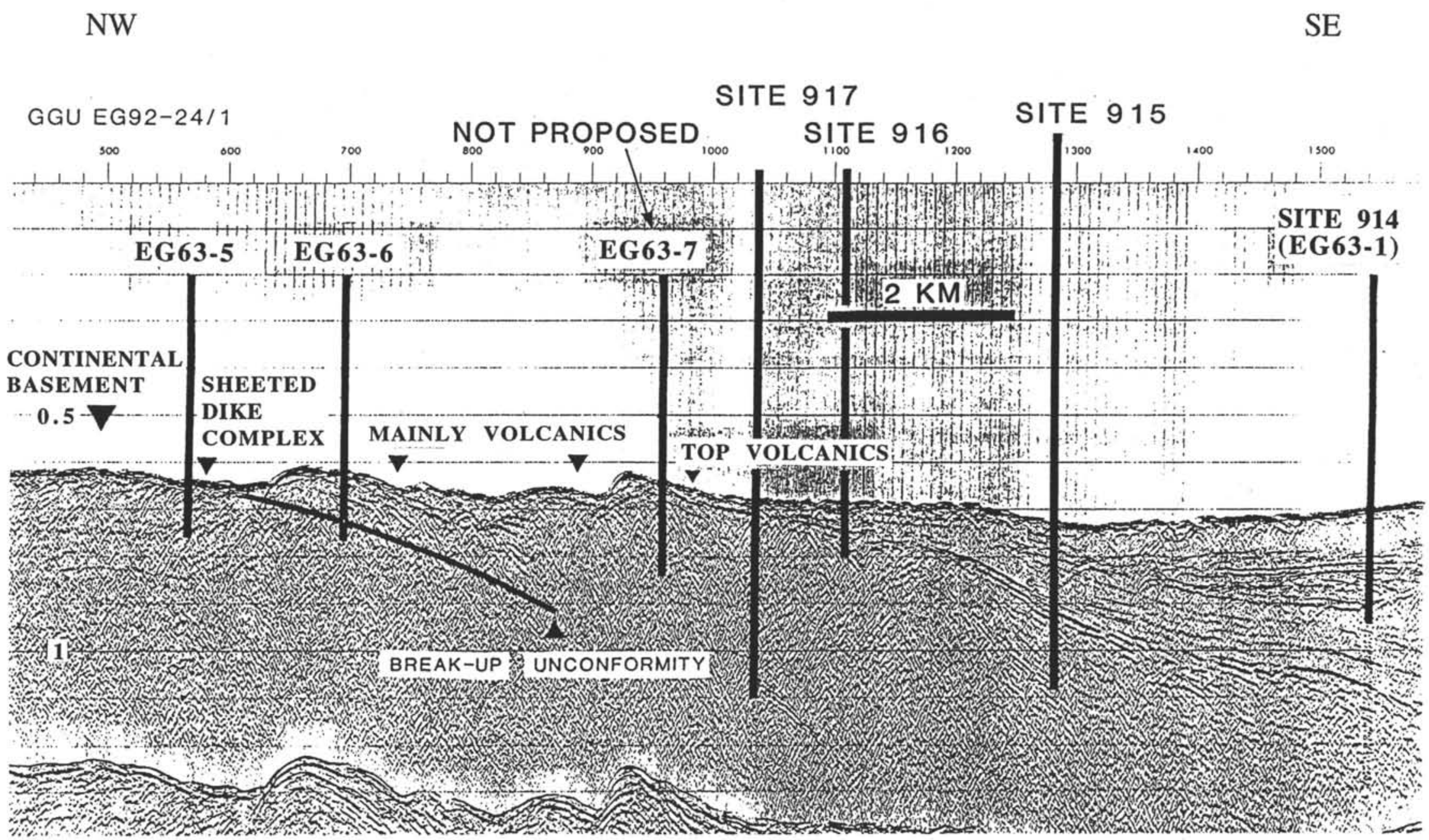

NW
SE
GGU EG92-24/1
SITE 917
NOT PROPOSED
SITE 916
SITE 915
500
600
700
800
900
1000
1100
1200
1300
1400
1500
EG63-5
EG63-6
EG63-7
SITE 914
(EG63-1)
2 KM
CONTINENTAL
BASEMENT
0.5
SHEETED
DIKE
COMPLEX
MAINLY VOLCANICS
TOP VOLCANICS
1
BREAK-UP
UNCONFORMITY

Figure 8

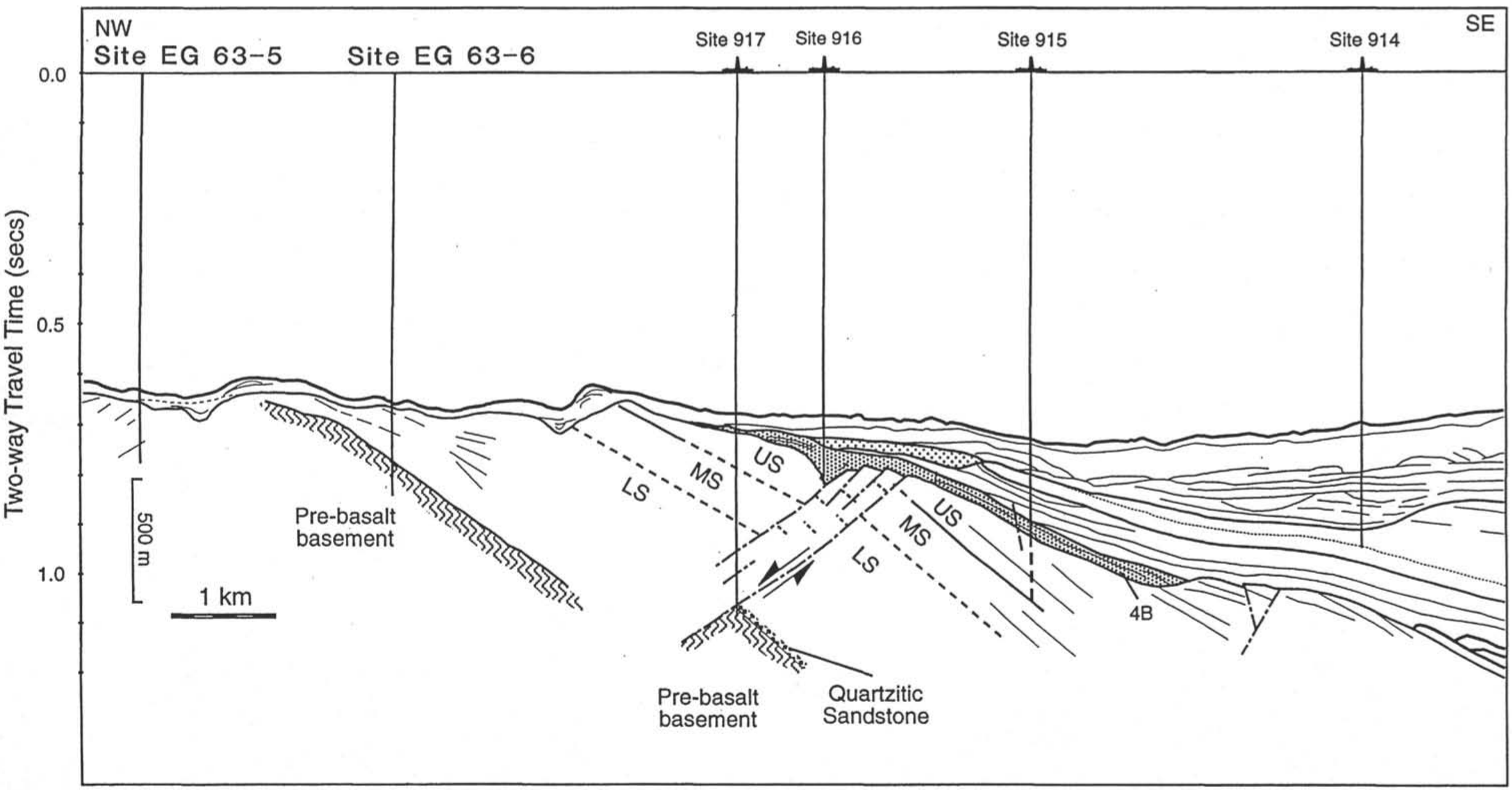

NW
SE
Site EG 63-5
Site EG 63-6
Site 917
Site 916
Site 915
Site 914
0.0
0.5
1.0
Two-way Travel Time (secs)
500 m
1 km
Pre-basalt basement
US
MS
LS
4B
Pre-basalt basement
Quartzitic Sandstone

Figure 9

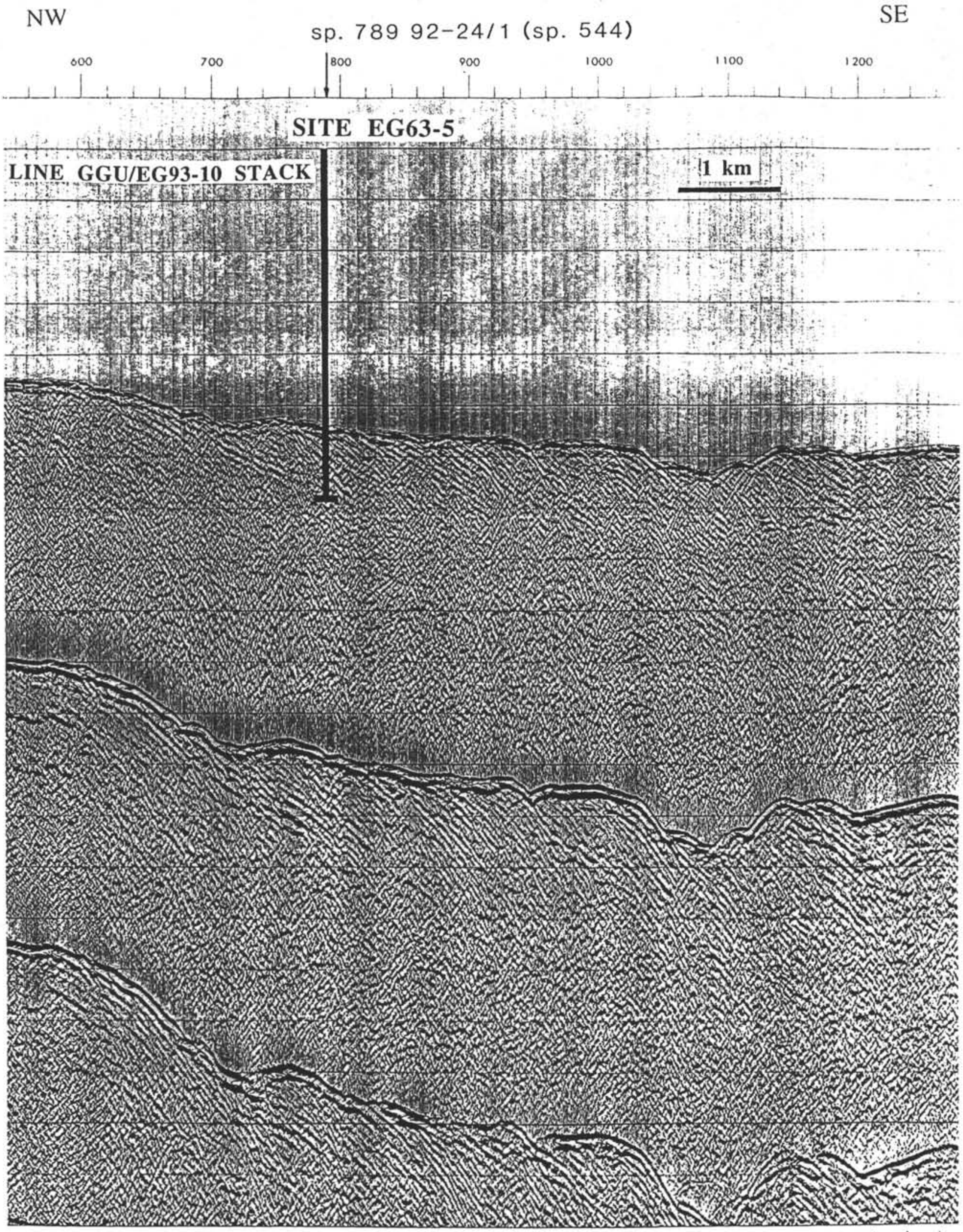

NW
SE
sp. 789 92-24/1 (sp. 544)
600
700
800
900
1000
1100
1200
SITE EG63-5
LINE GGU/EG93-10 STACK
1 km

Figure 10

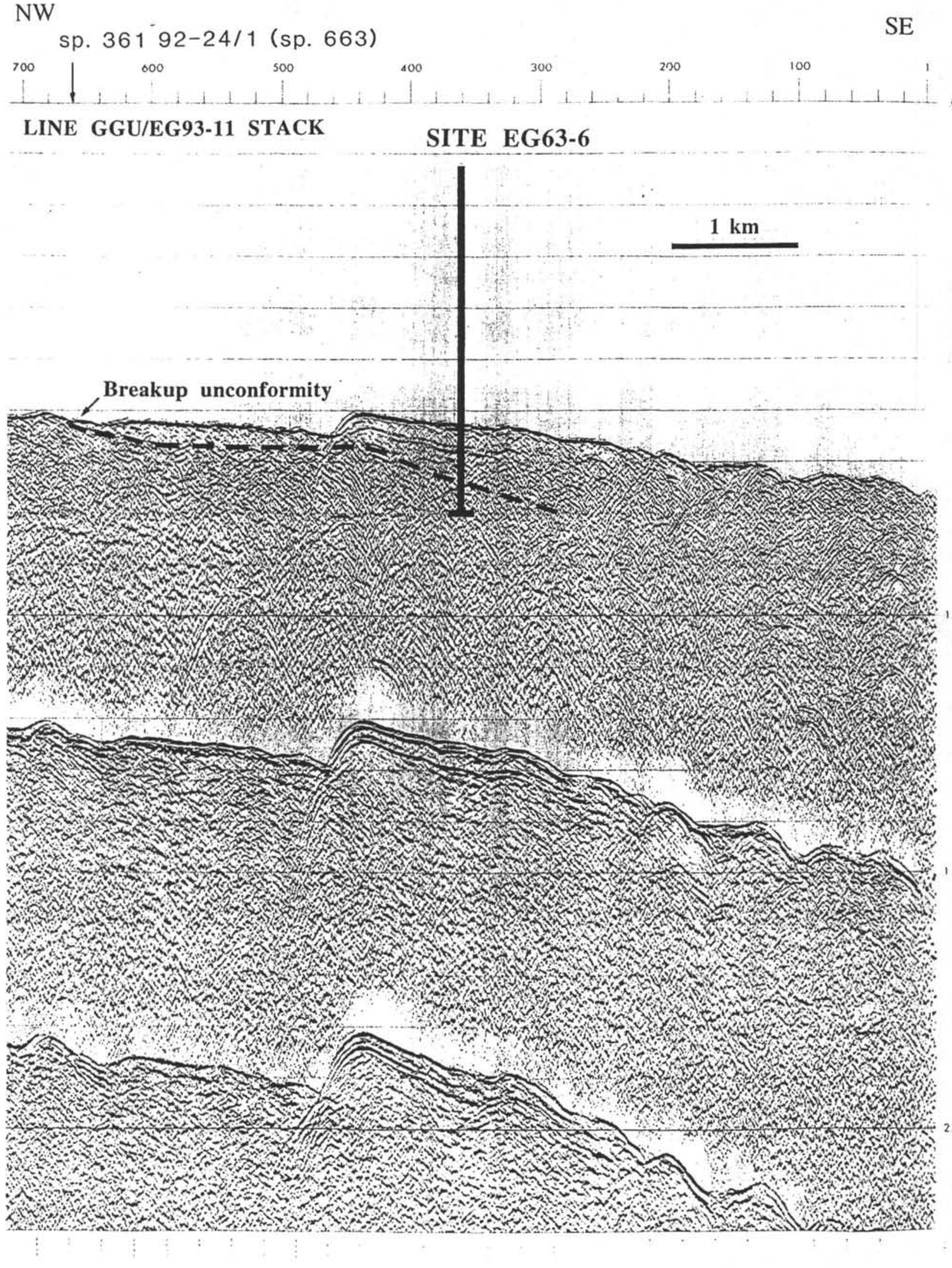
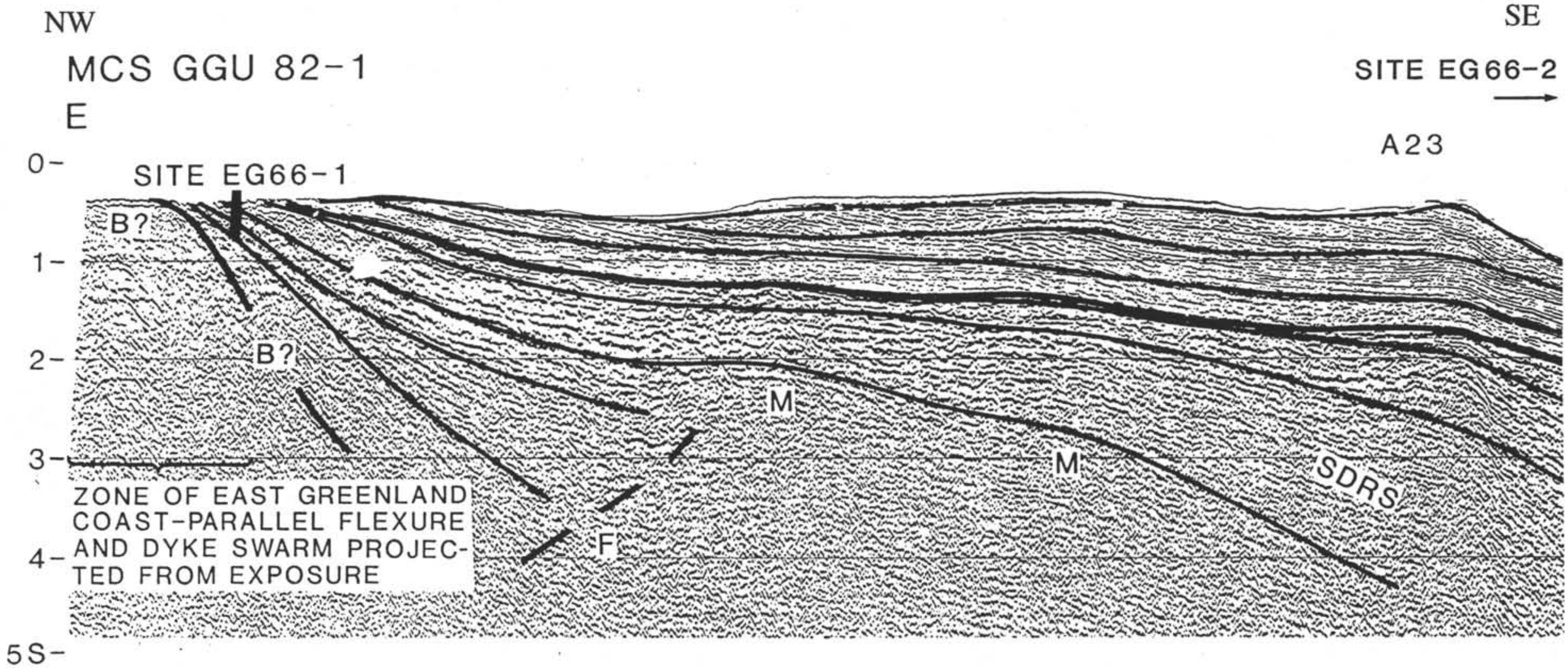

NW
sp. 361 92-24/1 (sp. 663)
SE
700
600
500
400
300
200
100
1
0
LINE GGU/EG93-11 STACK
SITE EG63-6
1 km
.5
Breakup unconformity
1.0
1.5
2.0

Figure 11



Seismic line GGU/82-1.

Figure 12

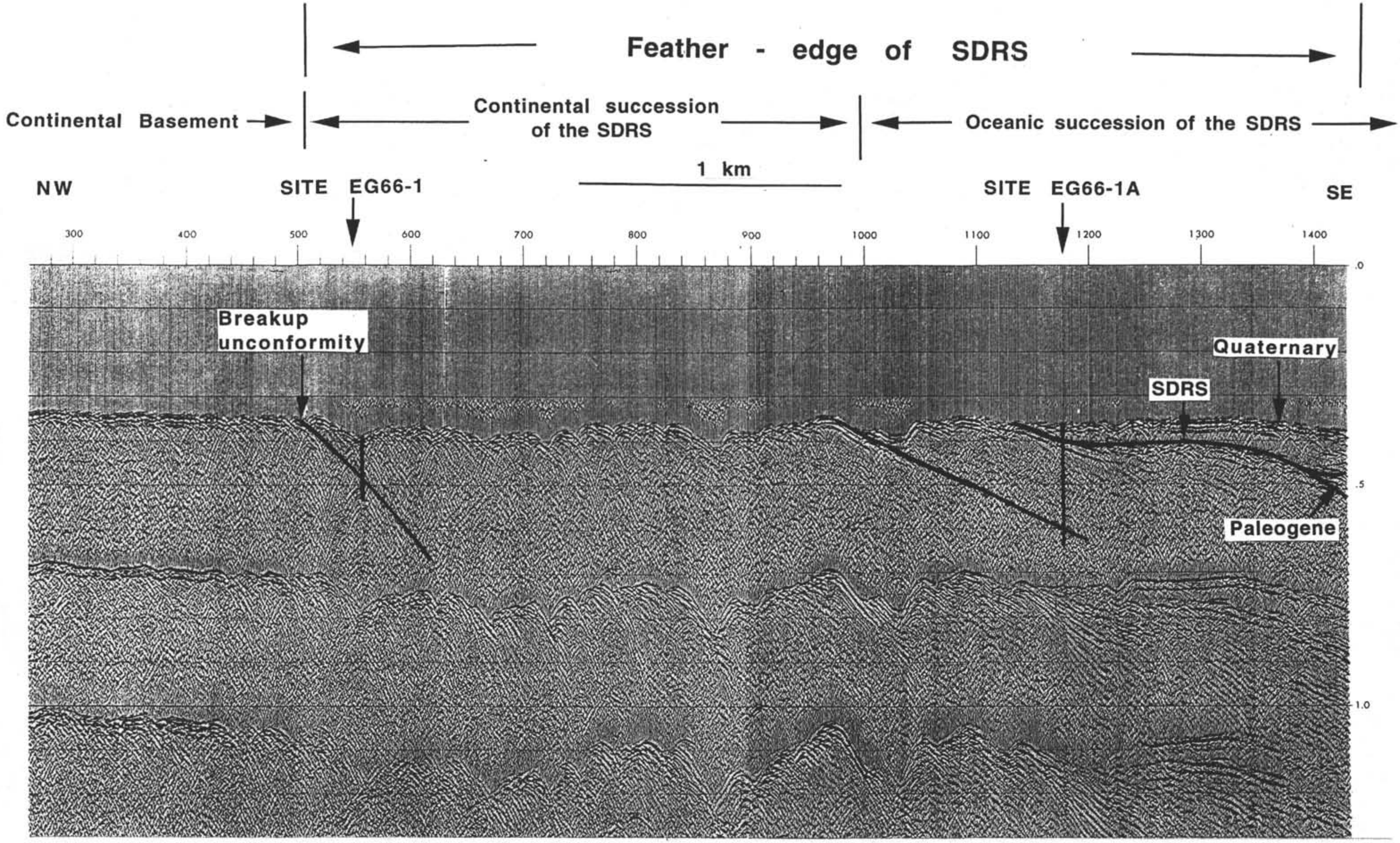

Feather - edge of SDRS
Continental Basement
Continental succession of the SDRS
Oceanic succession of the SDRS
1 km
NW
SITE EG66-1
SITE EG66-1A
SE
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
.0
.5
1.0
Breakup unconformity
Quaternary
SDRS
Paleogene

Figure 13

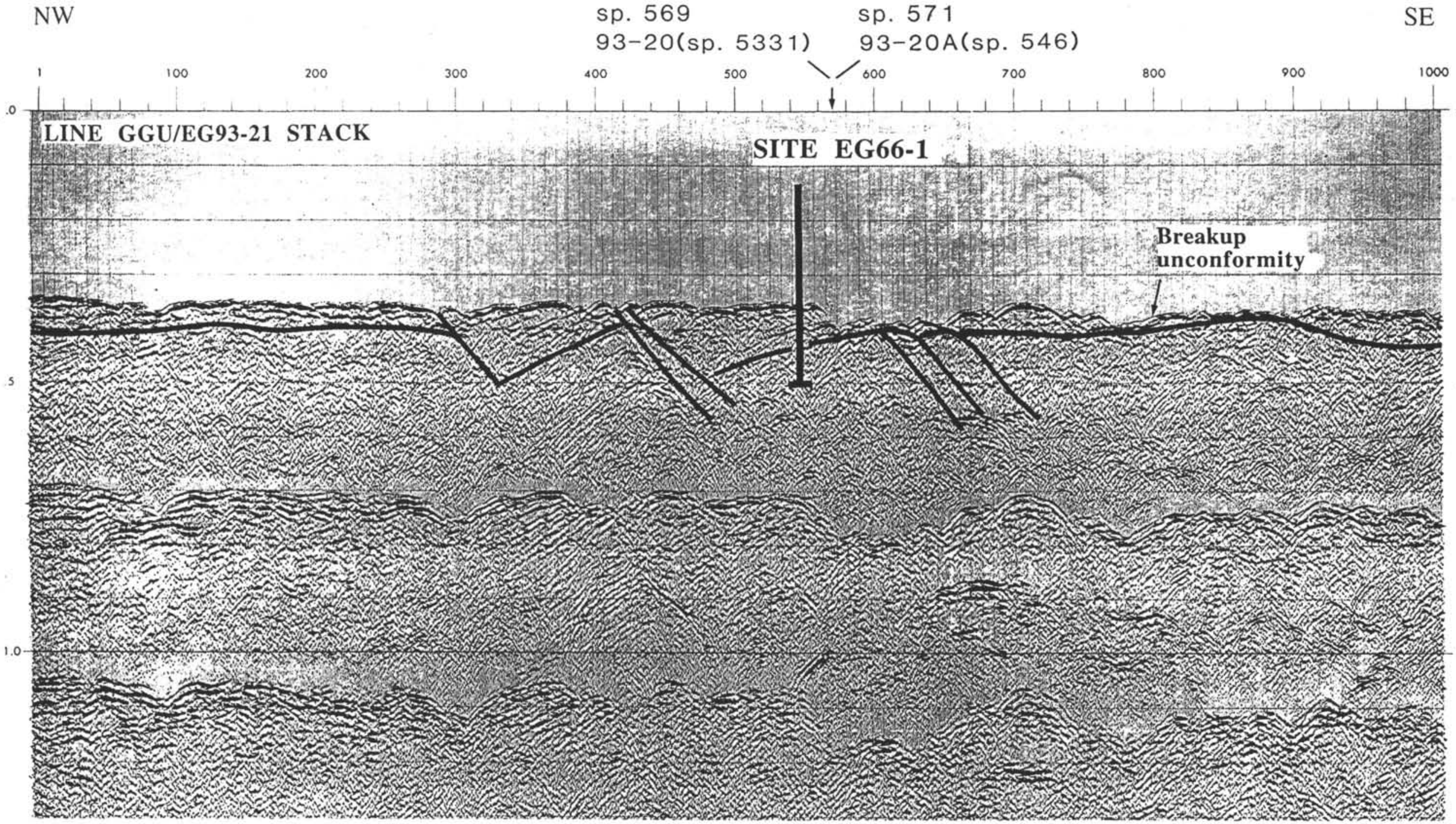

NW
sp. 569
93-20(sp. 5331)
sp. 571
93-20A(sp. 546)
SE
1
100
200
300
400
500
600
700
800
900
1000
.0
.5
1.0
LINE GGU/EG93-21 STACK
SITE EG66-1
Breakup
unconformity

Figure 14

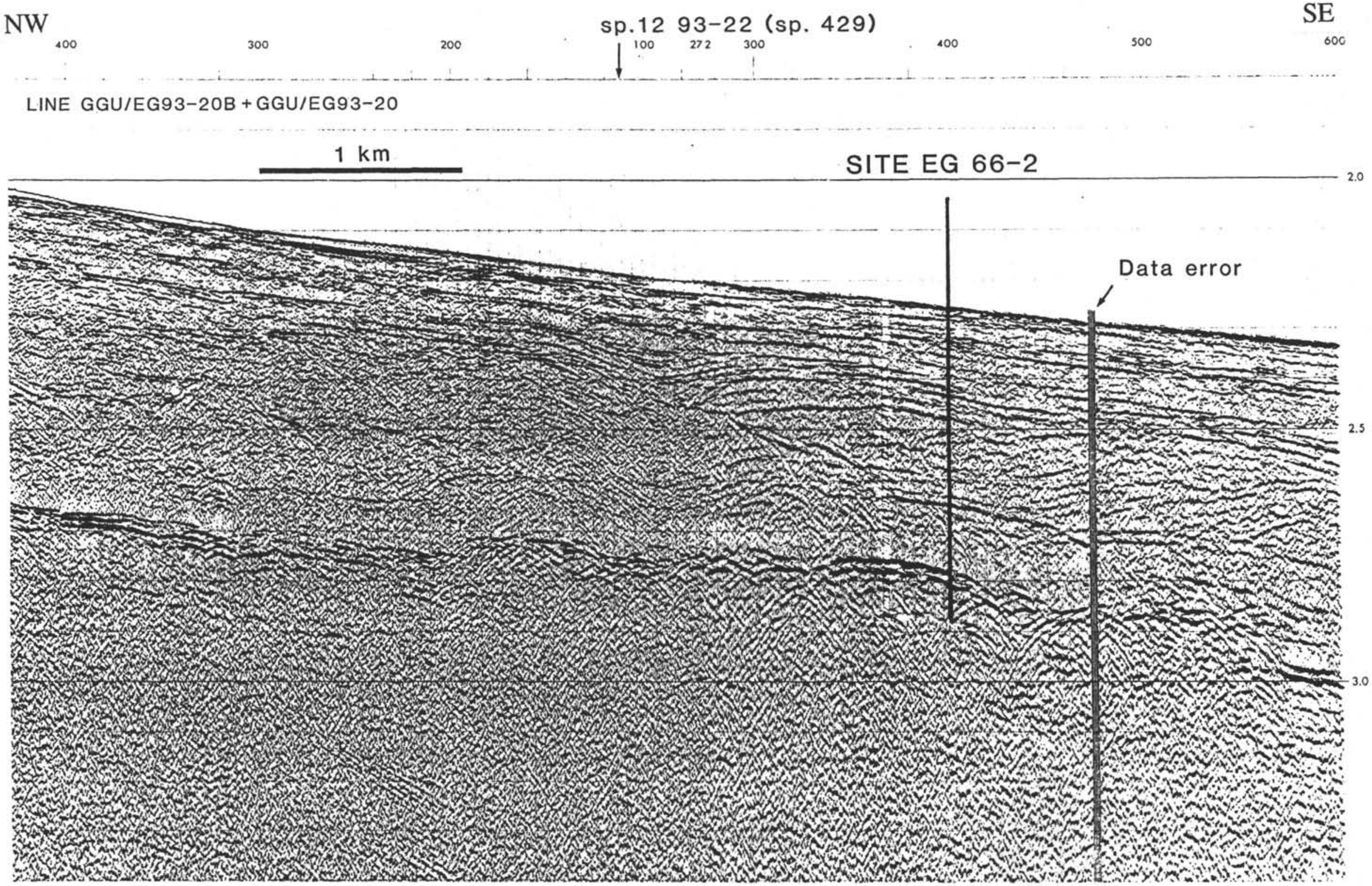

NW
SE
sp.12 93-22 (sp. 429)
400
300
200
100
272
300
400
500
600
LINE GGU/EG93-20B + GGU/EG93-20
1 km
SITE EG 66-2
Data error
2.0
2.5
3.0

Figure 15

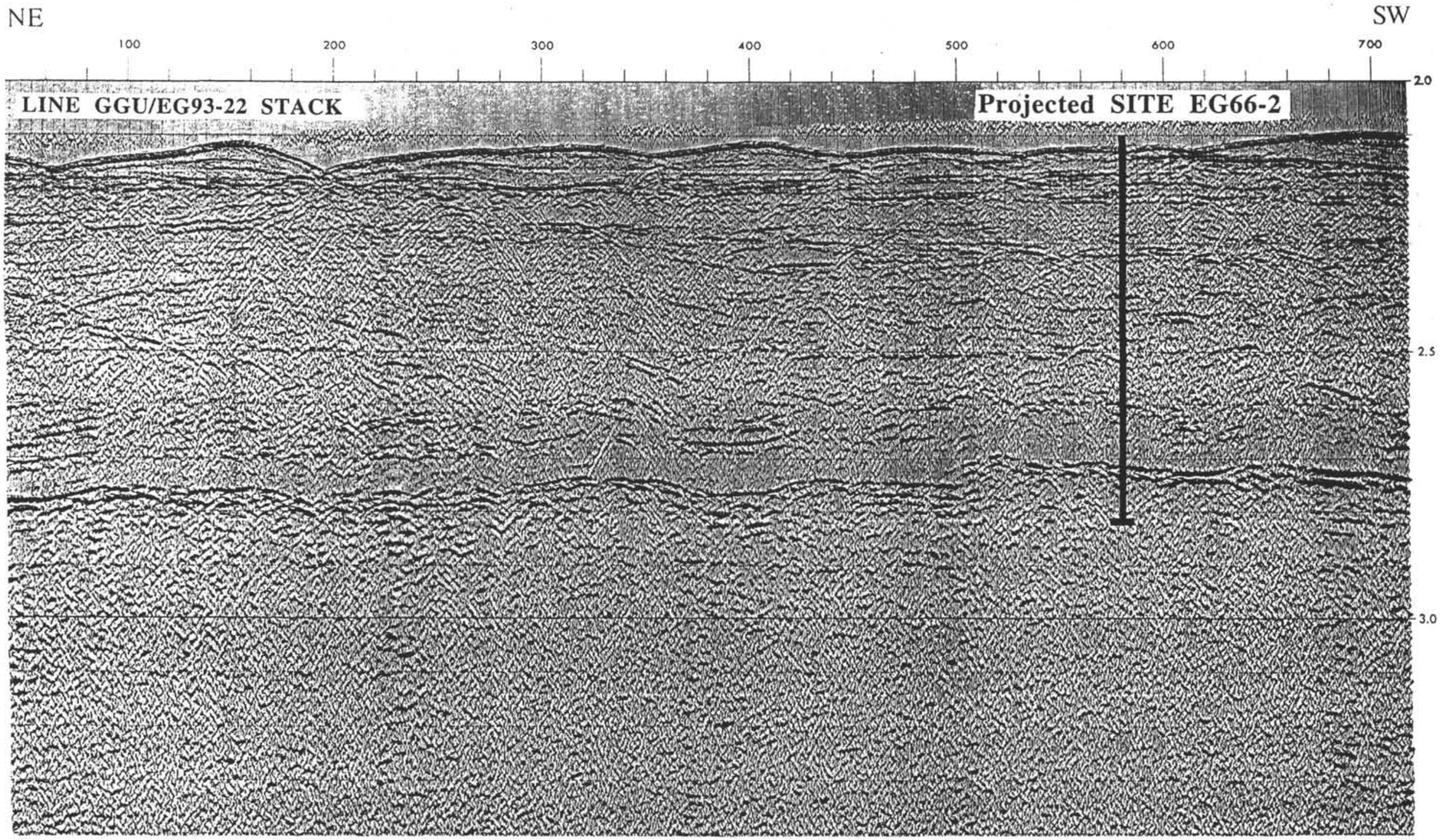

NE
SW
100
200
300
400
500
600
700
2.0
2.5
3.0
LINE GGU/EG93-22 STACK
Projected SITE EG66-2

Figure 16

Site: EG66-1
Priority: 1
Position: 65°44.81'N, 34°59.41'W
Water Depth: 260 m
Sediment Thickness: 0-5 m
Total Penetration: 280 m
Seismic Coverage: MCS EG93-21, SP 545 (Figure 14)

Objectives: To sample the oldest breakup volcanism, the breakup unconformity, and the underlying crust. To investigate the deformation (dike emplacement, faulting, and metamorphism) related to breakup.

Drilling Program: RCB core through the glacial overburden into the lavas and underlying pre-rift material and continue to 280 mbsf. If RCB spudding-in is made impossible by the conditions of bare hard rock at the seafloor with limited or absent sediment cover, a hard rock guide base may be deployed.

Logging and Downhole Operations: The hole is planned to less than 400 mbsf and will not require standard logging. Quad combo and FMS may be attempted if drilling conditions allow.

Nature of Rock Anticipated: Thin glaciomarine sediments overlying basaltic lavas and pre-rift crust, perhaps with dikes. Alternatively, gabbroic material may be present.

Site: EG66-1A

Priority: 1

Position: 65°42.08'N, 34°52.17'W

Water Depth: 270 m

Sediment Thickness: 20 m

Total Penetration: 520 m

Seismic Coverage: MCS EG93-20A, SP 1181 (Figure 13)

Objectives: To drill deeply into the basaltic basement to obtain a long section of rift volcanics, spanning the interval from volcanism affected by the continental lithosphere into more pristine ocean crust volcanism. The presence or absence of lower-mantle-enriched material in the core is the main scientific question to be addressed at this site.

Drilling Program: RCB core to 100 mbsf. Establish reentry cone and case through sediment cover into basement (~40 mbsf). Reenter with new drill bit and RCB core to primary target depth (520 mbsf). Round trip pipe for bit change as needed. If time permits, continue drilling to 700 mbsf (included in Table 1 calculations).

Logging and Downhole Operations: Quad combo and geochemical logging, and FMS.

Nature of Rock Anticipated: Thin glaciomarine sediments overlying basaltic basement.

Site: EG66-2
Priority: 1
Position: 64°57.84'N, 33°02.74'W
Water Depth: 1670 m
Sediment Thickness: 520 m
Total Penetration: 720 m
Seismic Coverage: MCS EG93-20B, SP 400 (Figure 15)

Objectives: To drill into the younger part of the SDRS to investigate if enriched Icelandic-plume-type mantle material is present at this location. Secondary objectives are the recovery of Paleogene sediments for subsidence analysis and Neogene sediments for paleoceanographic purposes.

Drilling Program: Two holes are planned. APC core Hole A until refusal (estimated at 150 mbsf). Deepen hole by XCB to refusal (estimated at 300 mbsf). RCB drill Hole B to XCB refusal depth and RCB core to 720 mbsf. Deploy FFF for bit changes.

Logging and Downhole Operations: Quad combo and geochemical logging, and FMS.

Nature of Rock Anticipated: 150 m of slope sediments with glacial dropstones, 190 m of Miocene slope contourites, and 200 m of Eocene to Oligocene shallow-water to deep-shelf sediments overlying subaerially erupted basaltic lavas.

Site: EG63-5

Priority: 1

Position: 63°31.83'N, 39°55.65'W

Water Depth: 475 m

Sediment Thickness: 5 m (unconsolidated, possibly indurated sediments)

Total Penetration: 210 m

Seismic Coverage: MCS EG92-24, SP 570 (Figure 8)

Objectives: To identify the nature of the landward dipping reflectors below the breakup unconformity and, if this is sedimentary in nature, to obtain a long section of pre-rift sediments for stratigraphic age determination. To identify the dip and deformation of the pre-rift crust, including possible dike complexes. To investigate alteration and metamorphism related to the continental breakup.

Drilling Program: RCB core through glacial overburden into the pre-rift material and continue to 210 mbsf.

Logging and Downhole Operations: The hole is planned to a total depth of less than 400 m and will not require standard logging. Quad combo and FMS may be completed assuming stable hole conditions remain.

Nature of Rock Anticipated: Thin glaciomarine sediments overlying either indurated pre-rift sediments or basement rocks with a sheeted dike complex.

Site: EG63-6
Priority: 1
Position: 63°31.35'N, 39°54.07'W
Water Depth: 460 m
Sediment Thickness: 5-10 m
Total Penetration: 410 m
Seismic Coverage: MCS EG92-24, SP 704 (Figure 8)

Objectives: To drill through the glaciomarine overburden (5-10 m), through lavas (250 m), and 150 m into pre-rift crust. To investigate the deformation (dike emplacement, faulting, and metamorphism) related to breakup.

Drilling Program: RCB core through glacial overburden into the lavas and underlying pre-rift material and continue to 410 mbsf. Drill bit change may require deployment of FFF (mini cone).

Logging and Downhole Operations: Quad combo and geochemical logging, and FMS.

Nature of Rock Anticipated: Thin glaciomarine sediments overlying basaltic lavas and pre-rift crust (sediments or basement rock with dikes).

Site: Site 915 (deepening)

Priority: 1

Position: 63°28.29'N, 39°46.91'W

Water Depth: 533 m

Sediment Thickness: 190 m

Total Penetration: 447 m

Seismic Coverage: MCS EG92-24, SP 1281 (Figure 8)

Objectives: To deepen Site 915 and achieve up to 250 m basement penetration to examine the nature of the volcanism following the pricritic volcanism recorded at nearby Site 917, which is interpreted as representing initial volcanism associated with continental breakup.

Drilling Program: Wash down to 180 m and RCB core to 447 mbsf or bit destruction.

Logging and Downhole Operations: Quad combo. Other logs may be prohibited because of expected poor hole conditions within the upper 100 m.

Nature of Rock Anticipated: Glaciomarine sediments (85 m) overlying Eocene shallow-marine to shelf sediments and basaltic basement (190 mbsf).

SCIENTIFIC PARTICIPANTS

OCEAN DRILLING PROGRAM LEG 163

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