5. BACKGROUND AND SCIENTIFIC OBJECTIVES, SHELF SITES 914 THROUGH 917[1]

Shipboard Scientific Party[2]

INTRODUCTION

Drilling along the margin transect EG63, scheduled for Leg 152, included two proposed sites: EG63-1, on the outer shelf, and EG63-2, on the continental rise. These sites were placed with a stratigraphic offset, and both were planned to have deep (400 m) penetration into volcanic basement. This was to provide a long (800 m), composite basement section for determining both short- and long-term variations in the volcanic history of the seaward-dipping reflector sequences (SDRS).

Initial drilling problems on the shelf caused by shallow, glaciogenic deposits prevented us from progressing as planned for proposed Site EG63-1 (Site 914). Originally, this entailed a cased hole to basement and multiple reentries (see "Operations" section, "Site 914" chapter, this volume). Instead, we drilled four offset sites on the shelf: three shallow-penetration sites (Sites 914 through 916) and one deep-penetration site (Site 917), to accomplish the original goals of planned Site EG63-1 (Figs. 1 and 2).

At all four sites, we recovered core from various parts of the section of middle Eocene to early Oligocene age shelf sediments and overlying glaciogenic sediments. This enabled us to establish a composite log of the sedimentary section. At Site 917, we achieved rapid basement penetration and high recovery of a volcanic, mainly basaltic sequence. Shipboard XRF analysis demonstrated significant geochemical variations within the SDRS at this site. We thus gave priority to drilling deep into the oldest part of the volcanic succession at Site 917. Furthermore, drilling results from Site 916 and from the upper part of Site 917 enabled us to extend the seismic interpretation to deeper levels within the volcanic rocks and, subsequently, to target the pre-basaltic substratum. Indeed, at Site 917, we drilled through the volcanic lava succession and through a fault into the breakup unconformity and the underlying pre-volcanic succession. Total penetration was 874.9 mbsf, of which 779.20 m were in the volcanic succession.

The individual sites have been described in the following site chapters. The sites all lie within a distance of 6 km from seismic profile GGU/EG92-24. Therefore, we present here a general introduction to all four sites and, after the individual site chapters, we present a stratigraphic summary based on an integration of the results from drilling at Sites 914 through 917 and accompanying seismic stratigraphic studies ("Shelf Stratigraphic Summary" chapter, this volume).

BACKGROUND AND GENERAL SETTING OF SITES 914 THROUGH 917

Along the proposed Site EG63 transect, the continental shelf is approximately 75 km wide. Precambrian high-grade metamorphic and plutonic rocks of Archean to early Proterozoic age occur all along the adjacent coast and continue onto the shelf (Bridgwater et al., 1976; Larsen, 1990). The distribution of Archean and Proterozoic rocks on the shelf is not known. However, it is likely that the drilling transect is located along the northern margin of an Archean terrane, close to an early Proterozoic plate suture (Fig. 1). A mid-Archean igneous complex is present on the coast south of the drilling transect and may continue onto the shelf south of the transect (Nielsen and Rosing, 1990).

Along the coast at latitude 63°N, only a few, generally coast-parallel dikes of probable Tertiary age indicate proximity to the initial line of breakup. Thus, this basement craton apparently stayed virtually unaffected by any major geological process since early Proterozoic time, until continental breakup in the early Tertiary. An increase in the intensity of Tertiary dikes is seen 300 to 400 km farther north along the coast (66°N and northward) and is associated with marked tectonism, including seaward rotation of fault blocks by up to 45° to 50° (Wager and Deer, 1938; Myers, 1980; Brooks and Nielsen, 1982). An offshore southward continuation of this intense, coast-parallel dike swarm was suggested by Larsen (1978). Thus, through dike injection and block faulting, the continental basement below the mid- to outer-shelf along the proposed EG63 transect may have suffered considerable magmatic and tectonic extension during breakup.

Marine to littoral sediments of Late Cretaceous to Paleocene age are found locally along the coast and also inland as far as 150 km. Onshore outcrops of these sediments are, however, restricted to the area of basalt cover (i.e., from 66° to 74°N) and, hence, are not exposed on the coast immediately adjacent to the transect. South of 68°N, these sediments generally are found as a thin layer between the basement and the basalts and, in the north, between Mesozoic sediments and the basalts (see Larsen, 1980, for review). Widespread occurrence of these sediments suggests that a marine basin existed along the initial rift zone, prior to the main breakup volcanism.

Along the EG63 transect, the inner 40 km or so of the shelf is thought to comprise Precambrian basement exposed below a thin layer of Quaternary deposits. About 40 km from the coast, early Tertiary lavas, overlain by Tertiary and Quaternary sediments, overlie the continental basement with its supposed dike complex. Originally, the volcanic sequence extended for at least some distance farther inland, but this inner part has been removed by erosion, following uplift of the coastal area and the inner shelf relative to the outer shelf, slope, and rise areas (Fig. 2). It is possible that Late Cretaceous to early Paleocene age sediments, similar to those seen along the coast farther north, also are present along the transect below the lava sequence.

Volcanic Basement

On the outer shelf, the continental basement disappears below the wedge of Tertiary rocks through a seaward-dipping, monoclinal flexure associated with normal faulting (Fig. 2). The breakup unconformity between the continental basement and the overlying lavas outcrops at the seafloor on the mid-shelf. This unconformity shows a gentle seaward dip that steepens to approximately 20° (east-southeast), at a depth of about 1 km below the seafloor.

Over a distance of approximately 50 km, the seaward monoclinal structure lowers the top of the volcanic basement from its position close to sea level on the mid-shelf down to about 3 km below sea level on the continental rise. About half of this lowering takes place within an inner, steep part of the flexure that is about 15 km wide. Because of the seaward-thickening nature of the volcanic sequence overlying the continental basement, this must have been downflexed by considerably more than 1.5 to 3 km (Fig. 2). Gravity data show landward,

[1] Larsen, H.C., Saunders, A.D., Clift, P.D., et al., 1994. *Proc. ODP, Init. Repts.,* 152: College Station, TX (Ocean Drilling Program).

[2] Shipboard Scientific Party is as given in list of participants preceding the contents.

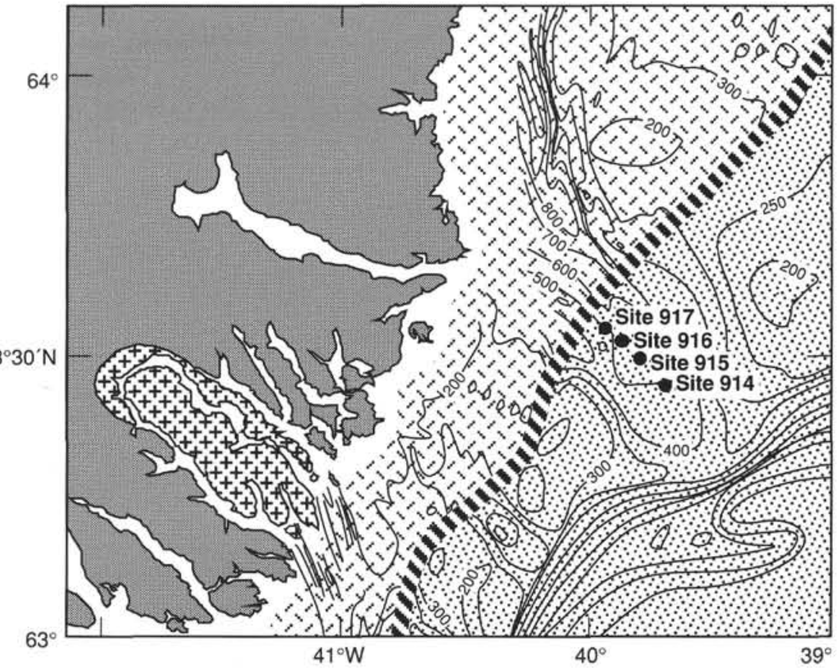

Figure 1. Location of Sites 914 through 917 on the outer, middle part of the East Greenland Shelf. The coastal area comprises Precambrian basement of Archean age (dark shading), but early Proterozoic rocks are present just north of the map boundary and may continue onto the shelf north of the drilling transect. A mid-Archean igneous rock complex (crosses) is present within the southern part of the map area and might extend onto the shelf south of the transect. The Precambrian basement is exposed below the inner shelf. The outer shelf is covered by Tertiary and Quaternary sediments (light shading) overlying thick, early Tertiary volcanic rocks that outcrop to the northwest of the drill sites (diagonal stippling), and which form the inner part of the seaward-dipping reflector sequence (see Fig. 2). The sites are located within a deep trough connecting deep fjords in the northwest with the continental slope and rise (Sommerhoff, 1973; see also "Introduction" chapter, Fig. 5, this volume). Near the shore, the trough is up to about 1 km deep, but only about 350 to 375 m deep at the shelf edge, where a shallow topographic sill is present.

strongly decreasing values (>60 mGal decrease) across this flexure zone (Larsen and Jakobsdóttir, 1988). This suggests that the flexure zone marks the transition from continental crust to oceanic igneous crust, not only within the upper crust, but also at deeper crustal levels. Because the SDRS show thinning and onlapping to the continental basement in the flexure zone, we refer to the zone as the "feather edge" of the SDRS.

Apart from the innermost part of the feather edge, the SDRS seem little eroded. The original top of the sequence has subhorizontal bedding overlying seaward-offlapping and -dipping beds that steepen with depth. Therefore, the overall state of the original volcanic carapace has been preserved. Within the most landward part of the flexure zone, the volcanic fill and its substratum (including the breakup unconformity) have been faulted by landward-dipping (westward) normal faults, with the updip parts of the fault blocks being most prone to erosion. The landward-dipping normal faults, inferred to be present within the monoclinal flexure zone, seem to dip landward at approximately 45° to 25° and to offset the breakup unconformity by several hundreds of meters. The apparent low dip of these faults might be in part because of (1) later monoclinal flexuring and (2) because the seismic line is not a perfectly true dip line. Hence, the original dip of these faults may have been approximately 45° to 65°.

Sedimentary Successions

The crustal flexure zone is overlain by a succession of Tertiary to Quaternary sedimentary strata that rapidly increase in thickness from a few tens of meters within the updip part of the flexure to more than 1 km thick, about 15 km to the southeast (Fig. 2). For the present purpose, we divided the sedimentary succession into four seismic stratigraphic sequences, Sequences 1 to 4 (Fig. 2). To facilitate comparisons between the seismic data and the lithostratigraphic units, defined on the basis of well data, we have numbered seismic stratigraphic sequences from top to bottom, beginning with seismic stratigraphic Sequence 4 at the bottom.

The lowermost sequence, Sequence 4, was laid down soon after emplacement of the volcanic sequences and has been tilted seaward together with the volcanic basement. Locally, the lowermost part of Sequence 4 fills the half-graben structures related to the normal faults within the seaward flexure zone and shows onlap onto the volcanic basement in the steepest part of the flexure (Fig. 3). Hence, the normal faulting (and the central, steep part of the flexure) was initiated prior to deposition of Sequence 4. However, the broader structure and tilting first formed after deposition of Sequence 4.

Sequence 4 is followed by Sequence 3, which is divided into two subsequences (3A and 3B). The upper Subsequence 3A shows a seaward progradational pattern with shingled-type clinoforms. The upper and landward parts of the lower Subsequence 3B clearly have been eroded away, which suggests that like Sequence 4, Subsequence 3B may have experienced some, albeit limited, tectonic rotation. Thus, a considerable hiatus may exist between Subsequences 3B and 3A.

Sequence 2 dominates the structure of the outer shelf, where it is up to 1 km thick. The sequence clearly post-dates the formation of the basement flexure. It shows a remarkable, continuous formation of progradational, sigmoidal clinoforms, which span the whole thickness of the sequence and show downlap on the underlying sequence. The upward termination of the clinoforms has been developed as angular toplap in its most landward part, and as sigmoidal, nonerosive toplap farther seaward. Though extremely thick for a single progradational sequence, it exhibits no internal unconformities that could be related to changes in sea level. Furthermore, its upper boundary, defined by generally nonerosive toplap, exhibits a systematic shallowing toward the shelf edge. It is this shallowing of the top of Sequence 2 that is responsible for the relative shallowness of the shelf-trough below the outermost shelf (Fig. 2). Moreover, the very steep, modern-day, continental slope parallels the internal progradational pattern within this sequence. Therefore, important parts of the present-day shelf morphology result from "positive" depositional features within Sequence 2, rather than from "negative" (erosional), features.

The uppermost Sequence 1 fills in and onlaps the partly erosional and partly depositional relief below this sequence. On the outer shelf, Sequence 1 overlies the nonerosive top of Sequence 2. Sequence 1 drapes the preexisting relief on the outer shelf, where it also becomes involved in the progradational clinoforms of the underlying Sequence 2 (Fig. 4). Furthermore, strata from the lower part of Sequence 1 continue through preserved, depositional contact into the sigmoidal clinoforms of the older parts of the prograding Sequence 2. Thus, Sequences 2 and 1 are, at least in part, contemporaneous, but clearly related to different depositional and lithofacies.

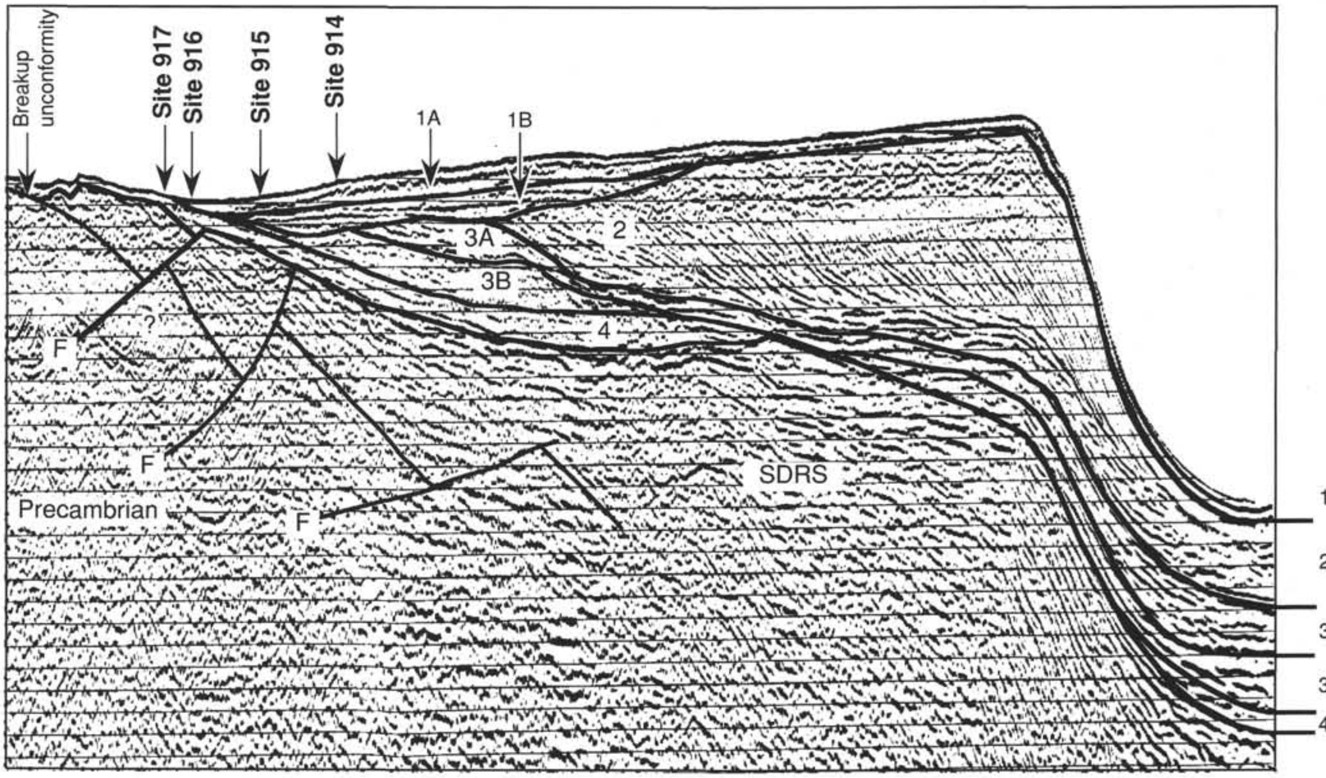

Figure 2. Interpreted seismic Line GGU81-08 through Sites 914 to 917 and the outer continental shelf and slope. Seismic stratigraphic Sequences 1 through 4 and Precambrian and volcanic basement (SDRS) are shown. Fault interpretation is provisional. Note that the vertical exaggeration is up to approximately 5:1 within the sediments and up to between 2:1 and 3:1 within the basement. Thus, the faults involving basement only dip 25° to 45°. The general dip of the lavas within the flexure zone may vary from 10° to 25°. The present low dip of the faults results partly from late flexuring by up to as much as 20°. The Precambrian basement most likely is intruded by dikes that intensify in density seaward.

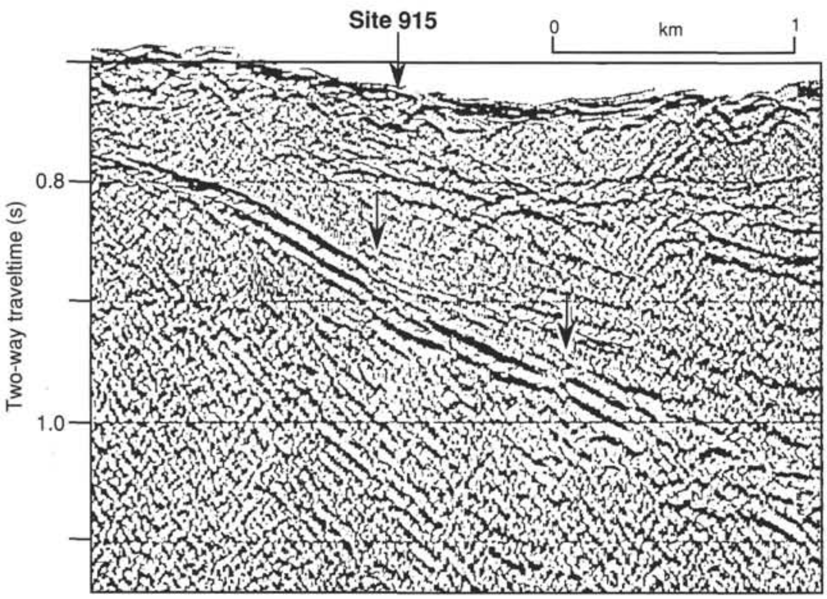

Figure 3. Detail of seismic Line GGU/EG92-24 showing the onlapping within the steep part of the flexure zone of seismic stratigraphic Sequence 4 onto the volcanic basement.

Larsen (1990) provisionally assigned a late Paleocene to Eocene age to Sequence 4, an early Oligocene to Miocene age to Sequence 3, and a Miocene to Quaternary age to Sequences 2 and 1. The seismic stratigraphy of the drilled shelf transect is described further in the "Seismic Stratigraphy" section, "Shelf Stratigraphic Summary" chapter (this volume).

MAIN SCIENTIFIC OBJECTIVES

Proposed Site EG63-1 was originally sited to obtain long, continuous stratigraphic sampling of the volcanic development during the early part of the breakup period. This was to be achieved by drilling approximately 400 m into the feather edge of the SDRS. The site was

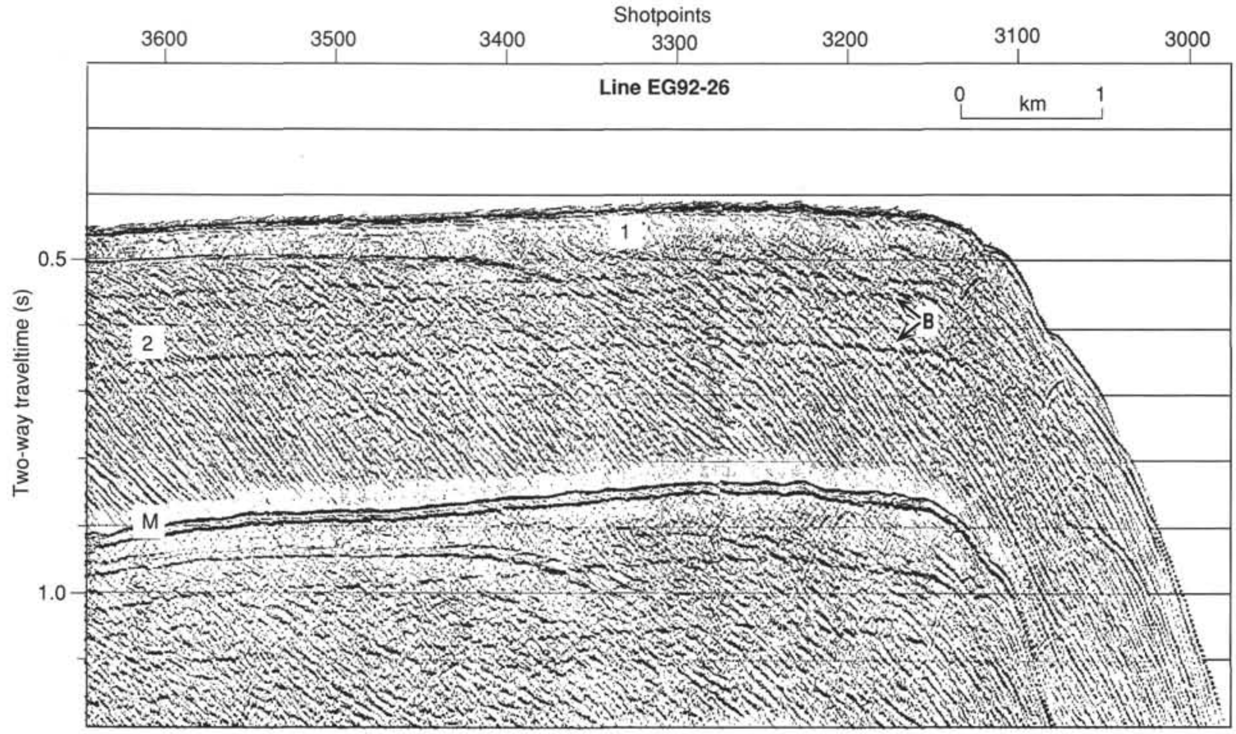

Figure 4. Detail of seismic Line GGU/E92-26 from the outer shelf showing the nonerosive toplap of seismic stratigraphic Sequence 2 and the lateral continuity in part of seismic stratigraphic Sequence 1 into Sequence 2 through this nonerosive toplap.

also planned to recover material from the overlying Cenozoic sediments. In particular, recovery from seismic stratigraphic Sequences 1, 3, and 4 was expected to be helpful with interpreting the chronographic and lithostratigraphic parts of the seismic data, which in turn have bearings on the subsidence of the margin and the Quaternary glaciation history. The main scientific objectives of the original Site EG63-1 can be summarized as follows:

1. To determine the emplacement environment of the early part of the SDRS;
2. To determine the age of the oldest part of the SDRS;
3. To determine the compositional variations in chemistry and magma processes within parts of the early SDRS, for distinguishing between competing models for excessive magmatism and thinning of the lithosphere during breakup;
4. To study the subsidence history, possible tectonism, and heat flow of the inner part of the SDRS to constrain the crustal structure at the supposed continent/ocean transition (COT);
5. To contribute to the investigation of the Cenozoic evolution of the Iceland plume activity by studying recovered tephra samples;
6. To retrieve and establish paleomagnetic and biostratigraphic events in the Paleogene geological record for general stratigraphic purposes and for precise dating; and finally,
7. To investigate glaciomarine processes and history of the Southeast Greenland Shelf.

The strategy of drilling four offset holes along a transect from the original Site EG63-1 (Holes 914A, 914B) and 6 km to the west (Sites 915, 916, and 917) instead of the originally planned single, deep hole was imposed by the drilling difficulties met at Site 914. The offset strategy by no means compromised any of the above objectives. These were achieved, completely or in part, with the main deficiencies being caused either by lack of relevant material in the geological record, or simply by little or no recovery. In fact, for some aspects of our work, the improved lateral control provided by multiple penetration was valuable. The main deviation from our original drilling plan was sampling of volcanic basement within a slightly older part of the SDRS and drilling to a deeper level, including the breakup unconformity and underlying metasediments (Site 917; total depth, 874.9 mbsf).

Satisfactory to excellent data were recovered in relation to our main Objectives 1 through 4. Objectives 5 and 6 were severely hampered by the coincidence of an incomplete stratigraphic section and low to poor recovery within certain intervals. Despite low recovery, important data were obtained with regards to Objective 7.

Basement was recovered at Sites 915, 916 (in-situ?), and 917. Important normal faults were penetrated at shallow and deep levels at Sites 916 and 917, respectively. Pre-basaltic sediments were recovered at Site 917. Middle and late Eocene sediments overlying the SDRS were recovered at Sites 917 and 915. The late Eocene to early Oligocene strata higher in the succession were recovered at Site 914. The most important recoveries of the Quaternary section were at Sites 914 and 916. Details of the cored sections are given in the site chapters that follow.

Ms 152IR-105