10. SHELF STRATIGRAPHIC SYNTHESIS[1]

Shipboard Scientific Party[2]

INTRODUCTION

Sites 914 through 917, drilled in the vicinity of proposed Site EG63-1, lie along a short (6 km) transect on the outer middle East Greenland continental shelf, approximately 25 km inboard of the shelf edge (see "Background and Scientific Objectives, Shelf Sites 914 through 917" chapter, this volume). We recovered sediments of Holocene to Eocene age from each of the sites and recovered basaltic basement from two sites (915 and 917). A basaltic conglomerate thought to be directly overlying basaltic basement was recovered at Site 916.

In this chapter, we present the results of integration of seismic stratigraphic studies and drilling data with regards to the Tertiary–Quaternary sedimentary section overlying the early Tertiary volcanic basement. First, we review the seismic stratigraphy and explain the correlation of lithostratigraphic observations made at Sites 914 through 917 to the seismic stratigraphic study. Next, we interpret the depositional environment of the various rock units encountered, the sedimentation rates, and the subsidence of this part of the margin. Finally, we discuss aspects of the glaciation history of the Southeast Greenland Shelf.

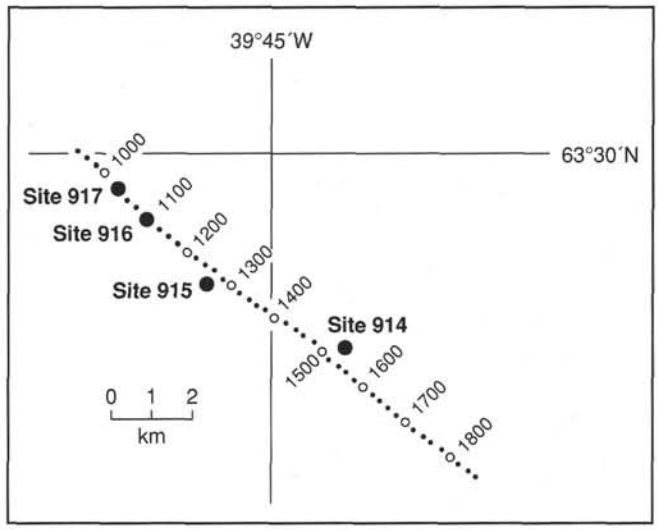

Figure 1. Location map of Sites 914 through 917 and part of the reflection seismic profile EG92-24.

SEISMIC STRATIGRAPHY

Sites 914 through 917 are all located on, or close to, the high-resolution seismic profile EG92-24 (Figs. 1 and 2). Acquisition and processing parameters are described in the "Pre-Cruise Survey" chapter (this volume). A stratigraphic interpretation of the seismic profile in the transect is described below.

Four seismic stratigraphic sequences are outlined in the "Background and Scientific Objectives, Shelf Sites 914 through 917" chapter (this volume). These sequences are described as follows, in order of decreasing age:

1. Sequence 4 rests directly on the volcanic basement. It shows coherent, relatively high-amplitude reflectors that onlap onto the basement. The lower part, Subsequence 4B, occurs locally as fills in half-grabens. The upper part, Subsequence 4A, has more regional extent.
2. Sequence 4 is overlain by Sequence 3, which is almost transparent in its lower part, Subsequence 3B. In the upper part, Subsequence 3A, internal reflectors show a seaward progradational pattern.
3. Sequence 3A is overlain by Sequence 2, which is a major sequence on the outer shelf, characterized by a distinct seaward progradational pattern.
4. Within the drilling transect, the erosional surfaces of Sequences 3 and 4 are directly overlain by Sequence 1. The lower part, Subsequence 1B, fills in erosional depressions and shows onlapping onto the flanks of the depressions. It is covered by Subsequence 1A, which is nearly transparent, except for the uppermost part, where high-amplitude reflections are parallel to the seafloor reflector. Except for Sequence 2, which thins landward and pinches out seaward of the drilling transect, all sequences identified in the high-resolution seismic profile can be correlated with the lithostratigraphy in the individual holes.

Seismic Velocities and Identification of Main Reflectors

The seismic velocity information available at Sites 914 through 917 is limited to discrete measurements performed on samples from intact parts of the cores. As core recovery within the sediments generally is low, especially in the Quaternary part of the sequences, the conversion of depths to two-way traveltimes (TWT) is not well constrained at any of the sites.

TWTs were calculated by assuming the simple stepwise variation of the velocities, as shown in Figure 3. We anticipate that the errors in the calculated TWTs may amount to about 10% (locally more) of the TWT below the seafloor. However, by correlation of key horizons (basement, distinct unconformities) to the seismic record, a considerable smoothing and improvement of the time-depth curve was obtained.

Basalts were not recovered at Site 914. However, the depth to the basalts is well constrained in Holes 915A and 917A. Volcaniclastic sediments, including basalt fragments, were recovered from the deepest part of Hole 916A. Therefore, the bottom of Hole 916A is probably very close to the top of the main basalt sequence. In the seismic profile, the surface at the top of the basalts corresponds to a high-amplitude reflector within a small down-faulted area around Hole 916A. At Site 917, the correlation between recovered core and the seismic profile is considered unambiguous (see Fig. 2). At Site 915, our interpretation is complicated by the presence of a series of closely spaced, high-amplitude reflectors in the TWT interval, within which the basalt surface can be expected (Fig. 4).

[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.

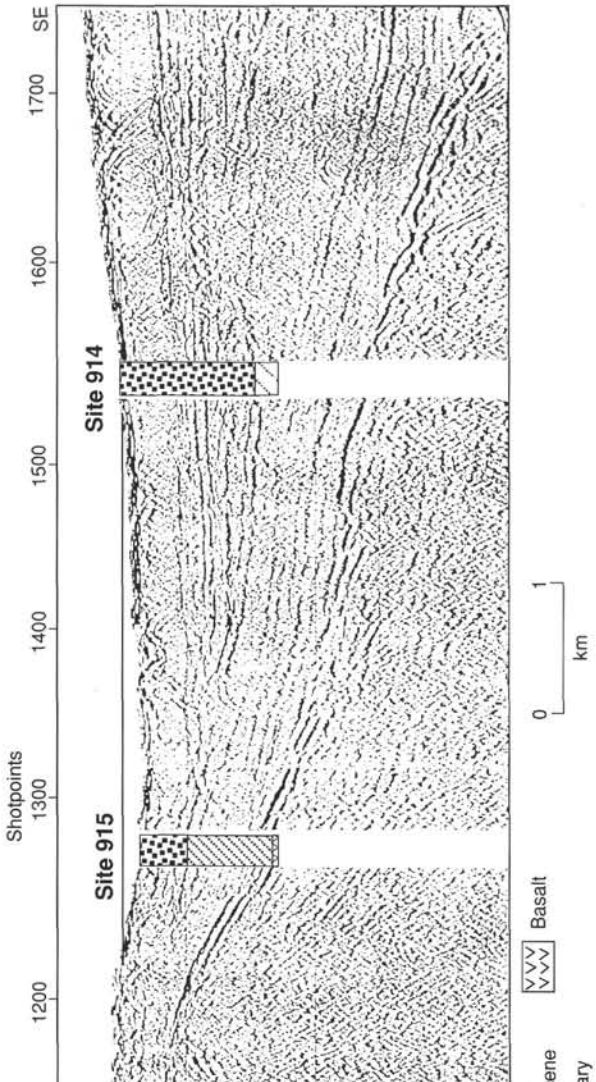

Figure 2. Stratigraphic profiles from Sites 914 through 917 pasted in the seismic profile EG92-24.

However, drilling data show that a pronounced velocity-inversion occurs at the boundary between clayey and sandy silts at a level about 27 m above the basalt surface (see Fig. 3) and, furthermore, that calcite-cemented sandstone beds, having high seismic velocity (about 4.0 km/s compared to about 1.7–2.0 km/s in the adjacent sediments), are present in an interval between 18 and 27 m above the basalt. Moreover, the upper, high-amplitude reflectors onlap the lowermost reflector in a "coastal onlap" fashion (Fig. 4). Therefore, the upper strong reflectors most likely were caused by marked velocity changes in the sediments and the lower reflector, by the basalt/sediment contact (Fig. 4).

A major unconformity, interpreted as the glacial/pre-glacial boundary, falls inside the broad TWT-windows predicted from coring results and other observations (Figs. 2, 4, and 5). This unconformity is easy to trace, except in the vicinity of Site 916, where two interpretations are possible. In the first, we assume that the surface of the Tertiary is smooth and nearly horizontal at a depth of about 35 m. In the second interpretation, we assume that Site 916 is located in the landward side of an erosional channel, of late Tertiary to Quaternary age, which cuts 20 to 40 m into the Tertiary section. The stratigraphically less constrained interval is shaded in Figure 6.

The time-converted depth sections obtained on this basis are shown in the seismic profile (Fig. 2).

Seismic Stratigraphic Sequences

The seismic stratigraphic interpretation of seismic profile EG92-24 is outlined in Figure 6.

Early Tertiary Basalts

Morphologically, the top surface of the basalt sequence is composed of smooth sections, as seen in the vicinity of Sites 915 and 917 (Figs. 2 and 6), and of sections characterized by a series of scarps, as seen on either side of Site 914 and at Site 916 (Fig. 7). The general apparent dip of the basalt surface is 4° to 5° in the seaward direction, but locally dips as high as 8° to 9° are seen. The scarps are all landward-facing and are 10 to 25 m high. Two different interpretations seem applicable to the scarp features; they may represent fault scarps, or the eroded and/or depositional edges of basalt flows or flow packages. This distinction is difficult because of the difficulties of unambiguous identification of reflectors inside the basalts. Drilling at Sites 916 and 917 greatly improved our interpretation with regard to this question.

At Site 916, minor displacements can be seen in the reflectors within the small grabenlike depression in the basalt surface. Faults also were observed in the cores from the same interval at Site 916 (Cores 152-916A-13R to -14R). This indicates hanging wall deformation over a major, landward-dipping normal fault. This main fault was verified in Hole 917A, where faulted and brecciated basalts with slickensides were penetrated in Core 152-917A-71R at a depth of 538 mbsf, corresponding to 290 ms TWT below the seafloor reflector at Site 917. A landward-dipping reflector present at this level (Figs. 2 and 6) has been interpreted as the fault. Nearly parallel reflectors close to Site 916 indicated the existence of a wide fault zone. This interpretation was supported by observations in Hole 917A. Thus, the cores in Hole 917A proved the existence of additional faults in Cores 152-917A-75R, -81R, and -102R at depths of 576, 586, 628, and 820 mbsf. With an assumed average velocity in the basalts of 4.0 km/s, this corresponds to TWTs of 310, 315, 335, and 430 ms below the seafloor reflector. This is in good agreement with the TWTs observed for three reflectors, interpreted as normal faults, in the seismic profile at about 300, 350, and 400 ms, respectively. A strong reflector on the seaward footwall side of the deepest of these reflectors (Fig. 2, 1050–1200 ms, s.p. 1040–1100) was tentatively interpreted as the surface of a seaward-tilted block of sub-basaltic basement rock. This assumption was confirmed by Hole 917A, where the base of the basalts was penetrated at a depth of 820 mbsf, corresponding to 430 ms TWT below the seafloor reflector.

The apparent dip angle of the faults in the seismic profile is only about 20° to landward. However, seaward tilting (maximum of about 20°) of the basalts makes us think that the original, true dip was considerably larger, perhaps near 45°.

The surficial structures in the basalt between Sites 914 and 915 seem less controlled by faulting than was the case at Site 916. The presence, however, of faults is indicated by (1) drape-folds in the covering sediments of Subsequence 4B and (2) by small, antithetic, reverse faults in the basalts on the landward side of the suggested major fault plane (Fig. 6). In addition to faulting, reflections from edges of stacked flows may have contributed to the steplike reflection pattern.

Seaward of this fault, relatively coherent internal reflectors below the scarps (Fig. 7) seem to exclude the presence of faults and, therefore, these scarps have been interpreted as the edges of stacked basalt flows, as described by Larsen (1990). Prior to transgression during the Eocene, erosion caused smoothing of the basalt surfaces in the elevated part of the SDRS around Site 914 and landward of Site 915.

Seismic Stratigraphic Sequences 3 and 4

As described above (see also "Background and Scientific Objectives, Shelf Sites 914 through 917" chapter, this volume), sediments of presumed Tertiary age appear in the profile as a wedge and can be resolved into seismic stratigraphic Sequences 3 and 4. Along the transect of Sites 914 through 917, the upper surface of Sequences 3 and 4 is an erosional unconformity. About 1 km landward of Site 917, the sequence seems to pinch out on the seaward side of a topographic high in the basaltic basement (Figs. 2 and 6). From there, the thickness increases in a seaward direction (maximum thickness in the profile in Figs. 2 and 6A is about 450 m). The two seismic stratigraphic Sequences 3 and 4 are readily identified in the cores from Sites 914 through 917 (Subsequences 3B in Cores 152-914B-12R, -13R, and -15R through -17R; Subsequence 4A in Cores 152-915A-16R through -20R; and Subsequence 4B in Cores 152-915A-21R through -23R, Cores 152-916A-13R through -15R, and Core 152-917A-4R).

The lower boundary of Sequence 4 is the partly eroded surface of the basalts. The upper boundary is defined in the vicinity of Site 915 by toplap/truncation and farther seaward by the correlative conformity. Sequence 4 is generally characterized by an abundance of closely spaced internal reflectors having high continuity. The reflectors are mainly concordant, but lower and upper subsequences (Subsequences 4A and 4B) may be discerned.

Subsequence 4B (Cores 152-915A-21R through -23R, 152-916A-13R through -15R, and 152-917A-4R) rests directly on the basalt and is restricted to the area landward of the inferred fault zone between Sites 914 and 915. It has a thickness that varies between 25 and 50 m and is upwardly bounded by a surface onlapped by internal reflectors within Subsequence 4A. Subsequence 4B contains a variety of internal reflector configurations, including reflectors concordant with the eroded basalt surface as well as mounded structures and onlap/downlap onto the basalt surface. Within the small half-graben structure at Site 916, one can see onlap onto the two flanks of the half-graben. In the vicinity of Sites 915 and 916, Subsequence 4B has been cut by minor normal faults having vertical displacements of approximately 2 to 5 m.

The base of Subsequence 4A is defined at Site 915 as an onlap-surface for internal reflectors in Subsequence 4A. Farther seaward, Subsequence 4A rests directly on the volcanic basement. Subsequence 4A is present at Site 916 and thickens in a seaward direction to a maximum of about 75 m around Site 915. The internal reflector pattern shows some drape over the surface of the underlying basalts (Fig. 6A and 7). Subsequence 4A is probably represented only in Cores 152-915A-16R through -20R.

The base of Sequence 3 at Site 915 is defined by a low-angle unconformity with toplap/truncation of internal reflectors in Subsequence 4A. Farther seaward, the base is defined by the correlative conformity. The top surface of Sequence 3 in the landward direction is defined by an erosional unconformity at the base of Sequence 1. The boundary between Sequences 3 and 2, in the complex of seaward-prograding clinoforms, is defined by the youngest (most seaward) reflector within Sequence 3, which shows clear updip, erosional truncation at the base of Sequence 1 (Fig. 6).

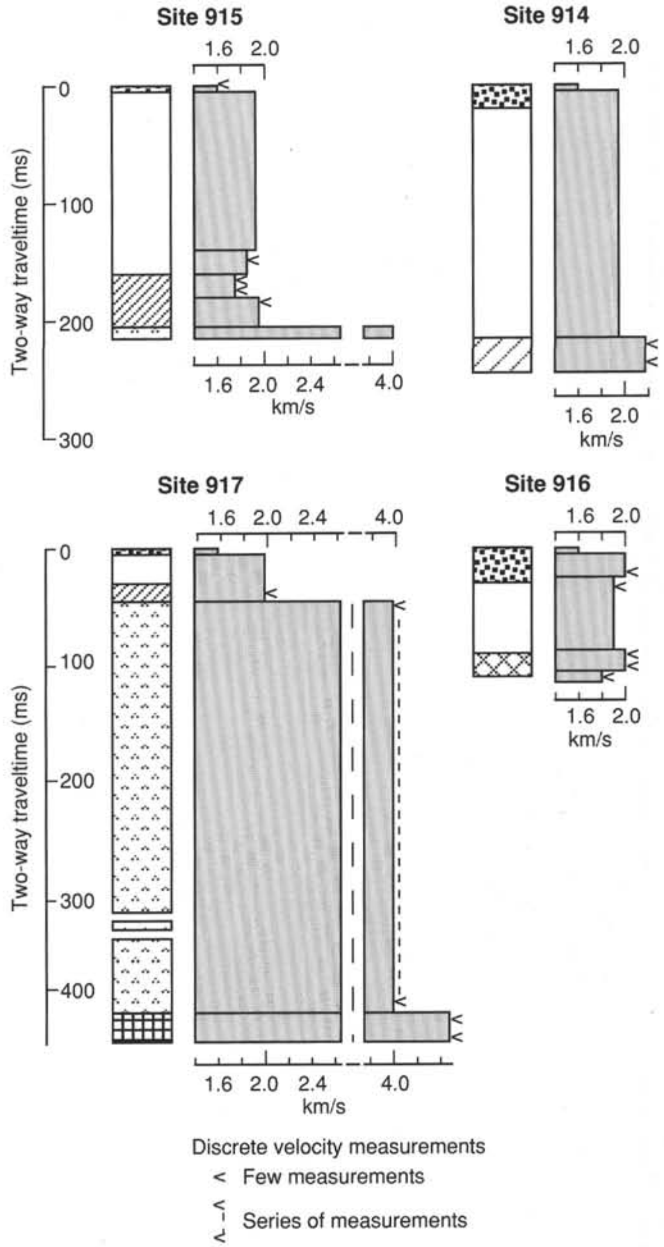

Figure 3. Stratigraphic profiles from Sites 914 through 917 with the depths converted to two-way-traveltime (TWT). For legend see Figure 5. Velocity functions are indicated by shading.

Sequence 3 is divided into Subsequences 3A and 3B. The boundary between the two subsequences is a surface defined by toplap of internal reflectors in Subsequence 3B and downlap of the internal reflectors in Subsequence 3A. Subsequence 3B is most completely preserved on the seaward side of Site 914, where its thickness is about 200 m. At the steep cuesta-flank immediately on the seaward side of Site 914, the thickness is reduced by erosion to less than 50 to 60 m. Between Sites 914 and 915, only about 25 m of Sequence 3B has been preserved, and it thins to zero thickness about 500 m landward of Site 915.

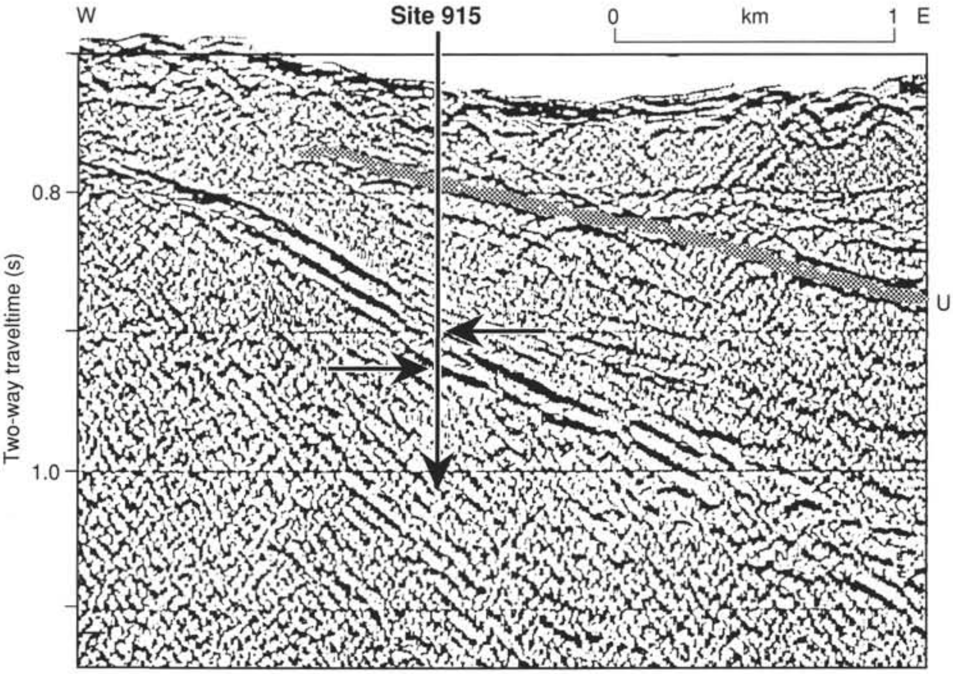

Figure 4. Part of the reflection seismic profile in the vicinity of Site 915. Arrows indicate the possible window for the top of the basalt. The level of the lower arrow is assumed to be the top basalt reflection. U indicates the erosional unconformity that defines the base of Sequence 1.

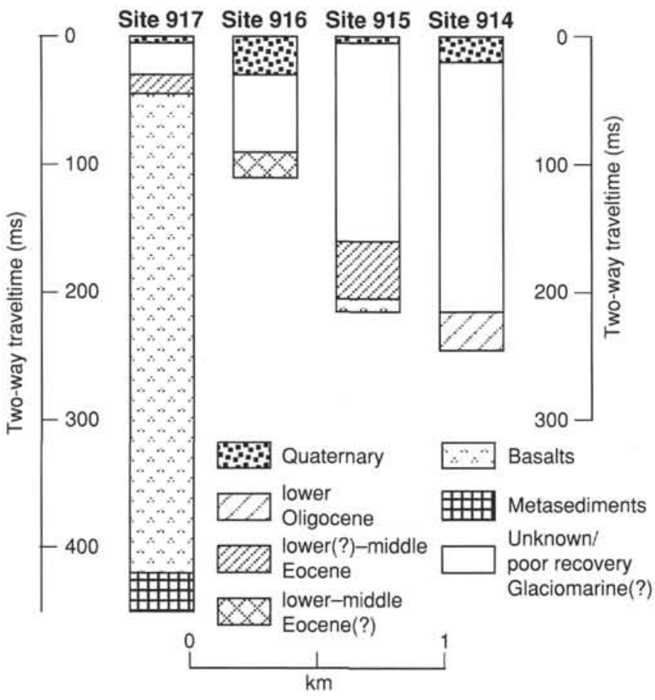

Figure 5. Simplified stratigraphic logs with depths converted to two-way traveltimes. The intervals labeled "unknown" represent the maximum gaps between deepest Quaternary and shallowest Tertiary core material. Drilling characteristics within these "unknown" intervals suggest that they are mainly glaciomarine deposits of generally unconsolidated nature.

The internal reflector pattern near the base of Sequence 3 is concordant with the top of Subsequence 4A. The upper part of Subsequence 3B is mainly transparent, with a few weak reflectors that indicate low-angle onlap in a landward direction at median levels in the subsequence, and toplap or truncation in the seaward direction at the top of the subsequence. Subsequence 3B was drilled and recovered in Cores 152-914B-12R through -17R.

The stratigraphic boundary between late Eocene and early Oligocene, which was recorded in the lower part of lithologic Unit II in Hole 914B does not manifest itself as a reflector in the seismic profile. However, the chronostratigraphic Eocene/Oligocene boundary must be concordant with the nearly parallel reflectors in the lower part of Sequence 3 and is located approximately as shown by the dotted line in Figure 6. The boundary is truncated by the basal unconformity of Subsequence 1B a few hundred meters seaward of Site 915.

Subsequence 3A forms a wedge-shaped body, which pinches out 1.5 km seaward of Site 914. The maximum thickness recorded in the profile is about 150 m. Seaward-dipping internal reflectors downlap the base of Subsequence 3A and are truncated at the top. The eroded surface of Subsequence 3A is almost horizontal, but slightly undulating. Subsequence 3A was not recovered at Sites 914 through 917.

Seaward of Site 914, Subsequence 3A (Figs. 2 and 6A) is overlain by a huge sedimentary body (Sequence 2) with seaward-prograding internal reflectors (see "Background and Scientific Objectives, Shelf Sites 914 through Site 917" chapter, this volume). Sequence 2 is not discussed here further.

Seismic Stratigraphic Sequence 1

Seismic stratigraphic Sequence 1 rests on the erosional surface of Sequences 3 and 4, except in the extreme landward side of the profile, where the basalts and sub-basaltic basement rock seem to be exposed at the base of Sequence 1. Sequence 1 is bounded on its upper surface by the seafloor. Sequence 1 is divided in two Subsequences 1A and 1B (Fig. 6). The boundary between the two subsequences is at the basal downlap surface of mounded features in Subsequence 1A.

The lower Subsequence 1B extends in the landward direction until, near Site 915, it pinches out. Subsequence 1B was recovered in

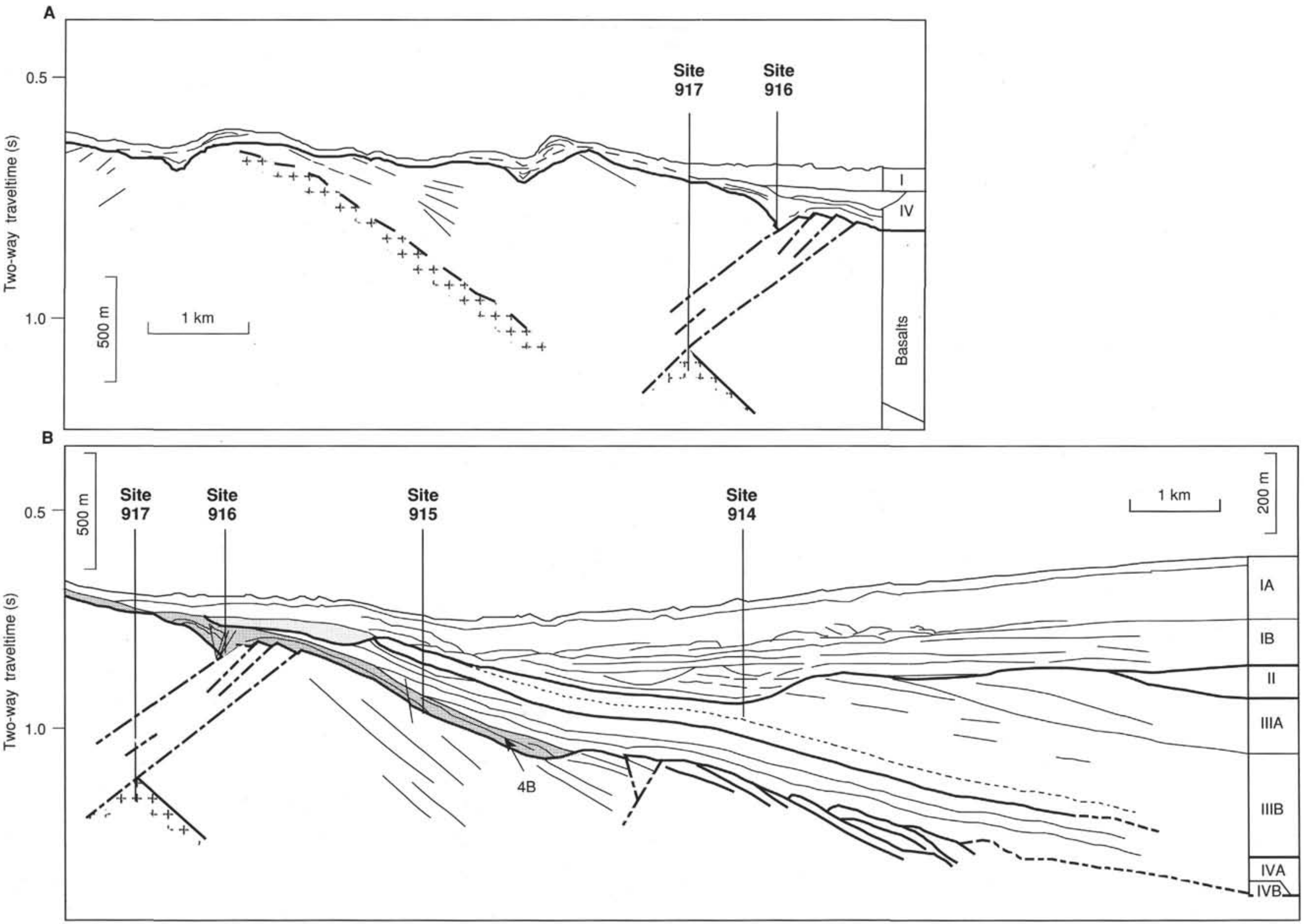

Figure 6. **A.** Seismic stratigraphic interpretation of the seismic profile EG92-24 in the transect, southeastern part. **B.** Seismic stratigraphic interpretation of the seismic profile EG92-24 in the transect, northwestern part. The boundaries delimiting the main sequences (1, 3, and 4) are marked by heavy lines. The subsequence boundaries are shown by complete lines of medium thickness, and the internal reflectors are indicated by thin lines. Lines are dashed where reflectors are weak or incoherent. Faults are indicated by dot-dashed lines. Furthermore, the assumed surface of the rocks below the Tertiary basalts is indicated by a cross-signature line.

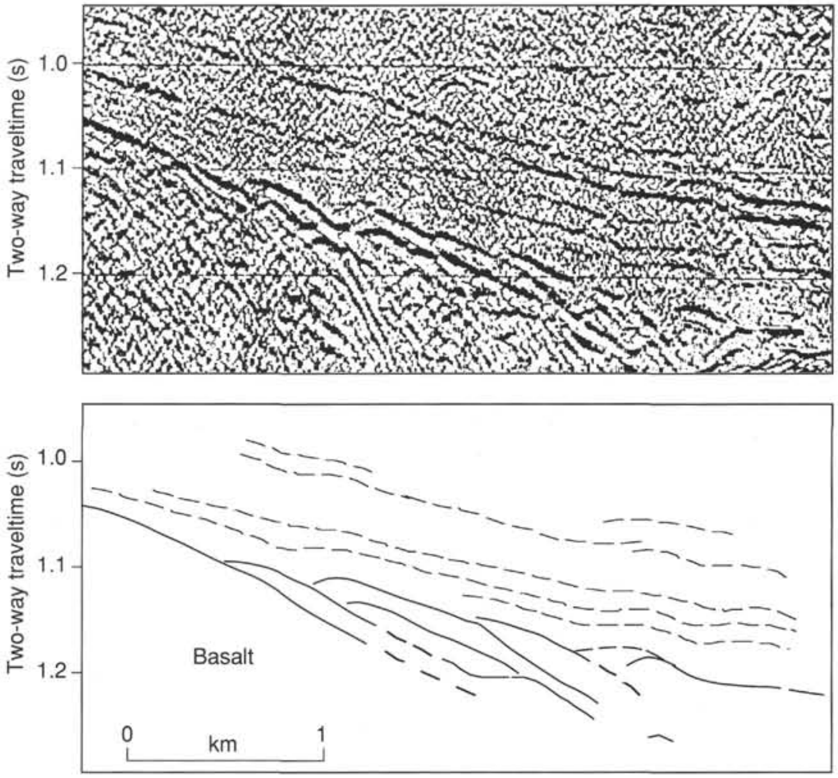

Figure 7. Reflection pattern interpreted as stacked basalt flows, with steep scarps at the flow fronts. The reflections in the sedimentary cover are conformable with the basalt surface.

Cores 152-914B-4R through -8R. The thickness is controlled by the erosional relief at the base of Sequence 1. A maximum thickness of 125.0 m is reached at Site 914, where a deep depression occurs in the eroded surface of Subsequence 3B. Subsequence 1B is characterized by an abundance of high-amplitude and relatively coherent reflectors. On the landward side of the profile, cut-and-fill structures can be seen. This pattern changes to a more regular pattern of parallel reflectors dipping gently seaward.

The upper surface of Subsequence 1B is nearly planar, with a gentle landward dip of about 2°. Thus, Subsequence 1B levels out the relief on which Sequence 1 was deposited. The only exception is at Site 915, where the surface is somewhat hummocky.

Subsequence 1A has a thickness of about 100 m on the seaward side of the profile, gradually decreasing to about 50 m at Site 915 and about 25 m at Site 917 (Fig. 6).

Internal reflections are mainly seen in the basal and topmost part of Subsequence 1A. The internal part is transparent, and diffraction noise generated at the rugged seafloor makes identification of weak reflectors difficult. In the landward, slightly elevated area between Sites 915 and 917, nearly parallel, high-amplitude reflectors onlap the seaward-dipping surface of the substratum, and downlap on Subsequence 1B in a seaward direction. On the seaward side of Site 915, the reflectors near the base of Subsequence 1B are relatively irregular, but they tend to form patterns of stacked sheets or mounds. The younger strata in the stacks appear to have locally shifted landward relative to the older strata (Figs. 6 and 8).

In the uppermost part (10–20 ms bsf) of Subsequence 1A, a few closely spaced, high-amplitude reflectors of high continuity are forming a "boudin"-like pattern, possibly formed as an interference between diffractions and/or reflections from the seafloor and reflections from boundaries close below the seafloor. (Fig. 8).

On the landward side of Site 917, a thin veneer of Subsequence 1A covers the basalts and the sub-basaltic basement rocks (Fig. 6B). The thickness is generally on the order of 10 m, but on the landward side of the hills and in eroded depressions, the thickness may increase to 20 to 25 m.

LITHOSTRATIGRAPHY

Based on sedimentological investigations, the sediment recovered at Sites 914 through 917 overlying the basaltic basement can be divided into glaciogenic deposits of Quaternary age (lithologic Unit I) and early Oligocene- to Eocene-aged mixed volcaniclastic and siliciclastic deposits (lithologic Units II and III; Fig. 9 and Table 1). Additional sediment was recovered at Site 917, either intercalated in the basaltic basement sequence (lithologic Unit IV) or below an unconformity at the base of the basaltic lava pile at Site 917 (lithologic Units V and VI). These latter units are presumed to be of early Tertiary or Late Cretaceous age. Lithologic Unit V is a thick, quartz-rich sandstone. Lithologic Unit VI is made up of low-grade, metamorphic (greenschist facies) volcaniclastic sandstone, siltstone, and claystone (see "Lithostratigraphy" section, "Site 917" chapter, this volume). Little direct age control was obtained from the cores in the Quaternary successions, where mainly gravel was recovered. In this case, age estimates depend in part on correlations with other cores and regional seismic stratigraphy.

In this section, we summarize the distinguishing features of Units I through IV and correlate them between the different sites. We begin by discussing the correlation of lithology with seismic stratigraphy, continue with a discussion of the lithologic units, and end with a summary of the shipboard interpretations.

Correlation of Lithology with Seismic Stratigraphy

Correlation of lithologic units with seismic stratigraphic sequences at the four shelf sites is good, considering the poor recovery within some of the cored intervals. Reflection studies identified and mapped four seismic stratigraphic sequences that either delineate boundaries between lithologies (e.g., basalt and sediments) or represent distinct changes between depositional packages. In some places, closely spaced and highly reflective beds (e.g., within lithologic Unit II of Hole 915A) could be directly related to high seismic velocity, cemented sandstone beds in the drill cores.

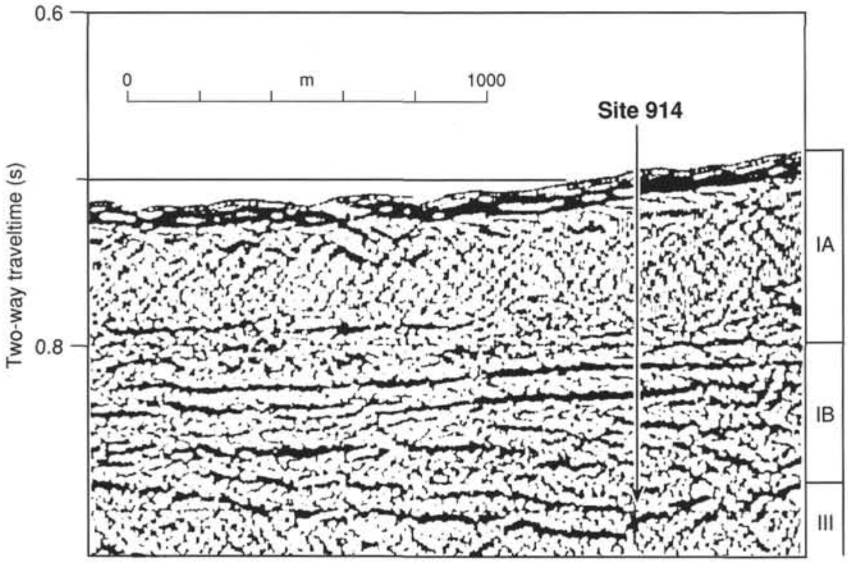

Figure 8. Lens-shaped reflection patterns within the topmost 10 to 20 ms of Subsequence 1A (unknown origin).

We were able to correlate four seismic stratigraphic sequences and seven subsequences with three lithologic units (including six subunits). These correlations are shown in Figure 10. Some problems existed with the correlation of seismic stratigraphic sequences with lithologic units at Site 915. At Site 915, two unit/subunit boundaries have different depths than those predicted by seismic data. One problem exists between the Quaternary and the Tertiary, and another between subunits of lithologic Unit II. These problems are discussed below.

The base of the Quaternary was judged to be at about 75 mbsf, based on the seismic profile. However, core data alone place it at 84.8 m, a discrepancy of 10 m. Only a few drilling-brecciated boulders and cobbles were observed in Cores 152-915A-2R and -3R (4.3–21.4 mbsf). One small cobble was found in the core catcher of Core 152-915A-4R (30.5 mbsf). No recovery was obtained from Cores 152-915A-5R through -13R (30.5–112.0 mbsf), except for a handful of pea-sized gravel washed from the liner of Core 152-915A-11R (84.8–93.7 mbsf). Core 152-915A-14R had a small amount of uppermost Eocene siltstone. Without other information, the top of the Tertiary would have been placed at the top of Core 152-915A-14R, or at a depth of 112.0 mbsf. However, the small amount of pea-sized gravel washed from the plastic liner of Core 152-915A-11R comprised pieces of igneous and metamorphic boulders from the diamicton with a small piece (few grams) of sediment containing uppermost Eocene nannofossils. Therefore, the boundary between the Tertiary and Quaternary was conservatively placed at the top of Core 152-915A-11R, at a depth of 84.8 mbsf.

A second depth discrepancy was identified near the base of Hole 915A, where multiple reflections from high velocity (greater than 4.0 km/s) sandstone beds in Subunit IIC blurred the seismic image of lithologic Unit III, Subunit IIC, and the basalt/sediment boundary. The multiple reflector acoustic package was assigned to a separate seismic stratigraphic subsequence (4B) and correlated with the combined lithologic Unit III and Subunit IIC.

Lithologic Units

Lithologic Unit I: glacial sediments
Depth: 158.5 m thick at Site 914, 84.8 m at Site 915, 78.6 m at Site 916, 28.7 m at Site 917
Age: Quaternary

Quaternary glacial sediment was a major constituent of all cores on the East Greenland continental shelf and forms lithologic Unit I. This was divided into three subunits: an upper sequence of glaciomarine gravel and silt (Subunit IA), overlying a thick compact diamicton (Subunit IB), which in turn overlies washed gravel (Subunit IC). Foraminifers and nannofossils in Subunit IC indicate an age no older than 1.7 Ma. Small fragments of mollusk shells (*H. arctica*?) also occur in Subunit IA. The Subunits IA and IB were normally magnetized and so, were probably deposited during the Brunhes Chron. Poor core recovery precluded our obtaining paleomagnetic data from Subunit IC.

Subunit IA is marine sediment with a significant dropstone and washed gravel component. It was recovered from the uppermost one or two cores at each site. Subunit IA ranged from 2.2 m thick at Site 915 to 15.1 m thick at Site 916. The washed gravel probably represents originally ice-rafted dropstones with the matrix washed out by drilling. The recovered gravel range from 4 to 8 cm in diameter and include igneous, metamorphic, and sedimentary rock fragments. These were probably deposited during the late Pleistocene and Holocene.

Subunit IB includes massive, heterolithic diamicton recovered from Site 914 between 5.0 and 14.0 mbsf, and from Site 916 at depths of 15.0 to 33.0 mbsf. Some of the recovered gravel was intercalated with the diamicton; it probably represents zones where the diamicton matrix was lost. A small amount of this diamicton was recovered at Site 915. It has also has been inferred to be present below Subunit IA at Site 917 on the basis of the recovery of washed gravel and correlations with seismic stratigraphic profiles. Where recovered, the diamicton exhibits a preferred fabric in both hand specimen and thin section. It is also extremely compact, dewatered, and indurate. Gravel-sized clasts are scattered randomly through the diamicton. Most cobbles are angular, but a few are rounded. The diamicton matrix consists of sandy silt and clay, and numerous grains of quartz, feldspar, and amphibole are present. XRD analyses indicate that the diamicton matrix also includes phillipsite and aragonite. No microfossils were present in the diamicton, although rare fragments of mollusk shells were found.

Five independent lines of evidence indicate that the diamicton recovered at Sites 914, 915, and 916 is a basal till:

1. Although found only a few meters in depth below the surface of the seafloor, the diamicton is indurate, compact, and dewatered. It is easily distinguished on this basis alone from the overlying glaciomarine deposit. The overconsolidation is thought to have been produced as a result of loading by a thick, grounded ice sheet.
2. The clasts in the diamicton show a strong preferred orientation. This type of fabric, is typical of basal tills and is generated by subglacial shear and transport of debris.
3. The matrix of the diamicton also shows a well developed microfabric (Fig. 11). A microfabric is characteristic of basal tills, and can be particularly useful for recognizing basal till in the limited

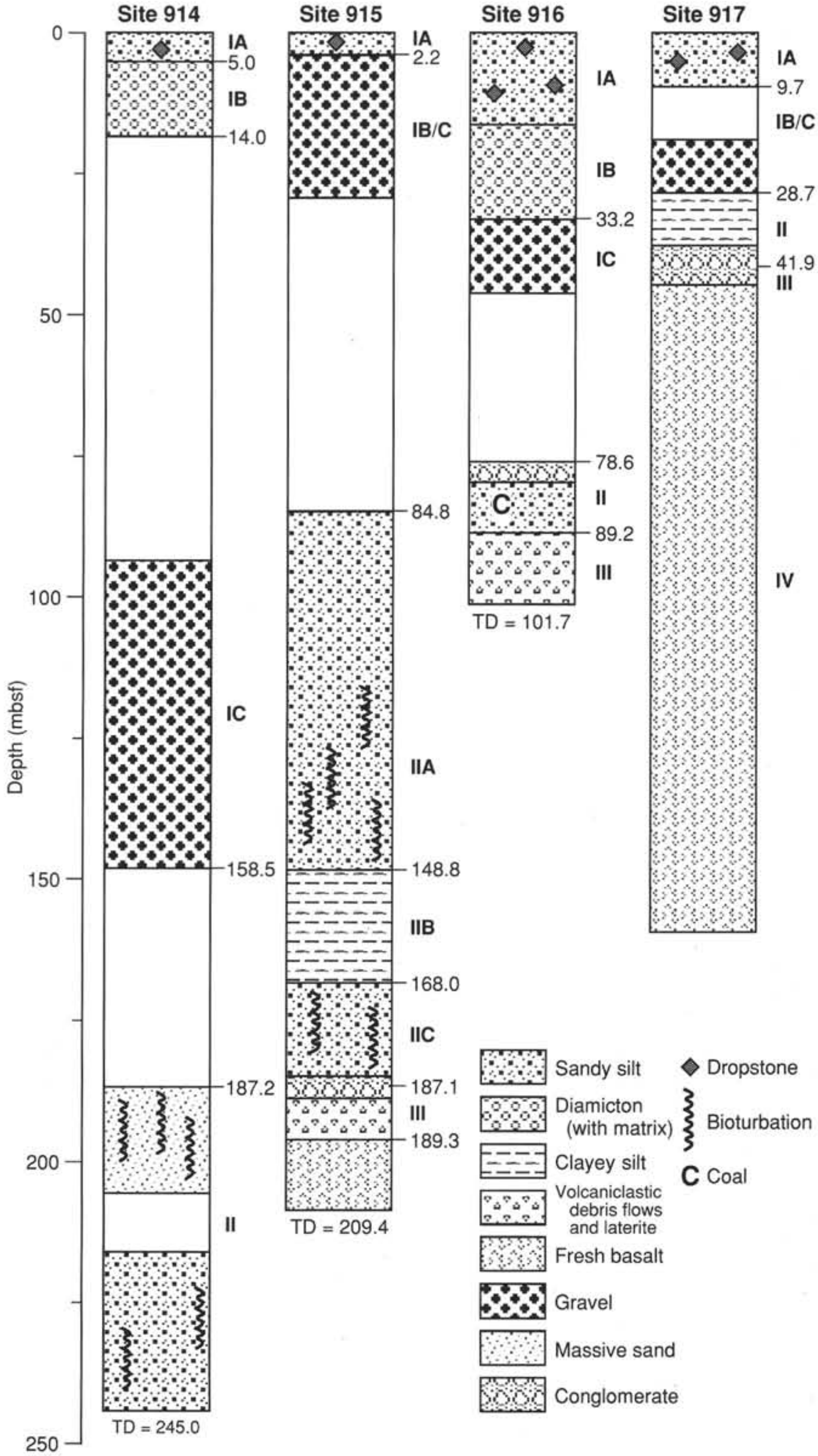

Figure 9. Lithostratigraphic summary of East Greenland Margin shelf sites, Leg 152.

exposure afforded by drillcore samples (Porter and Begét, 1979). In contrast, glaciomarine drift deposited by sediment fallout exhibits little or no fabric (Fig. 12).

4. The rock fragments in the diamicton differ from those found in the overlying glaciomarine deposits, as they are richer in clasts of metamorphic and Precambrian crystalline rock and relatively poorer in basalt (Fig. 13). The basal till in Subunit IB contains primarily Precambrian crystalline rocks, apparently derived from nearby areas of Greenland. The small percentage of basalt clasts found in the diamicton may have been derived from erosion of nearby submarine basaltic outcrops. These, however, are thought to be of very limited areal extent on the basis of seismic profiling. In contrast, the high frequency of basalt clasts in the glaciomarine deposits of Subunit IA and IC most likely were derived from icebergs transported south by

Table 1. Summary of lithologic units, East Greenland Margin (shelf Sites 914 through 917).

Lithologic unit	Lithology	Depth (mbsf)			
		Site 914	Site 915	Site 916	Site 917
I	Glaciomarine mud with dropstones, diamicton, and gravel	0–158.5	0–84.8	0–78.6	0–28.7
IA	Glaciomarine mud with dropstones	0–5.0	0–2.2	0–15.1	0–9.7
IB	Compacted diamicton	5–14.0	NR	15.1–33.2	NR
IC	Gravel	14.0–158.5	2.2–84.8	33.2–78.6	9.7–28.7
Gap	No recovery.	158.5–187.2	30.5–84.8	60.4–78.6	
II	Green sandy silt with silty sand interbeds (Sites 914, 915); black volcanic silt (Sites 916, 917)	187.2–245.0 (t.d.)	84.8–187.1	78.6–89.2	28.7–41.9
IIA	Green sandy silt	NR	84.8–148.8	NR	NR
IIB	Laminated brown mud	NR	148.8–168.0	NR	NR
IIC	Green sandy silt	NR	168.0–187.1	NR	NR
III	Basalt cobble, conglomerate, volcaniclastic debrites, and paleosols	NR	187.1–189.3	89.2–101.7 (TD)	41.9–46.1
IV	Volcaniclastic debrites, paleosols, fluvial sediment, and possible pyroclastic and/or hyaloclastic sediment	NR	NR	NR	Intercalated within basalt

Note: NR = no recovery, and TD = total depth.

the East Greenland Current (Thiede et al., 1990), possibly from the extensive outcrops of Tertiary volcanic rocks in the Kangerdlugssuaq region, 500 km to the north (68°N).

5. The diamicton matrix contains phillipsite and siderite, which are, respectively, a zeolite and a marine authigenic mineral found at greater depth in Tertiary sediment on the Greenland Shelf, but absent from the late Quaternary sediment of Subunit IA. The presence of these reworked minerals in the diamicton matrix is best explained by subglacial erosion of the seafloor during emplacement of the basal till.

The lowermost Quaternary subunit (IC) is 149.5 m at Site 914, thinning shoreward to 45.4 m at Site 916 and 19 m at Site 917. Subunit IC is characterized by the recovery of washed gravel that generally ranges from 4 to 8 cm in diameter and is composed principally of igneous and metamorphic rocks. Occasionally, small clasts of compacted silt also were recovered. It is likely that the gravel of Subunit IC was recovered primarily from glaciogenic deposits from which the associated matrix was lost during drilling. This gravel, like that in Subunit IA, probably originated as ice-rafted dropstones, although it is possible that some of it may have washed in from the subunits above.

These three Quaternary lithologic subunits can be correlated with two seismic stratigraphic subsequences identified in seismic profiles across the coring sites on the East Greenland Shelf (Fig. 14). Lithologic Subunit IA, the recent glaciomarine drift, evidently correlates with the top of seismic Subsequence 1A, found at the top of seismic profiles. The remainder of seismic Subsequence 1A, characterized by an absence of internal reflections except near the base and top, clearly correlates with lithologic Subunit IB, the diamicton. The thickness of seismic Subsequence 1B has been estimated at about 100 m near Site 914, thinning to about 50 m a few kilometers to the west near Site 915. Recovery of the diamicton was poor, and a maximum of 18.1 m was recovered between 15.1 and 33.2 mbsf at Site 916; however, the total thickness of lithologic Subunits IA and IB is in fair agreement with the approximately 100-m-thick seismic Subsequence 1A.

Seismic Subsequence 1B, characterized by a regular pattern of layered reflectors, evidently corresponds to lithologic Subunit IC. The 125-m thickness estimated for seismic Subsequence 1B at Site 914 is in fair agreement with the 149.5-m thickness assigned to lithologic Subunit IC. Both seismic Subsequence 1B and lithologic Subunit IC thin landward. The layered reflectors observed in seismic Subsequence 1B may be deposits of intercalated glaciomarine and interglacial marine sediment.

Lithologic Unit II: marginal marine to shelf sequence
Depth: 57.8 m thick at Site 914, 102.3 m at Site 915, 18.1 m at Site 916, and 13.2 m at Site 917
Age: lower Oligocene to middle Eocene

Lithologic Unit II comprises silty sand and sandy silt with variable amounts of clay, calcareous mudstone, calcareous sandstone, and calcareous conglomerate, which can be grouped into four facies: (1) a fossiliferous, mid- to outer-shelf silty unit with thin sandstone interbeds (lithologic Unit II, Sites 914 and 917; lithologic Subunit IIC, Site 915); (2) a barren, laminated, reddish brown silt sandwiched within shelf silt (lithologic Subunit IIB, Site 915); (3) a barren, marginal marine-to-freshwater facies having sequences that coarsen upward (lithologic Unit II, Site 916); and (4) a calcite-cemented basalt cobble conglomerate. The conglomerate occurs at the base of the shallow-marine silt that was dated as CP14a (middle Eocene) at both Sites 915 and 917 (Fig. 9). Site 916 lies between these two sites in a half graben (see "Seismic Stratigraphy" section, this chapter; Fig. 2); here, the conglomerate lies at the top of the undated marginal marine-to-freshwater facies. The striking similarity of the conglomerate at all three sites, and its similar age at the two sites that envelop the third, suggest that the conglomerate was deposited as one unit and represents a basal transgressive unit. The high degree of rounding of the cobbles suggests a significant amount of aqueous transport. If the conglomerate was deposited as a single unit, the marginal marine/freshwater facies at Site 916 is older than the fully marine shelf facies at Sites 914, 915, and 916.

Thus, the oldest sediment in lithologic Unit II is the barren, marginal marine/freshwater facies at Site 916. This sediment is composed of black, pyritic silt with abundant wood fragments and delicate leaf fossils, suggesting quiet, euxinic to anoxic waters. The sediment coarsens upward in three separate sequences with increasing amounts of siderite as the principal sand-sized component. The coarser material exhibits abundant ripples, small fining-upward sequences, convolute laminae, and load-casted ripples, all suggestive of rapid deposition from repeated flooding events. The combination of graded bedding, climbing-ripple lamination, soft-sediment deformation, abundant organic debris, coarsening-upward beds, and diagenetic Fe-rich carbonate suggests progradation of crevasse splays into an interdistributary bay in a fluvially dominated deltaic system (e.g., Galloway and Hobday, 1983). Siderite is probably a diagenetic product of what was once sand-sized iron oxides and hydroxides. The variety of sedimen-

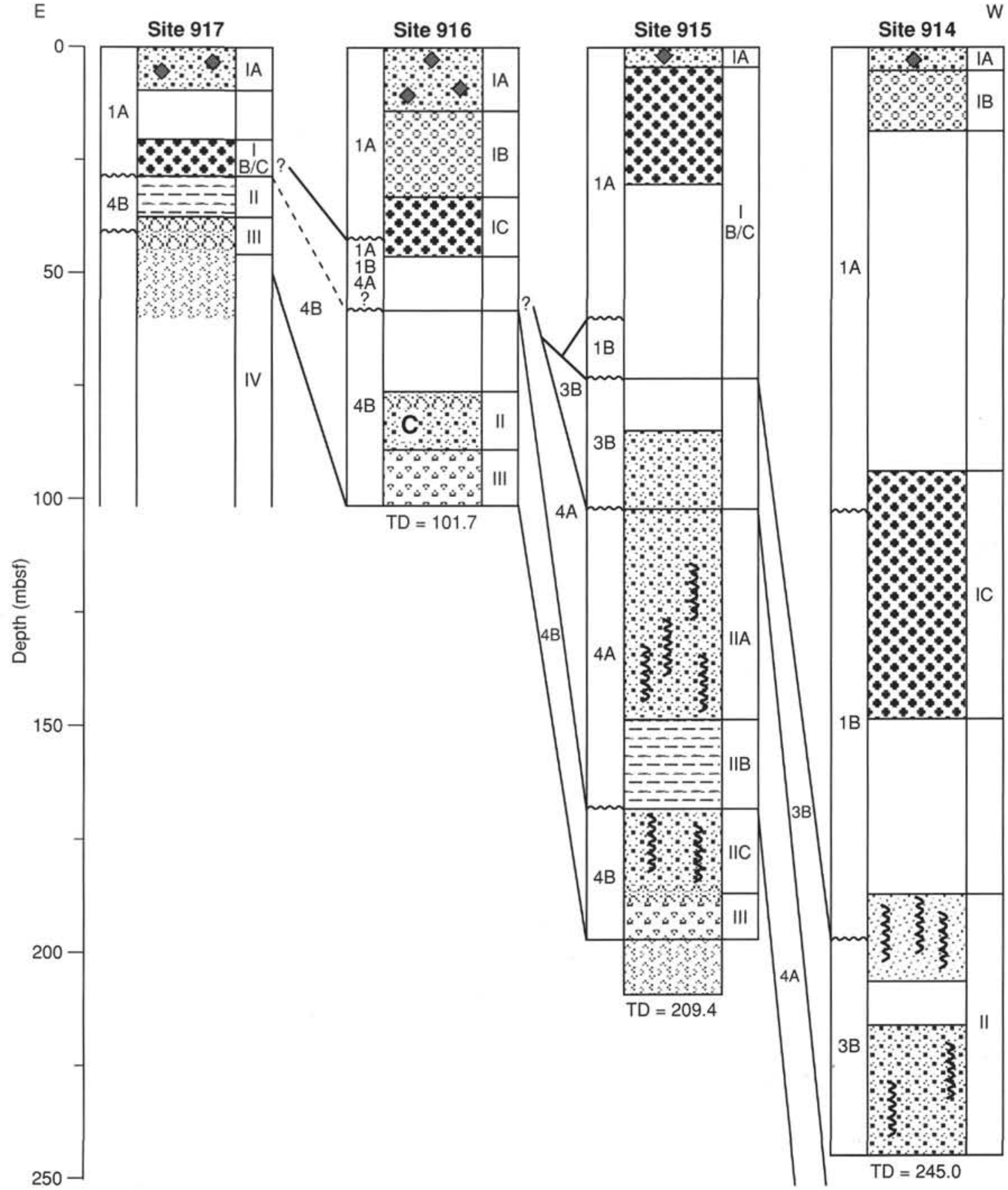

Figure 10. Correlation of seismic stratigraphic sequences (left of each lithic graphic) with lithologic units (right of each lithic graphic) for the four shelf sites, Leg 152. Correlation lines are based on the seismic boundaries. For an explanation of the symbols in the graphic column, see Figure 9.

tary structures in the sand reflects rapid but scattered deposition (Galloway and Hobday, 1983). A marine connection may not have existed in this half-graben while it was being filled (see "Seismic Stratigraphy" section, this chapter; Fig. 2). Shore-based palynomorph studies are planned to elucidate the extent of marine influence and the age of the sediment.

Following this filling of this small basin, the basalt cobble conglomerate was deposited, possibly as a basal marine transgressive event. This was followed by a rise in relative sea level or shelf subsidence during the middle Eocene, and mid- to outer-shelf conditions began at Sites 917 and 915 (lithologic Unit II and Subunit IIA, respectively) and probably at Site 914 also, although there we did not drill deep enough to recover this sediment. The sediment deposited in this environment is largely volcaniclastic in nature and contains basalt lithic fragments, pyroxene, phillipsite, opaque minerals, and volcanic glass. These predominate over continental components, such as quartz and amphibole. The volcaniclastic components decrease upward in the section, and continental components, including zircon, garnet, and amphibole, increase, indicating the erosion of the flood basalts and unroofing of continental basement onshore Greenland through the middle Eocene to early Oligocene.

The shallow-marine silt is a greenish black, massive, nannofossil-rich (up to 25%) sandy silt with interbeds of intensely bioturbated sand. The silt is also heavily bioturbated and, consequently, massive

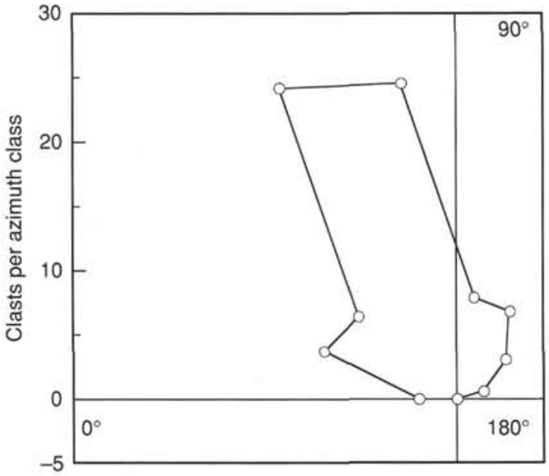

Figure 11. The microfabric of the diamicton shows a strong preferred orientation characteristic of basal till. This orientation plot, drawn from microscope slide data, shows the high number of clasts having a preferred parallel orientation toward the north-northeast relative to an arbitrary grid. These data have been reflected into a 180° field (Sample 152-914A-2H-3, 30–32 cm).

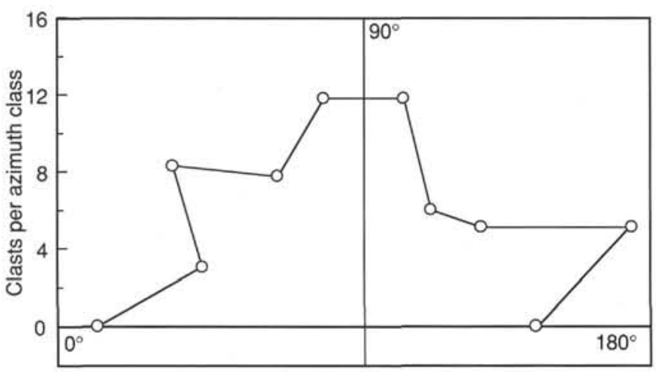

Figure 12. Microfabric of glacial marine drift, showing little or no sign of preferred orientation of clasts (Section 152-915A-1R-1, 141–146 cm).

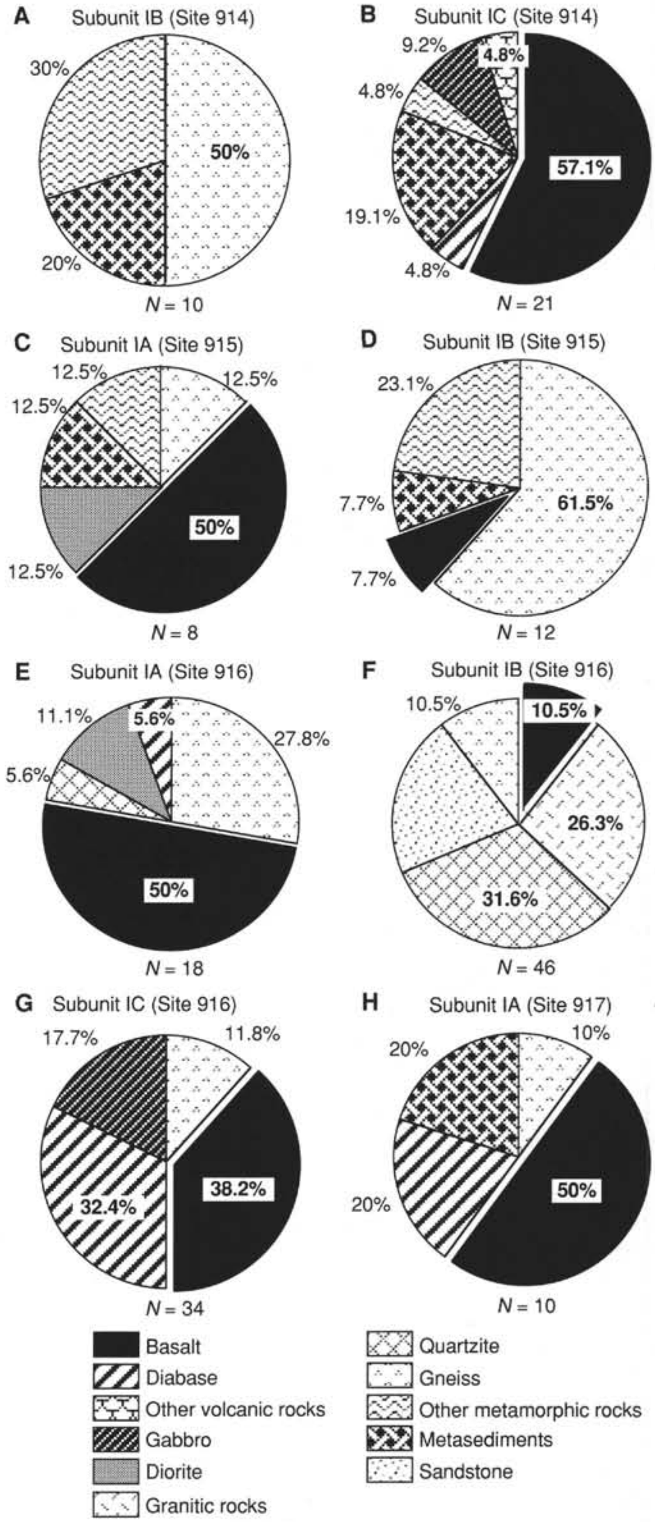

Figure 13. Composition of coarse clasts in the Quaternary subunits. **A.** Rock fragments at Site 914, Subunit IB. **B.** Rock fragments at Site 914, Subunit IC. **C.** Rock fragments at Site 915, Subunit IA. **D.** Rock fragments at Site 915, Subunit IB. **E.** Rock fragments at Site 916, Subunit IA. **F.** Rock fragments at Site 916, Subunit IB. **G.** Rock fragments at Site 916, Subunit IC. **H.** Rock fragments at Site 917, Subunit IA.

in appearance. Glauconite pellets are a minor but persistent component. The sandy interbeds are enriched in quartz and glauconite pellets. Many of the sand beds are cemented with calcite, which in smear slides and thin sections appears to be derived from the dissolution of calcareous plankton. No sedimentary structures are evident in the sand beds, but the acoustic anisotropy of these intervals is high, indicating rapid deposition from very strong currents, such as might be encountered in strong storms (see "Physical Properties" section, "Site 914" chapter, this volume). This rapid deposition is followed by a hiatus during which the sandy floor was intensely bioturbated and later cemented. These sandy interbeds suggest periodic episodes of increased current activity, probably related to heavy storms. These punctuated an otherwise low-energy regime, with most of the sediment accumulating below wave base.

Laminated, reddish brown silt interrupted middle Eocene shallow-marine silt deposition at Hole 915A (lithologic Subunit IIB). The dominant components are reddish, semi-opaque particles, probably iron oxides and hydroxides, and strongly weathered volcanic rock fragments, indicating a highly weathered, perhaps even lateritic, basaltic provenance. The presence of kaolinite in bulk XRD supports the idea of a highly weathered source area as the source for this sediment. Illite and quartz also were identified, suggesting a continental source area in addition to the basaltic one. Only rare benthic foraminifers were identified in this interval, and the presence of the genus *Uvigerina*

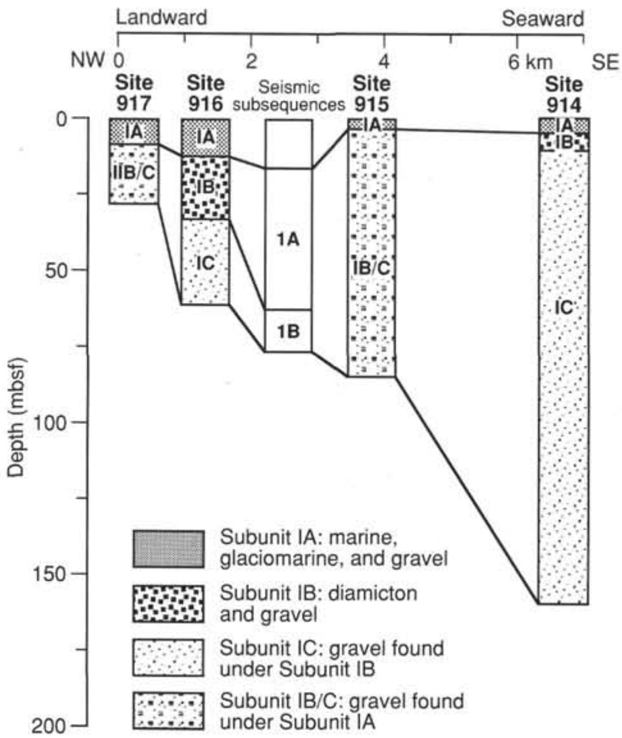

Figure 14. Thickness of Quaternary lithologic subunits at Sites 914, 915, 916, and 917. Also shown is a generalized section of seismic subsequences identified in profiles through the coring sites.

suggests an oxygen-poor environment (Streefer and Shackleton, 1979). A few ripples occur at the base of this subunit; otherwise, the only sedimentary structures are centimeter-thick laminae. The 20-m-thick Subunit IIB is overlain by more greenish black, shallow-marine silt (Subunit IIA), identical to the silt of Subunit IIC below it, but having better preservation of nannofossils and a lower volcaniclastic component.

The vertical sequence of green, shallow-marine silt with sand interbeds, red laminated silt, followed by the reappearance of green, shallow-marine silt with sand interbeds, suggests that these subunits may have been lateral facies. One possible depositional environment might be a prodelta setting where muds, derived in part from a highly weathered basaltic source area, prograded across the shelf, perhaps during a lowered sea-level stand. Possibly a change in drainage patterns occurred as a basaltic edifice was eroded away. This might explain why different components were observed in this subunit, and why pyroxene is nearly absent in the overlying shallow-marine silt, when it was a persistent component in the shallow-marine silts underneath. Progradation is indicated by an increase in silt content relative to clay and a thickening of laminae from Cores 152-915A-20R to -19R (e.g., Wright, 1985). A calcite-cemented, highly burrowed hardground was observed at the top of Core 152-915A-18R, indicating a hiatus in deposition.

"Normal" shelf deposition returned to Site 915 and persisted from early late Eocene to at least early Oligocene (Site 914). The sediment records the removal of a basaltic cover followed by erosion of continental rocks (Fig. 15). Benthic foraminifers indicate that during this development a mid-shelf to uppermost bathyal environment was present at Site 914 (see "Biostratigraphy" section, "Site 914" chapter, this volume).

Lithologic Unit III: volcaniclastic sediment immediately overlying the basaltic basement

Depth: 2.2 m thick at Site 915, 5.0 m at Site 916, and 4.2 m at Site 917

Age: unknown (probably upper middle Eocene to uppermost Paleocene)

Lithologic Unit III was recovered from Sites 915, 916, and 917. Its thickness decreases eastward, although irregularities along the basalt surface have a local effect. This unit consists of polymict conglomerate, polymict volcanic breccia, volcanic silt, sand, and red clay. The conglomerate occurs interbedded with sandstone, and its composition is predominantly basaltic with subordinate dolerite, gabbro, sandstone, and claystone set in a calcareous sandy matrix. The polymict volcanic breccia also is composed of mainly basaltic clasts and has a matrix of reddish sand, silt, and clay. Furthermore, some evidence exists for a paleosol in Unit III of Site 915. Fossils were not identified in this unit.

Most of the dominant sedimentary facies occurring in Unit III are also present in Unit IV. Therefore, a more detailed description and discussion of these deposits ("Sediments Occurring in Units III and IV," this chapter) has been placed following the description of lithologic Unit IV.

Lithologic Unit IV: volcaniclastic sediment intercalated with basaltic basement

Age: unknown (presumably of Chron C24r age; i.e., latest Paleocene to earliest Eocene)

Lithologic Unit IV, was recovered from only Site 917. It is composed of several thin volcaniclastic intervals that are intercalated with the thick succession of basaltic lava. These sediments consist of reddish-brown volcanic conglomerate, breccia, lapillistone, sandstone, siltstone, and claystone (tuff). The absence of marine fossils, the occurrence of plant fragments and the existence of in situ red soils, strongly suggest that the thick basaltic lava piles were built up in a nonmarine and at least temporarily subaerial environment.

Apart from the deposits described below ("Sediments Occurring in Units III and IV," this chapter), volcaniclastic sediment occurs interbedded in the upper part of the flood basalt sequence as thin beds (<50 cm) of ash or lapilli-sized material. We could distinguish three types of these deposits: (1) finely laminated tuff having a high content of crystals, (2) lapillistone or lapilli-tuff consisting of small basaltic fragments and crystals in an ash-sized matrix, and (3) massive or finely bedded, reddish, ash-sized deposits. Distinct lamination in type 1 sediment suggests redeposition by water. Poor sorting in type 2 sediment indicates rapid deposition, although whether this was from water or primary airfall is unclear. On the other hand, the high crystal content of type 1 is characteristic of magmatic eruptions. The specific eruption and emplacement mechanisms of all three sediment types are uncertain without further shore-based studies.

Sediments Occurring in Units III and IV

Three types of sediment are present in cores recovered just overlying and intercalated with the flood basalts from Units III and IV at Sites 915, 916, and 917 (Fig. 16). The three types are (1) polymict debris flow deposits, (2) fluvial sediment, and (3) paleosols, which are differentiated on the basis of sedimentary structures and degree of alteration as estimated from the color and, in some cases, the mineral composition.

We identified polymict debris flow deposits as matrix-supported, angular to rounded polymict clasts having a matrix color ranging from dark green through various shades of brown to bright red. The clasts vary in color, vesicularity, degree of alteration to clays and zeolites, size, and primary mineral composition. Some of these flows exhibit crude bedding and normal grading, which we interpret as being the product of more liquid debris flows.

We identified fluvial sediment as clearly laminated, often with wood fragments, and in one case, a variation in grain size from massive conglomerate up through cross-bedded sand to a laminated claystone. We identified paleosols when relict parent material (basalt or debris flows) structure was evident, but overprinted by mottling and a high degree of alteration to clay minerals.

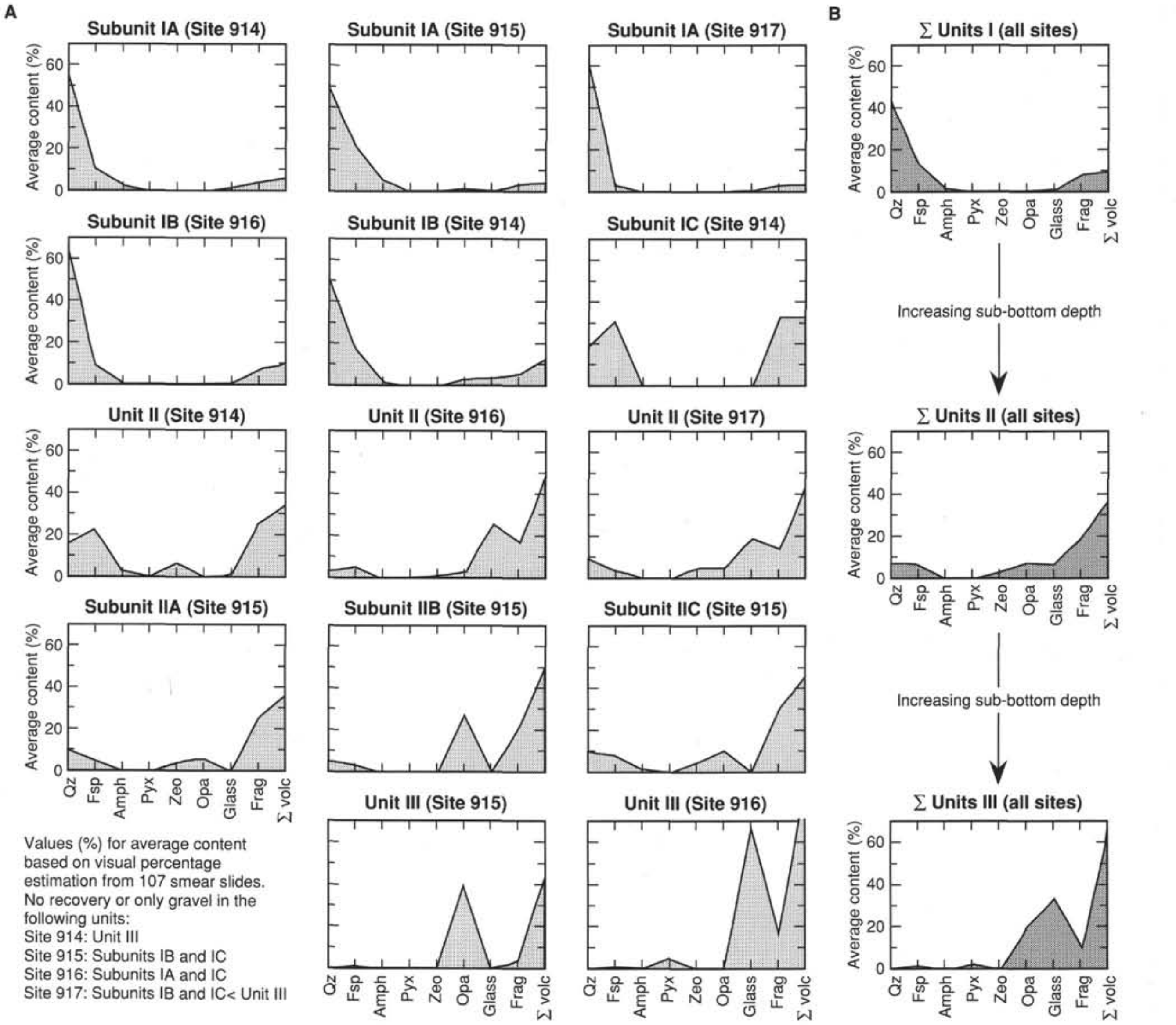

Figure 15. Average mineralogical composition of lithologic Units I through III recovered above the basaltic basement at Sites 914 through 917 ("shelf sites"). **A.** Average mineralogical composition of every recovered lithologic unit. **B.** Characteristic mineralogical configurations for the three different lithologic units. Graphs comprise average values (%) of the respective units from all shelf sites.

Polymict Debris Flow Deposits

Polymict debris flow deposits (i.e., the lithified products of matrix-supported fluid flow) occur immediately overlying basalt at Sites 915 and 916 (Fig. 16). These in turn are overlain by the coarse, volcanic cobble conglomerate that underlies marine or marginal marine sediment at Sites 915, 916, and 917. These polymict debris flow deposits show several features typical of lahars, such as poor sorting, abundant clay-sized material, inverse grading, a high amount of volcanic components, and predominantly angular to subangular clasts. Furthermore, most common lahars form during the waning stage of an eruption (Fisher and Schmincke, 1984) and the polymict debris flow deposits recovered at Sites 915 through 917 occur always on top of a sequence of lava flows and are overlain by a sedimentary succession. From these observations, the polymict debris flow deposits are probably lahar deposits, which developed when the effusive activity temporarily or finally decreased.

Fluvial Sediments

Fluvial sediments were recovered immediately overlying basalt and intercalated in the basalts at Site 917. The fluvial deposit immediately overlying the basalt constitutes 13 cm of laminated, red mud. Lower in the sequence, in Core 152-917A-22R, one complete fining-upward sequence was recovered. This sequence is made up of a basal, soft-pebble conglomerate channel lag, overlain by coarse, cross-bedded sand that was deposited as part of a point or braid bar and overlain in turn by laminated overbank muds with wood clasts. Fining-upward sequences containing discrete beds, such as this example, are typical of meandering, fluvial environments of deposition (e.g., Walker and Cant, 1984; Collinson, 1986). Laminated mud underlies the sequence, but the contact was destroyed by drilling. It is possible that two fining-upward sequences are stacked one on top of the other in this part of the core. Deposition from a meandering stream is suggested by the presence of overbank mud and soft pebble (rip-up) clasts, which are

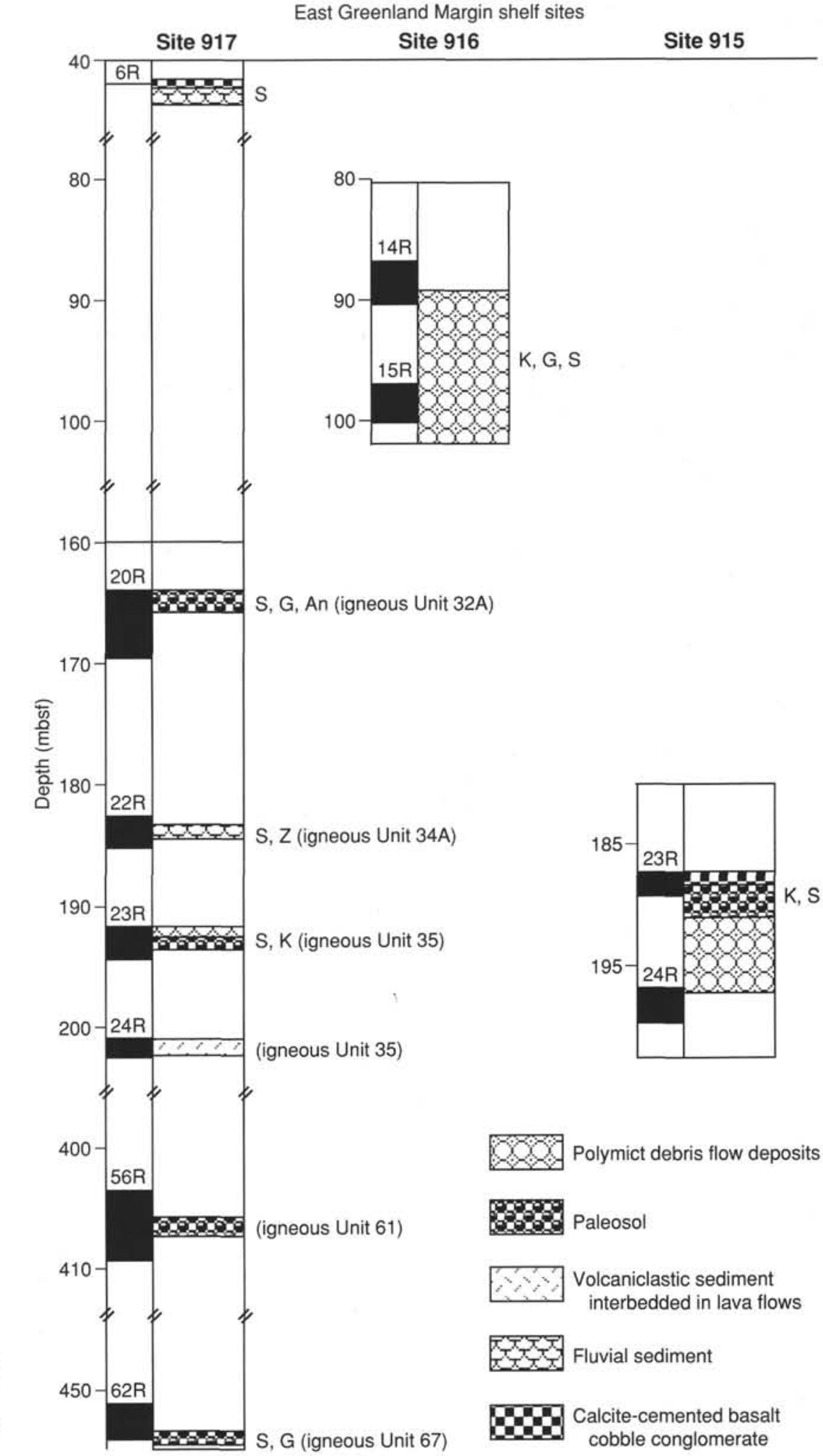

Figure 16. Intervals of polymict debris flow deposits, fluvial sediment, paleosols, and volcaniclastic sediments of uncertain origin intercalated in the basalt flows (lithologic Units III and IV). Minerals identified by XRD are indicated at the appropriate intervals as follows: An = analcime; G = goethite; K = kaolinite; S = smectite; Z = unidentified zeolite.

eroded from the banks of this type of channel. The lamination of the mud is well-preserved despite the occurrence of basalt immediately above it. The base of this flow is slightly brecciated.

The only clay mineral identified by shipboard XRD from the overbank mud was smectite. A zeolite also is present, but precise identification awaits shore-based analysis. The absence of quartz or other continental material in the fluvial sediment as well as its position within the thick basaltic sequence strongly suggest that the watershed for this area was a basaltic terrane. The initial weathering of the basalt would have generated smectitic soils. More intense or prolonged weathering generates kaolinite. Because kaolinite is present in a soil below this fluvial sequence, the smectitic soils adjacent to the stream (which supplied the mud) were immature. This is a common feature of soils adjacent to streams, which are often classified as fluvents, or entisols (immature soils having poorly developed B horizons) adjacent to streams (fluv; Soil Survey Staff, 1978).

Paleosols

Only the base of two soils and three very immature soils, mere weathering rinds, were recovered at Sites 915 and 917. Pedogenic alteration of a polymict debris flow at Site 915 was interpreted from mottling in the matrix and from the "fading" of debris-flow clasts relative to those immediately underneath. "Fading" means that the clasts become difficult to differentiate from the matrix because they are altered to clay. Relict structure in the form of the clasts is evident, however, and no soil horizons are present. This indicates that only the base (C horizon) of the soil has been preserved. The presence of a basalt cobble conglomerate immediately overlying the soil supports this interpretation.

The clay mineral composition of this soil base is kaolinite and smectite. The presence of kaolinite this deep in the soil indicates that it was a fairly mature soil that formed in a moist, subtropical to tropical climate.

At Site 917, thin, immature soils were recovered intercalated in the basalts. In Core 152-917A-20R, either the top of the soil is missing or the soil is very immature, as only 38 cm of soil was recovered. Crude lamination, probably relict flow structure from the parent basalt, is evident in the upper 10 cm, while the lower part appears massive. Mottling, a bright red color, and a pure clay texture with the absence of sedimentary structures all indicate that this is a paleosol. Smectite is the only clay mineral present. Goethite and analcime also were identified. The zeolite indicates that weathering and soil development, at least at this level in the profile, were moderate to slight.

Only the top 6 cm of a soil was recovered in Core 152-917A-23R. This fragment contains smectite and a trace of kaolinite. The base is also missing as a result of incomplete recovery of a soil in Core 152-917A-56R. A complete weathering rind, 7 cm deep, was recovered atop a basalt flow in Core 152-917A-62R. Goethite and smectite are its only components.

The scattered occurrence of kaolinite in these sediments suggests mild temperate or warmer weathering conditions and moderate to heavy amounts of rainfall. The basalt appears to have been erupted too rapidly for mature soils to develop atop the flows. Significant amounts of kaolinite were detected in the red, laminated, Eocene mud at Site 915 (lithologic Subunit IIB), indicating that some part of the watershed was stable enough for mature soils to develop. These soils were then eroded onto the adjacent shelf, but possibly only after volcanic activity decreased. A pre-middle Eocene, lateritic soil, with abundant kaolinite and anatase, was recovered from DSDP Site 336 on the Iceland-Faeroe Ridge. This indicated a subtropical-to-tropical climate there at that time (Nilsen and Kerr, 1978). However, kaolinite was not detected in Oligocene sediment from Site 914, suggesting climatic deterioration for this area from the Paleocene to early Oligocene.

General Compositional Features of Units I–III: Implications for Development of Erosion and Climate

Although essential textural changes in grain size (Fig. 17) and grain roundness were not observed among the different lithologic units, fundamental differences do occur in the mineralogical composition of the sand and silt fractions within and between the lithologic units, regardless of site (Fig. 15A). Major constituents of the sediment found in Unit I are quartz (average 50% or more of all components) and feldspar grains (up to approximately 30%), whereas rock fragments make up usually not more than 10%. By contrast, the average quartz content is less than 16% in Unit II, and in Unit III, quartz appears in most beds only in trace amounts. The major constituents of Unit II are rock fragments (average content, 14%–30%), feldspar (up to 22%), and, in some layers, zeolites (predominantly phillipsite), opaque minerals, red "semi-opaque minerals," as well as volcanic

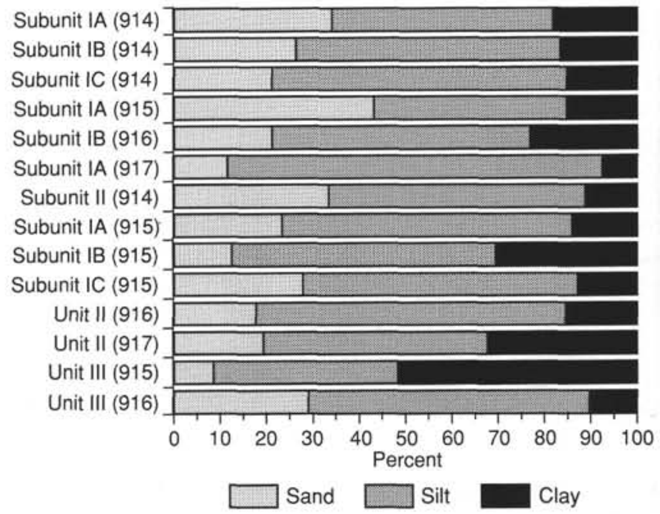

Figure 17. Grain-size relationships (sand-silt-clay) of the different lithologic units and subunits recovered above the basaltic basement at Sites 914 through 917 ("shelf sites").

glass. The silt and sand fractions in Unit III consist predominantly of opaque minerals and reddish semi-opaque minerals or volcanic glass, rock fragments (average, 4%–16%), and pyroxene (up to 5%). Feldspar makes up less than 1% of the sediment, and other components occur only in traces.

Altogether, the sediments recovered at Sites 914 through 917 show two important features concerning their mineralogical composition. First, each of the lithologic units has its own characteristic composition independent of the particular site where it occurs (Fig. 15B), and second, quartz decreases significantly with increasing subbottom depth, whereas components of predominantly volcanic origin increase (e.g., pyroxene, zeolites, opaque minerals, volcanic glass, rock fragments). This trend is clearly displayed by all successive units and subunits without exception (Fig. 18).

These observations support our lithological division of the sediment recovered at Sites 914 through 917, overlying basaltic basement. Furthermore, the trend to higher amounts of volcaniclastic components in the older units reflects a continuous change of the sediment source area from a volcanic to a crystalline terrane.

We observed pyroxene in the oldest sediment at Site 915, along with some kaolinite in the silt and clay fractions. Kaolinite also was found in some of the older sediment intercalated in basalt flows (lithologic Unit IV). The presence of kaolinite suggests a warm, wet climate that would quickly degrade pyroxene, suggesting a proximal source for the pyroxene. Kaolinite persists through the upper Eocene sediment at Site 915, but was not observed in lower Oligocene sediment at Site 914, in which pyroxene is diminished. The loss of both kaolinite and pyroxene suggests that the proximal source for the pyroxene was eroded away by the early Oligocene and also that the climate had cooled or dried considerably. Alternatively, deepening shelf depths may have trapped kaolinite in sediment farther toward the shore. Shore-based studies will focus on the changes in mineral composition of the sediment through time to clarify the effects of climate, source terrane, and proximity to the beach on the composition of East Greenland Shelf sediments.

Sedimentation Rates

A few age control points were available for constructing age-vs.-depth diagrams for Sites 914 and 915 (Fig. 19). Because of poor core recovery and/or absence of calcareous planktonic fossils, true datum levels often could not be precisely determined. Consequently, only the minimum sedimentation rates were calculated (Fig. 19; see "Sedi-

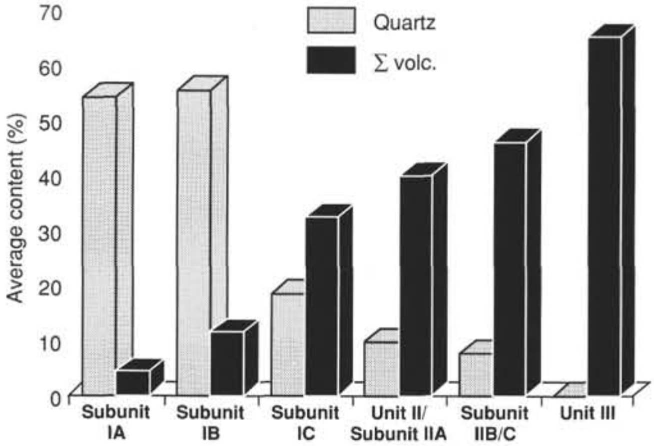

Figure 18. Average contents of quartz and volcaniclastic components in each unit and subunit. The graph shows clearly the trend that quartz increases significantly in younger sediments, whereas volcaniclastic components decrease. Σvolc. = Σ of all components with probably predominantly volcanic origin: pyroxene, zeolite, opaques, volcanic glass, and rock fragments.

mentation Rates" sections of "Site 914" and "Site 915" chapters, this volume, for details). Thus, the absence of useful age control points in Sites 916 and 917 does not allow for construction of meaningful sedimentation rates for these sites.

Subsidence History

The subsidence history for the top of the basalt sequence was reconstructed based on data from Sites 914, 915, and 917 (Fig. 20). The paleodepth data used in Figure 20 were taken from the "Biostratigraphy" sections of chapters for Sites 914, 915, and 917. Because only two or three useful data points exist for each site, the subsidence curves are poorly constrained and are so indicated by question marks. Nevertheless, Figure 20 provides useful information about the general subsidence trend for the three sites. Figure 20 indicates that some time near 50 Ma, the top of the basalt sequence was at about sea level at all sites. By about 30 Ma, Site 917 had subsided to about 200 m below sea level; Site 915 had subsided to 250 m below sea level; and Site 914 had subsided to about 300 m below sea level. Higher subsidence rates for seaward sites resulted in seaward dipping of the basalt sequence.

Glaciation of the East Greenland Continental Shelf

Jessen (1896) suspected that the Greenland Ice Sheet was much larger during past glaciations and extended out onto the continental shelf. Banks of sediment off East Greenland have been interpreted as hummocky moraine and push moraines on the basis of topography and seismic profiling (Funder and Larsen, 1989; Sommerhoff, 1979).

The recovery of basal till at Sites 914 and 916 provides the first direct, sedimentological evidence of large-scale glaciation of the East Greenland continental shelf and demonstrates that the southeastern Greenland Ice Sheet extended far out onto the shelf at least once, and possibly several times, during the Pleistocene.

In addition to its occurrence at Sites 914 and 916, the till forms a prominent seismic subsequence that can be recognized widely in seismic sections from the East Greenland continental shelf, showing that this event was of regional significance. On the East Greenland mainland, field evidence suggests that the penultimate glaciation was unusually extensive, and coeval glacier ice, "extended for an unknown distance onto the shelf" (Funder, 1989a, p. 784). It is possible that the diamicton encountered during drilling is correlative with the Scoresby Sund Glaciation, described in eastern Greenland (Funder, 1989b). The Scoresby Sund Glaciation is generally correlated with the penultimate global glaciation (i.e., with marine isotope stage 6, Saale/Illinoian). The available chronology suggests that this glacial event occurred about 175,000 to 150,000 yr ago.

Ms 152IR-110

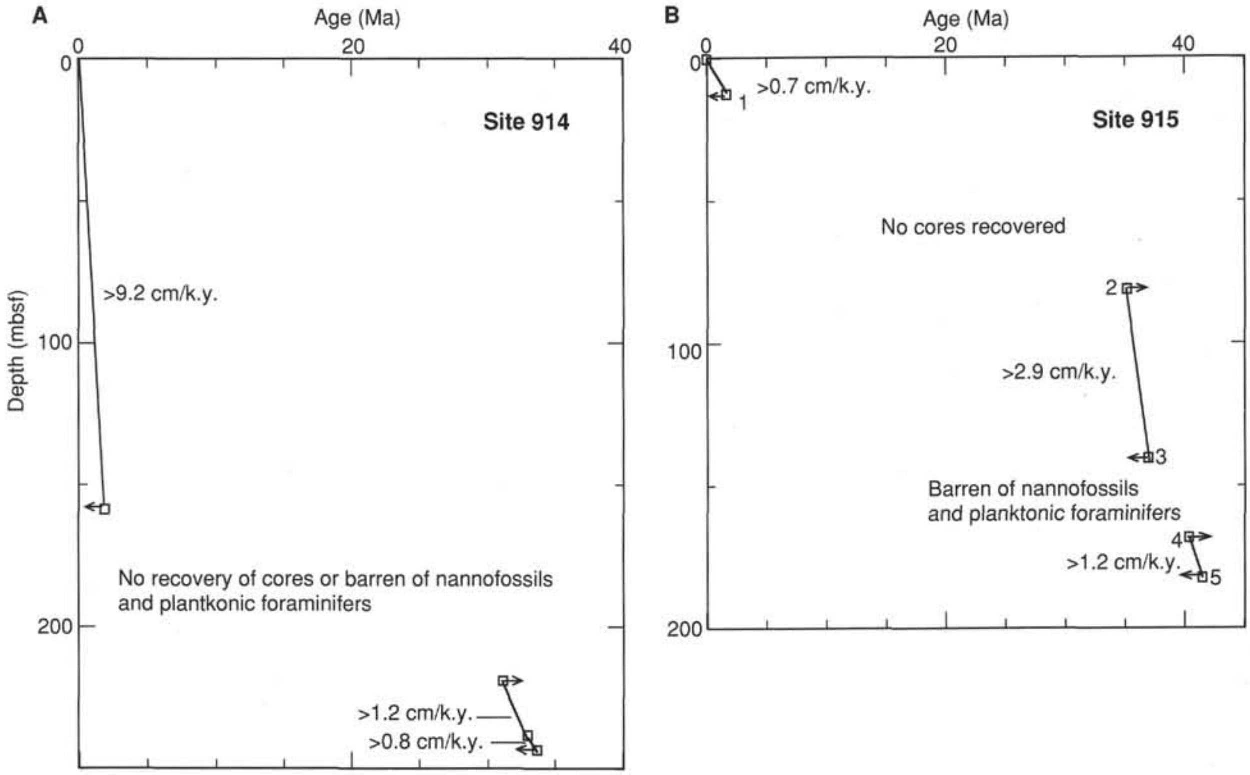

Figure 19. Diagrams of age vs. depth for Sites 914 (**A**) and 915 (**B**). Sedimentation rates for different stratigraphic intervals are shown.

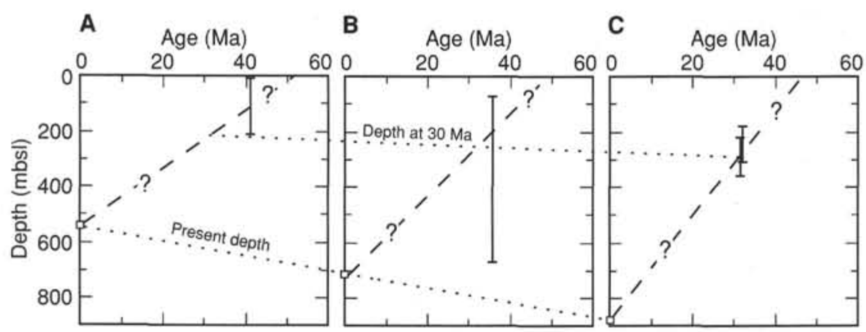

Figure 20. Diagrams of age vs. depth for Sites 914 (**A**), 915 (**B**), and 917 (**C**). Paleowater depths and general subsidence trend for these three sites are shown.