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4. EVIDENCE FROM SEDIMENTARY STRUCTURES FOR PROCESSES OF SEDIMENT TRANSPORT AND DEPOSITION DURING POST-MIOCENE TIME AT SITES 645, 646, AND 647, BAFFIN BAY AND THE LABRADOR SEA[1]

Richard N. Hiscott,[2] Michel Cremer, [3] and Ali E. Aksu[2]

ABSTRACT

Nonbiogenic, primary physical sedimentary structures are, for the most part, restricted to Pliocene-Pleistocene strata at Leg 105 sites, after the onset of Northern Hemisphere glaciation. In Baffin Bay (Site 645), a predominantly ice-rafted record is punctuated by thin, graded and laminated, silt-mud couplets (turbidites) and ungraded, cross-laminated silts (possible bottom-current deposits). In the Pliocene record at this site, thick, sharp-based and ungraded sandy beds may have been emplaced by high-concentration sediment gravity flows.

Recovered sediments from Sites 646 and 647 contain spaced, composite detricarbonate turbidites (graded, laminated couplets) with an approximate mean recurrence interval of 100,000 yr. These packets of very thin-bedded turbidites are each interpreted to coincide with a period of active overspill from the Northwest Atlantic Mid-Ocean Channel (NAMOC), beginning at about 2.4 Ma. Parallel- and cross-laminated siliciclastic silts at Site 646 are believed to represent traction transport by vigorous bottom currents (contour currents) in the vicinity of Eirik Ridge since the early Pliocene. Most intercalated deposits are bioturbated, but these may also have been deposited beneath weaker bottom currents.

INTRODUCTION

Three sites (645, 646, and 647) were cored during Leg 105 of the Ocean Drilling Program (Fig. 1). A major difficulty when evaluating sedimentary environments is the general lack of primary sedimentary structures, except in a restricted number of facies in the Pliocene and Pleistocene sections at each site. Figure 2 summarizes the depth ranges and ages of post-Miocene lithologic units recognized by the shipboard party at the Leg 105 sites; Table 1 lists the main physical structures present in each of the these units.

In general, physical sedimentary structures are best preserved in strata inferred to have been deposited after the local onset of Northern Hemisphere glaciation. In Baffin Bay (Site 645), scattered, unambiguous dropstones are found in sediments as old as upper Miocene (605 meters below seafloor [mbsf]), and sharp-based graded beds at this site characterize Subunit IIIA to depths of about 750 mbsf. Near Eirik Ridge (Site 646), laminated and cross-laminated silts are found in Subunit IA, but much less frequently in the underlying section; the base of Subunit IA is of late Pliocene age. South of Gloria Drift (Site 647), laminated silts are entirely restricted to the Pliocene-Pleistocene lithologic Unit I. Other sediments at all three sites, particularly below 750 mbsf at Site 645, below 400 mbsf at Site 646, and below 116 mbsf at Site 647, essentially lack current-generated structures and are instead bioturbated. Bioturbation or lack of current-formed structures also characterizes the bulk of the Pliocene-Pleistocene record at all sites, but the volumetrically minor facies that do display primary structures provide an opportunity to partly deduce elements of the paleohydrodynamic regime.

Arthur et al. (this volume) interpret some intervals at Sites 645, 646, and 647 as products of deep thermohaline circulation based on seismic evidence for intimate association with inferred sediment drift deposits. Cores of these intervals, however, are almost completely bioturbated, so that few data in support of bottom-current action can be gleaned from primary sedimentary structures. Based on preliminary analysis of air-gun records from post-Leg 105 *Hudson* cruise 87033, two of us (RNH and AEA) believe that the sediment drift interpretation in Baffin Bay may be premature, and that the moundlike masses may be large detached blocks above low-angle faults.

This paper describes and interprets primary sedimentary structures preserved in post-Miocene strata at Leg 105 sites. The discussion includes comments about the implication of the inferred transport processes to depositional history in Baffin Bay and the Labrador Sea. To set the framework properly for this paleoceanographic discussion, descriptions are preceded by a brief overview of the main sediment accumulations and transport processes in Baffin Bay and the Labrador Sea, based on acoustic, hydrographic, and shallow coring studies.

MAJOR SEDIMENT ACCUMULATIONS AND PROCESSES

Baffin Bay

Baffin Bay is a narrow, semi-enclosed seaway having a maximum water depth of about 2400 m. The bay is connected to the North Atlantic Ocean by Davis Strait, which is a bathymetric saddle having a maximum present depth of only 650 m (Manchester and Clarke, 1973). Connection to the Arctic Ocean is through Lancaster Sound, Jones Sound, and Nares Strait at the head of the bay (not shown in Fig. 1).

Because all parts of Baffin Bay are near adjacent landmasses, the entire bay is underlain by a thick sedimentary section of Tertiary age; in the central part of the bay, sediments range up to about 9 km thick (Srivastava et al., 1981). The continental shelf is broadest along the Greenland margin, with progradational character (Fig. 9 of McWhae, 1981). The Baffin Island shelf is narrower and steeper, whereas the northern end of Baffin Bay has no shelf-slope differentiation; instead, there is a

[1] Srivastava, S. P., Arthur, M., Clement, B., et al., 1989. *Proc. ODP, Sci. Results*, 105: College Station, TX (Ocean Drilling Program).
[2] Department of Earth Sciences and Centre for Earth Resources Research, Memorial University of Newfoundland, St.John's, Newfoundland A1B 3X5, Canada.
[3] Laboratoire de Géologie et Océanographie (L. A. 197), Université de Bordeaux I, Avenue des Facultés, 33405 Talence Cédex, France.

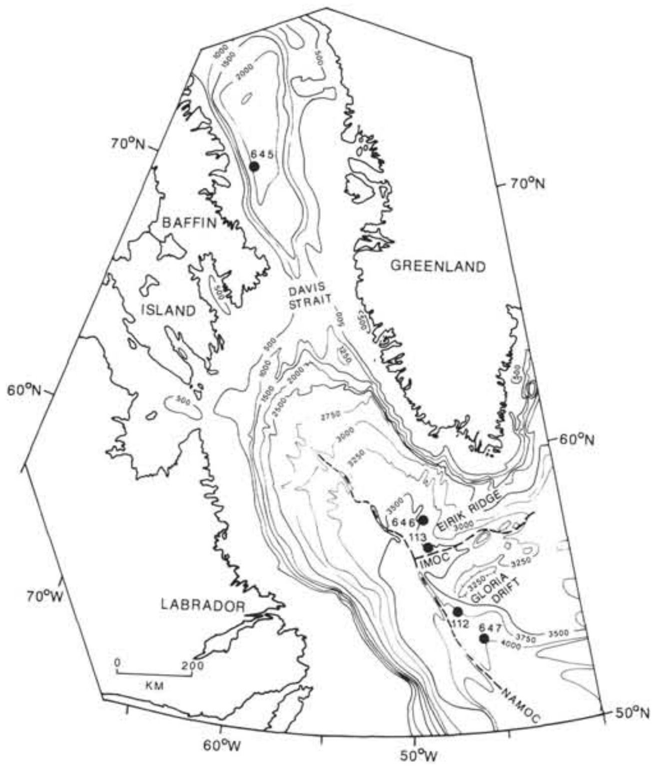

Figure 1. Bathymetry of central and southern Baffin Bay, Davis Strait, and the Labrador Sea, from Johnson and Vogt (1973). DSDP Leg 12 and ODP Leg 105 drill sites are shown, as are the main sediment accumulations in the Labrador Sea. *IMOC* = Imarssuak Mid-Ocean Channel.

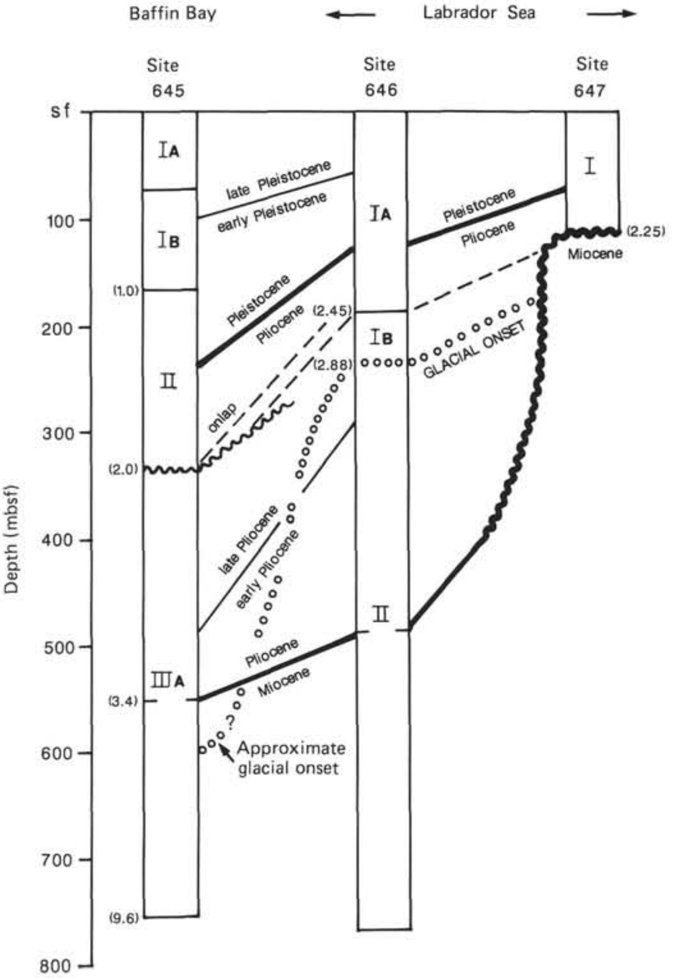

Figure 2. Lithostratigraphy, biostratigraphy, and thicknesses of Pliocene and younger sediments at Leg 105 sites. Ages of stratigraphic boundaries in Ma (brackets) are based on sedimentation rate curve (Srivastava, Arthur, et al., 1987).

gently sloping ramp ($\sim 4°$) from the coast to the central abyssal plain (Aksu, 1984).

The major part of the Quaternary section sampled by piston coring in Baffin Bay was probably emplaced by ice rafting, with subsidiary transport into the deep basin by debris flows and low-concentration turbidity currents (Aksu, 1984; Aksu and Piper, 1987; Aksu and Hiscott, 1988). Transport by thermohaline bottom currents was and is minor but is interpreted to have occurred in the late Pleistocene (e.g., Aksu and Piper, 1987). The ice-rafted component in piston cores was dropped from icebergs that, at present, calve primarily from the Greenland side of Baffin Bay (Murray, 1969). Today's icebergs are carried by surface currents (Fig. 3) from the eastern to the western side of the bay, through Davis Strait and southward along the Labrador coast.

Ice-rafted units in piston cores and the upper parts of Leg 105 cores commonly have relatively sharp bases and tops that grade into mud (Fig. 2 of Hiscott et al., this volume). This grading is accompanied by systematic mineralogical changes, and is interpreted as the result of sharp increases and gradual decreases in the delivery of ice-rafted detritus from changing sources around the bay. Hence, this mineralogical and textural cyclicity is not a reflection of hydrodynamics at the site and is not discussed here.

Labrador Sea

Except for the considerable accumulations of sediment beneath the continental margins of Labrador, southern Baffin Island, and southwestern Greenland, the prominent sediment accumulations in the Labrador Sea are (1) deposits of the broad levees and channel system of NAMOC (Fig. 1) and (2) sediment drifts, specifically Eirik Ridge at the southern tip of Greenland and Gloria Drift just north of the Charlie Gibbs Fracture Zone and east of NAMOC (Fig. 1). NAMOC is now inactive (periods of sediment transport through this channel system have been tentatively linked to meltwater pulses from the margin of continental ice sheets during the Neogene; Hesse et al., 1987). Eirik Ridge also appears to be primarily a relict feature because the uppermost lithologic Unit I at Site 646 drapes the mounded relief of the mainly Pliocene drift sequence (Arthur et al., this volume). Nevertheless, moderate bottom currents are still active in the Labrador Sea, with maximum measured bottom velocities of about 20 cm s^{-1} near the southern tip of Greenland (Rabinowitz and Eittreim, 1974).

NAMOC extends from the northern end of the Labrador Sea to the Sohm Abyssal Plain, a distance of about 3800 km (Chough and Hesse, 1976). The sinuous channel contains sediment as coarse as gravel, whereas the broad levees consist predominantly of silts and muds (Hesse and Chough, 1980). Measured at the levee crests, the channel is from 6 to 16 km wide; channel depth is between 100 and 200 m (Chough and Hesse, 1976). The levees and their adjacent "floodplain" deposits extend 50 to 100 km on either side of the channel (Egloff and Johnson, 1975). The thickest part of the NAMOC sequence is about 500 m thick; at the distal edge of the levee-floodplain wedge, overspill deposits interfinger with hemipelagic and bottom-current deposits (e.g., Gloria Drift).

Table 1. Summary of physical structures in Leg 105 Pliocene-Pleistocene lithologic units.

Site and Lith. unit	Depth (mbsf)	Major lithologies	Physical structures
645-IA	0–71.6	Gravel-bearing sandy mud, dark silty mud, rare laminated silts.	Graded gravel-bearing units, graded silt-mud couplets, cross-lamination.
645-IB	71.6–168.1	Silty clay and silty mud, with dropstones.	None of significance.
645-II	168.1–335	Silty mud, clayey silt, and silty clay, with dropstones.	None of significance.
645-IIIA	335–753.4	Muddy sand and sand-bearing silty mud.	Sharp-based, thick-bedded units.
646-IA	0–188.2	Silty clays and clayey silts, biogenics to 50%, laminated detricarbonate silty muds and siliciclastic silts.	Graded and laminated detricarbonate silt-mud couplets, cross- and parallel-laminated siliciclastic silts.
646-IB	188.2–236.4	Muddy sands and silty muds.	Vague ?stratification.
646-II	236.4–766.7	Silty clay, clayey silt, clay, biogenics to 60%, siliciclastic silts.	Cross- and parallel-laminated siliciclastic silts.
647-I	0–116	Silty clay, clayey silt, clayey mud, biogenics to 40%, laminated detricarbonate silty muds.	Graded and laminated detricarbonate silt-mud couplets in compound units.

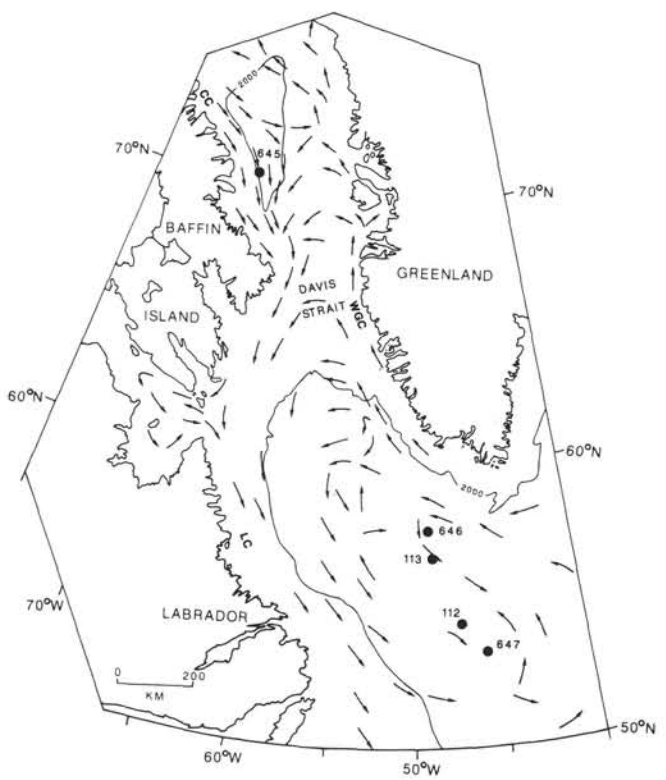

Figure 3. Average surface currents and iceberg drift in the Labrador Sea and Baffin Bay, simplified from Fillon and Full (1984). *WGC* = West Greenland Current; *LC* = Labrador Current. Leg 12 and Leg 105 sites and the 2000-m bathymetric contour are shown. Deep circulation in the Labrador Sea is believed to be essentially identical in pattern to the surface circulation (Lonsdale and Hollister, 1979); information on the modern deep circulation in Baffin Bay is not available.

Chough and Hesse (1985) studied sediments from the southern flank of Eirik Ridge in piston cores. In general, the clayey silts and silty clays are strongly bioturbated, with only about 1% of the sampled interval preserving wavy parallel lamination. Essentially the same pattern emerges from a DSDP Leg 94 study of other major sediment drifts in the North Atlantic (Hill, 1987). Recall, however, that the main period of drift construction was in the Pliocene (consistent with Kidd and Hill, 1987), when presumably stronger bottom currents would have left a stronger imprint of tractional transport in the sedimentary record.

METHODS

Most analyses of sedimentary structures were conducted at the core description table during drilling. Post-cruise activities included (1) grain-size analyses at intervals of $1/2\ \phi$ (sieves and pipette) by RNH on selected samples taken from intervals having clear or inferred primary structures, (2) examination of thin sections of laminated intervals prepared both on board the ship and on shore (MC and RNH), (3) examination of X-radiographs taken on board the ship and a set of X-radiographs obtained by RNH and AEA for about the upper 45 m at Site 645 after the cruise (to the base of Section 105-645B-6X-1).

SITE 645 - BAFFIN BAY

The post-Miocene record at this site is notable for its general lack of primary structures. The two exceptions are (1) thin and very thin, bedded, laminated, and commonly graded detricarbonate silts associated with dark gray clayey silts and silty clays in lithologic Subunit IA at Site 645 (Fig. 2), and (2) thick- and very thick-bedded, ungraded to subtly graded, poorly sorted, sandy units (coarsest percentile of grain-size distribution about 1 mm) in Subunit IIIA at Site 645 (Fig. 2). High-resolution seismic evidence exists for mound-shaped slide or debris-flow deposits (debrites) in Subunit IA (Fig. 4; Aksu and Hiscott, 1988), but no features in the recovered cores suggest disturbed or chaotic deposits.

Detricarbonate Silts

Subunit IA at Site 645 is characterized by a meter-scale mineralogical alternation of (1) gravel-bearing detricarbonate muddy sands and (2) siliciclastic silty clays and clayey silts (Pl. 1, Fig. 1; Fig. 2 of Hiscott et al., this volume). In several cases, finely laminated or cross-laminated detricarbonate silts of two varieties can be seen in these latter intervals. The first variety, which is the more commmon, consists of sharp-based, graded units (Pl. 1, Figs. 1 through 6). These are generally only a few centimeters thick and are overlain by apparently structureless mud or, more commonly, by gravelly, ice-rafted sediments. In some cases, the internal laminated nature of these units was not clear during core inspection, but was revealed by X-radiography.

The second variety of laminated unit does not show sharp contacts or grading, and consists of wavy and cross-laminated silt in beds to about 10 cm thick (Pl. 1, Fig. 7).

The sharp-based, graded beds are interpreted as turbidites deposited from low-concentration flows during times of restricted iceberg melting over the site. In some cases, however, the ambient sediment was ice-rafted gravelly mud, so that the

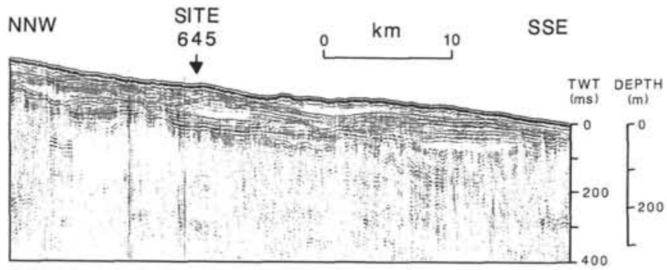

Figure 4. Air-gun seismic profile passing from north-northwest to south-southeast through Site 645, Baffin Bay, showing several acoustically transparent debris-flow lenses in the upper 170 m (Unit I). This profile runs along the slope at a water depth of about 2000 m and was obtained by AEA and RNH during *Hudson* cruise 87-033. The lens directly below the site is also shown in a downslope profile in Srivastava, Arthur, et al. (1987, p. 146).

"pelagic," or T_e division of the turbidite is considerably coarser than the underlying divisions (Pl. 1, Fig. 6).

Essentially ungraded, cross-laminated silts may also have been deposited by a succession of low-concentration turbidity currents, but the lack of both grading and repetitive sequences of structures may indicate that this facies was produced instead by relatively continuous traction transport beneath long-lived bottom currents. Aksu and Piper (1987) interpreted piston-core facies D(ii), "gravelly sands and sands with no structural sequence," as bottom-current deposits; these additional examples support the suggestion of periodic bottom-current activity during the late Pleistocene at Site 645.

Thick Ungraded Sands

About 10% of Subunit IIIA of Site 645 consists of sharp-based, unburrowed, muddy sands to sandy silty muds that we believed to be ice-rafted on the basis of shipboard description. These beds are about 1 m thick and, like the bulk of sandy sediments in Subunit IIIA, contain scattered floating black shale pebbles that are up to about 1 cm in size. However, the other 90% of the subunit is characterized by pervasive burrowing in texturally similar sediment believed to have been emplaced in part by ice-rafting. The Pliocene part of Subunit IIIA is characterized by an overall coarsening upward from 500 to 400 mbsf, followed by a fining to its top (based on weight percent >250 μm; Cremer, this volume). Superimposed on this trend are gradual coarsening-fining-coarsening trends several meters thick.

Grain-size analysis of samples from the base to the top of four of the sharp-based beds (Fig. 5) indicates that (1) sand content is generally less than the 35%–45% necessary in our classification scheme (Srivastava, Arthur, et al., 1987) to warrant the name muddy sand, so that "sandy" silty mud is generally the more appropriate term; (2) maximum grain size (excluding floating pebbles) is about 2 to 3 mm; and (3) grading cannot be demonstrated, and if any general attribute exists, it is that basal samples tend to be more poorly sorted and to contain a higher percentage of clay-grade sediment.

Two points from other post-cruise studies bear on the interpretation of the sharp-based beds: (1) no sharp-based beds were described from 380 to 450 mbsf, even though this interval has the highest percentage of sediment >250 μm in size (Cremer, this volume); and (2) there are quartzarenite rock fragments, and quartz grains recycled from quartzarenites, in samples from Subunit IIIA (Hiscott et al., this volume), even though the only known outcrops of quartzarenites (Proterozoic age) are at the north end off Baffin Bay about 700 km away, mostly in northern Greenland (Dawes et al., 1982).

The sharp bases, lack of lamination, and lack of burrowers, all suggest rapid emplacement of poorly sorted sandy sediment. A possible mechanism that could have produced the observed features is high-concentration sediment gravity flows that may have been weakly turbulent or nonturbulent (i.e., debris flows). Texturally similar sandy debrites have been reported, for example, from ancient fan settings (e.g., Hiscott and Middleton, 1979). A sediment gravity-flow explanation for deposition of all of the Pliocene part of Subunit IIIA from Site 645 is controversial, however. Why are the coarsest sediments (400–430 mbsf; Cremer, this volume) devoid of sharp-based beds, and how could immature flows that deposited sediment at the base of the Baffin Island slope contain grains that were probably derived from northern Greenland? Adjacent to Site 645, seismic profiles show no clear continuation of this subunit onto the upper slope or shelf of Baffin Island (Arthur et al., this volume). Given (1) the general coarsening upward from about 500 mbsf, (2) the ice-rafted origin of much of lithologic Units IA and II from Site 645, and (3) the inference that quartzarenite clasts in Units I and II were ice rafted to the site from northern Greenland (Hiscott et al., this volume), it is conceivable that the medium sand and coarser components in the Pliocene part of Subunit IIIA were also dropped from floating icebergs. Cremer (this volume) interprets gradual coarsening-fining-coarsening trends in sediments rich in fine and very fine sands below 550 mbsf at Site 645 as the imprint of fluctuating bottom currents (compare with Gonthier et al., 1984). Similar trends in the coarser sediments of Subunit IIIA above 550 mbsf may reflect a combination of bottom-current action and ice rafting of the >250-μm component, plus an unspecified quantity of finer sediment. The sharp-based beds without burrows may represent either spurts in accumulation of ice-rafted sediment, similar to the explanation for graded beds with mineralogical trends in Subunit IA in Site 645, or deposits of sandy debris flows or high-concentration turbidity currents generated periodically from rapidly accumulating glaciogenic sediment.

SITE 646

Lithologic Subunit IA, of late Pliocene and younger age, contains most of the well-preserved primary structures at this site. About 95% of this subunit is structureless or bioturbated, but 3% consists of thin to thick beds of variably laminated detricarbonate silt, and 1% to 2% of thin beds of laminated and cross-laminated, siliciclastic, very fine sand, silt, and clayey silt. Subunit IB, although predominantly siliciclastic sandy silty mud, as in Subunit IIIA of Site 645, is not characterized by the sharp-based and unburrowed sandy beds found in Baffin Bay.

Unit II is predominantly fine grained and bioturbated, but thin, cross- and parallel-laminated siliciclastic silt beds, such as those present in Unit I, persist to a depth of about 400 mbsf.

Laminated Detricarbonates and Clayey Silts

About two-thirds of the 27 detricarbonate beds (carbonate content to 50%) in Subunit IA at Site 646 are characterized by delicate lamination, which is almost entirely parallel lamination (Pl. 2, Figs. 1 and 2). These beds are burrowed only at the top. Limited X-radiography and thin-section studies (Pl. 2, Figs. 3 and 4) indicate that these beds are composed of many normally graded units, each <1 cm thick. These very thin units generally have sharp bases and, in some cases, are accompanied by erosion into underlying sediments. The basal deposits are sometimes cross-laminated and are generally succeeded upward by finer detricarbonate mud having millimeter-spaced and finer laminae of more silt-rich sediments.

Each of the <1-cm-thick graded units is interpreted as a T_{cd} or T_d turbidite, while the upper spaced silt laminae are identical to laminae described by Hesse and Chough (1980) from the upper part of spillover turbidites on the levees of NAMOC. The carbonate mineralogy of these beds at Site 646 (essentially a 2:1 calcite-to-dolomite ratio) also resembles that of the NAMOC

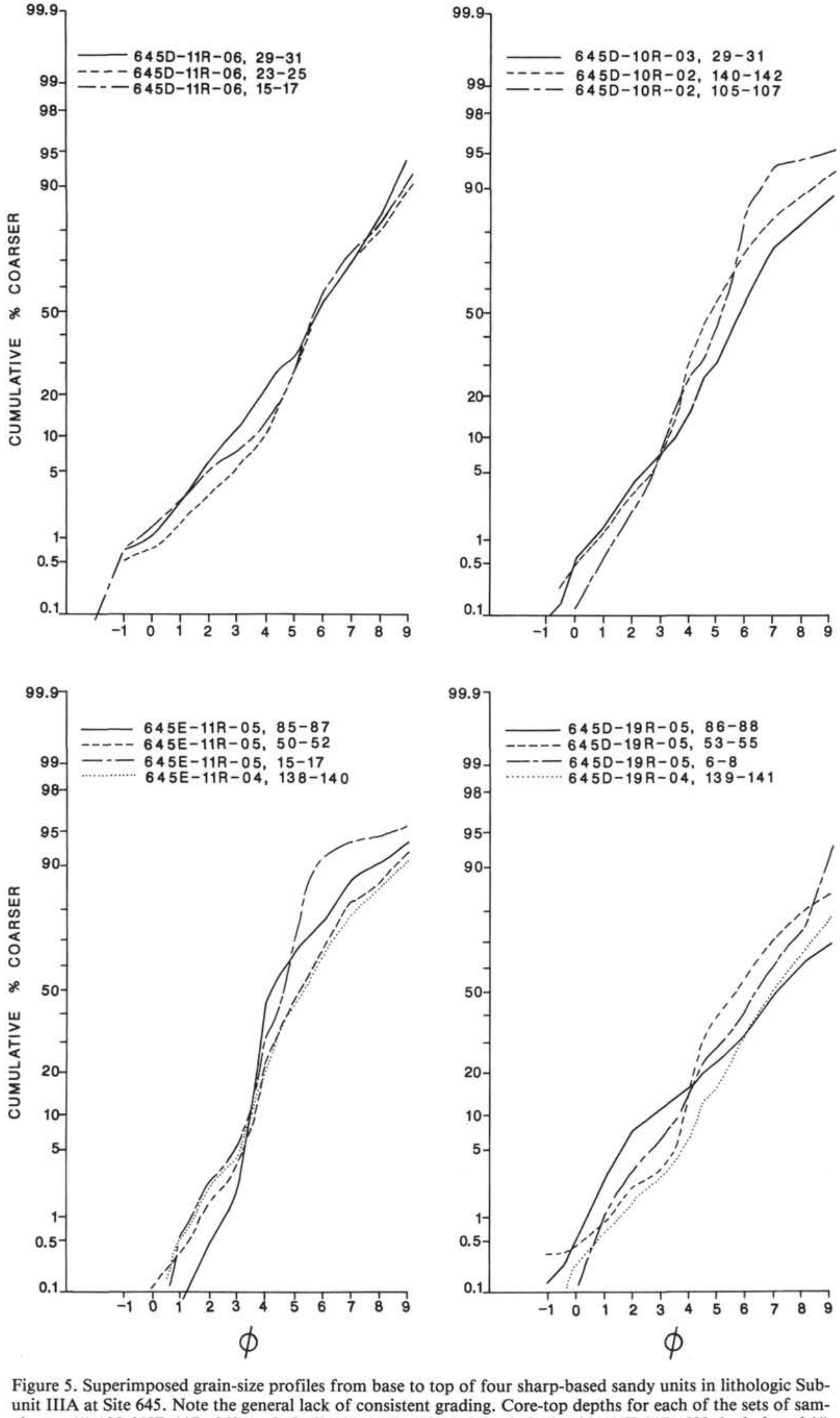

Figure 5. Superimposed grain-size profiles from base to top of four sharp-based sandy units in lithologic Subunit IIIA at Site 645. Note the general lack of consistent grading. Core-top depths for each of the sets of samples are (1) 105-645D-11R, 369.4 mbsf; (2) 105-645D-10R, 359.7 mbsf; (3) 105-645E-11R, 522.6 mbsf; and (4) 105-645D-19R, 446.5 mbsf.

levee sediments (see Latouche and Parra, 1979; Chough et al., 1987), and that of inferred NAMOC spillover turbidites at Site 647 (see following).

Site 646 is at a level about 100 m upslope from the nearest adjacent part of the levee crest of NAMOC about 175 km to the southeast, so that the detricarbonate silts and silty muds at this site could have been supplied only from NAMOC if the turbidity currents were very thick or if the flows climbed up the backside of Eirik Ridge to the shallower water depths (Srivastava, Arthur et al., 1987, p. 443). Either alternative is possible (see Piper and Normark, 1983), but it also is conceivable that slope gullies on the Greenland margin contributed the detricarbonate material, particularly as Paleozoic limestones and dolostones have been recovered in dredges along the nearby Greenland margin (Johnson et al., 1975).

Siliciclastic Cross-Laminated Silts

These silt beds have both sharp and gradational contacts and are wavy laminated (Pl. 3, Figs. 1 and 2) or cross-laminated (Pl. 3, Figs. 4 and 5), although somewhat irregular parallel lamination does occur (Pl. 3, Fig. 3). Smear slides indicate up to 10% heavy mineral grains in these beds, as well as local concentrations (a few percent) of sponge spicules, foraminifers, and diatoms. Basal grain size in one bed is very fine sand. Texturally, these silts and very fine sands are moderately well sorted, although a coarse tail (rare granules) and a fine tail (clays) are evident in one of the samples analyzed (Fig. 6).

There are at least 21 beds of this facies in cores from lithologic Subunit IA at Site 646. These range in thickness from a few centimeters to somewhat more than 10 cm. Unlike the detricarbonate silt beds, however, the occurrence of laminated siliciclastic silt beds extends downward to depths of about 400 mbsf (Section 105-646B-42X-03) in the early Pliocene part of Unit II (Fig. 2). Seven such beds were observed in core descriptions below Subunit IA.

We interpret the tractional structures, lack of consistent grading, moderately good sorting, and heavy mineral concentrations in the siliciclastic silts as the product of winnowing and transporting by thermohaline bottom currents. The spacing of beds of this facies in the section indicates that bottom-current velocities were capable only infrequently of transport silt and very fine sand in sufficient amounts to bury and preserve the primary structures beyond the reach of burrowers. The effect of weaker bottom currents at other times is not preserved in these cores because of bioturbation like that which typifies piston cores from the southern flank of Eirik Ridge (Chough and Hesse, 1985), and DSDP Leg 94 cores from Feni and Gardar drifts (Hill, 1987).

SITE 647

Site 647 is located on the southern margin of Gloria Drift. NAMOC passes 130 km west of the site (Fig. 1). Sediments are dominantly pelagic and hemipelagic in nature, and are either structureless or bioturbated. The only exception is sharp-based, laminated detricarbonate silty clay and clayey silt beds composed of several distinct graded units, each <3 cm thick. Sixteen beds of this facies were noted in Hole 647B.

Laminated Detricarbonate Silts and Clayey Silts

These beds resemble the same facies at Site 646 in all respects and thus are not redescribed here. Of paleoenvironmental interest, however, is the sequence preserved in a few cases in underlying deposits. Specifically, where the graded detricarbonate units overlie nannofossil-foraminifer silty clays or clayey silts, the biogenic content increases upward to the base of the sharp-based detricarbonate bed. In some nannofossil-foraminifer silty clay beds that also show an increase in biogenic content upward but that are not overlain by detricarbonate silt, nannofossils are depleted in the upper few centimeters of the deposit.

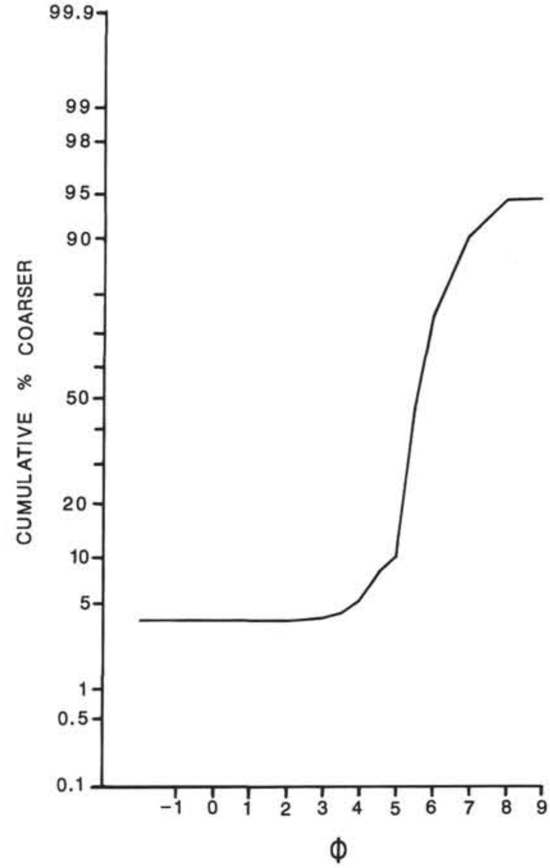

Figure 6. Grain-size profile from a siliciclastic silt bed (Sample 105-646A-5H-06, 118–120 cm). Note the 4% of the sample coarser than -2ϕ (4 mm). Core-top depth is 35.8 mbsf.

Proximity to NAMOC and strong similarity of the graded detricarbonate silts and clayey silts to levee deposits of NAMOC (Latouche and Parra, 1979; Hesse and Chough, 1980; Chough et al., 1987) leave little doubt that the graded, laminated detricarbonate beds of Unit I at Site 647 are distal tongues of spillover sediment related to pulses of maximum NAMOC activity. The upward increase over several centimeters in biogenic content in sediments beneath a few of these beds suggests that a general warming trend in surface water over Site 647 had begun before NAMOC initiated one of its more active phases. Also, biogenic enrichment in some nannofossil-foraminifer silty clays is associated with apparent winnowing of fine-grained nannofossils from the upper several centimeters of the biogenic sediments. This observation suggests bottom-current intensification near periods of maximum NAMOC activity, as evidence for both is associated with systematic increases in biogenic content.

DISCUSSION

Primary sedimentary structures and marked textural variations in beds at all three Leg 105 sites suggest sediment transport by both turbidity currents and bottom currents. In Baffin Bay (Site 645), turbidites are a minor component of the Pleistocene record and are concentrated in units having few large ice-rafted clasts. In fact, the bulk of the Site 645 Pleistocene sequence is believed to be of ice-rafted origin (Hiscott et al., this volume).

The lower upper Pliocene (and upper Miocene) poorly sorted, muddy sands and sandy silty muds at Site 645 may consist predominantly of ice-rafted detritus, with periodic resedimentation on basin slopes that produced essentially ungraded but sharp-based deposits from either high-concentration turbidity currents or sandy debris flows. It may be that Subunit IIIA at this site was formed by processes not unlike those that formed overlying ice-rafted deposits, with the main difference being the nature of the sediment, which seems to have been derived mainly from unconsolidated siliciclastic sediments (sandstones, siltstones, shales) during the late Miocene to early late Pliocene (Hiscott et al., this volume). Subunit IB at Site 646 appears to texturally and compositionally resemble Subunit IIIA at Site 645, which suggests that sediments derived from a poorly consolidated cover on adjacent land masses may be widespread in the Pliocene.

At Sites 646 and 647, a characteristic facies in the upper Pliocene and Pleistocene section is composite detricarbonate turbidites that are probably linked to periods of maximum activity of NAMOC and its tributaries; such times probably correspond to glacial meltwater pulses (Hesse et al., 1987) and associated high rates of delivery of sediment to the edge of the shelf. Pulses in overspill from NAMOC that reached Sites 646 and 647 have occurred about 20 times since ~2.4 Ma, with an approximate periodicity of 120,000 yr. There is no guarantee that all periods of NAMOC activity were equally vigorous, and overspill from some of the weaker pulses may not have reached these sites, or may have been so minor that the detricarbonate material became mixed into surrounding lithologies by burrowers (diffuse detricarbonate bands are present at both Labrador Sea sites). The actual periodicity of NAMOC activity thus may be shorter than the above estimate, perhaps nearer 100,000 yr.

The periodicity of meter-scale mineralogical and textural cycles in Baffin Bay (Hiscott et al., this volume) is much shorter than 100,000 yr, about 8,000 to 10,000 yr (Srivastava, Arthur, et al., 1987). There does not appear to be a direct link, therefore, between short-term meltwater cycles in Baffin Bay and pulses in NAMOC activity.

Volumetrically minor cross-laminated facies at Sites 645 and 646 can be interpreted as the deposits of relatively vigorous bottom currents, capable of (1) transporting detritus as coarse as very fine sand and (2) locally concentrating heavy minerals and biogenic grains. Sediment accumulation rates were sufficient to prevent significant burrowing, but at other times, sediments that may have been partly reworked by bottom currents, including deposits at Site 647, were thoroughly bioturbated, as predicted for bottom-current deposits by Gonthier et al. (1984), Chough and Hesse (1985), and Hill (1987). The lack of internal primary structures in much of the section believed to have formed during episodes of sediment drift construction (Arthur et al., this volume) makes it necessary to interpret depositional processes at these times primarily from regional seismic data, not from cores although Cremer (this volume) used grain-size distributions to advantage when elucidating such depositional processes.

SUMMARY

In lithologic Subunit IA at Site 645, volumetrically minor, laminated and cross-laminated, detricarbonate silts are of two types. The graded silt-mud couplets are interpreted as turbidites, whereas the ungraded, cross-laminated silts may have been reworked by periodically vigorous bottom currents. Thick, sharp-based, sandy, silty muds in Subunit IIIA are more difficult to interpret and may represent either sharp increases and gradual decreases in the supply of ice-rafted sand, or resedimentation of glaciogenic sediments by high-concentration turbidity currents or sandy debris flows.

Laminated detricarbonate silts and silty muds of Subunit IA at Site 646 and Unit I at Site 647 are interpreted as the deposits of spillover turbidity currents from the Northwest Atlantic Mid-Ocean Channel (NAMOC), at intervals of about 100,000 yr. The earliest evidence for NAMOC activity from Leg 105 cores is at ~2.4 Ma.

Siliciclastic cross-laminated silts in Units I and II at Site 646 are interpreted as bottom-current deposits formed beneath contour currents flowing around the southern tip of Greenland and over Eirik Ridge. Only the most vigorous currents formed this facies, whereas the possible imprint of weaker contour currents at other times was destroyed by burrowers.

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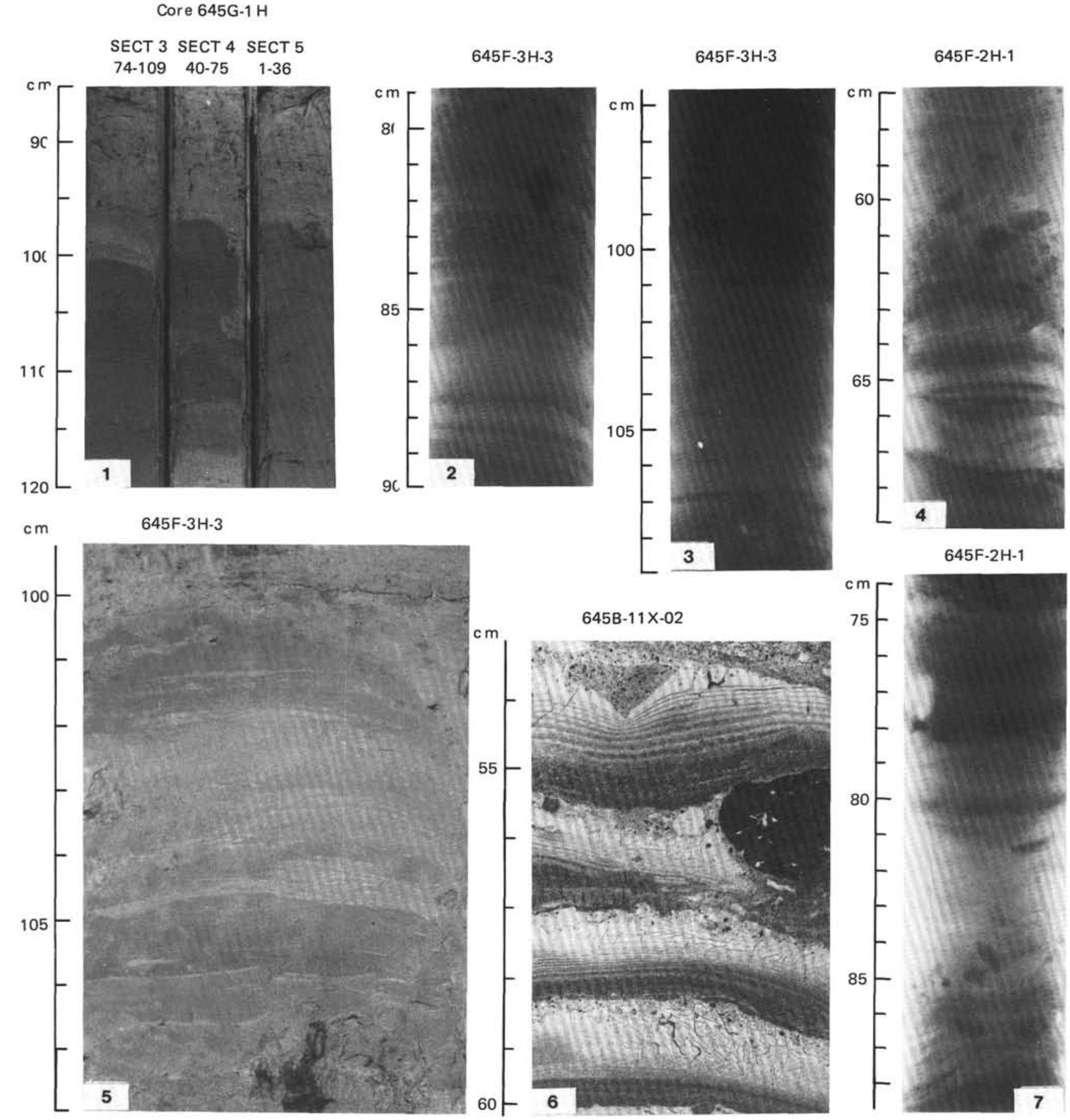

Plate 1. Primary structures from Site 645. To allow quick comparison with Figure 2 stratigraphy, core-top depths for cores illustrated in this plate are as follows: 105-645B-11X, 90.9 mbsf; 105-645F-2H, 4.0 mbsf; 105-645F-3H, 13.5 mbsf; 105-645G-1H, 1.0 mbsf. **1.** Three examples of contacts between dark gray muds and tan gravel-bearing silty muds, with graded, laminated turbidites at the contact (left) and within the gray mud unit (center). **2.** X-radiograph of several graded turbidites (bases dark) with fine-scale silt-mud laminae and scattered ice-rafted pebbles. **3.** X-radiograph of centimeter-thick, sharp-based, silt-mud couplets with fine-scale lamination. **4.** X-radiograph of laminated silt-mud couplets sharply overlain by gravel-bearing sediments. **5.** Core photograph of the silt-mud couplets shown in photograph 3. **6.** Thin-section enlargement of delicately laminated silt-mud couplets with granules and gravel characterizing the T_e divisions and piercing underlying sediment. **7.** X-radiograph of ungraded, cross-laminated silts with scattered gravel clasts.

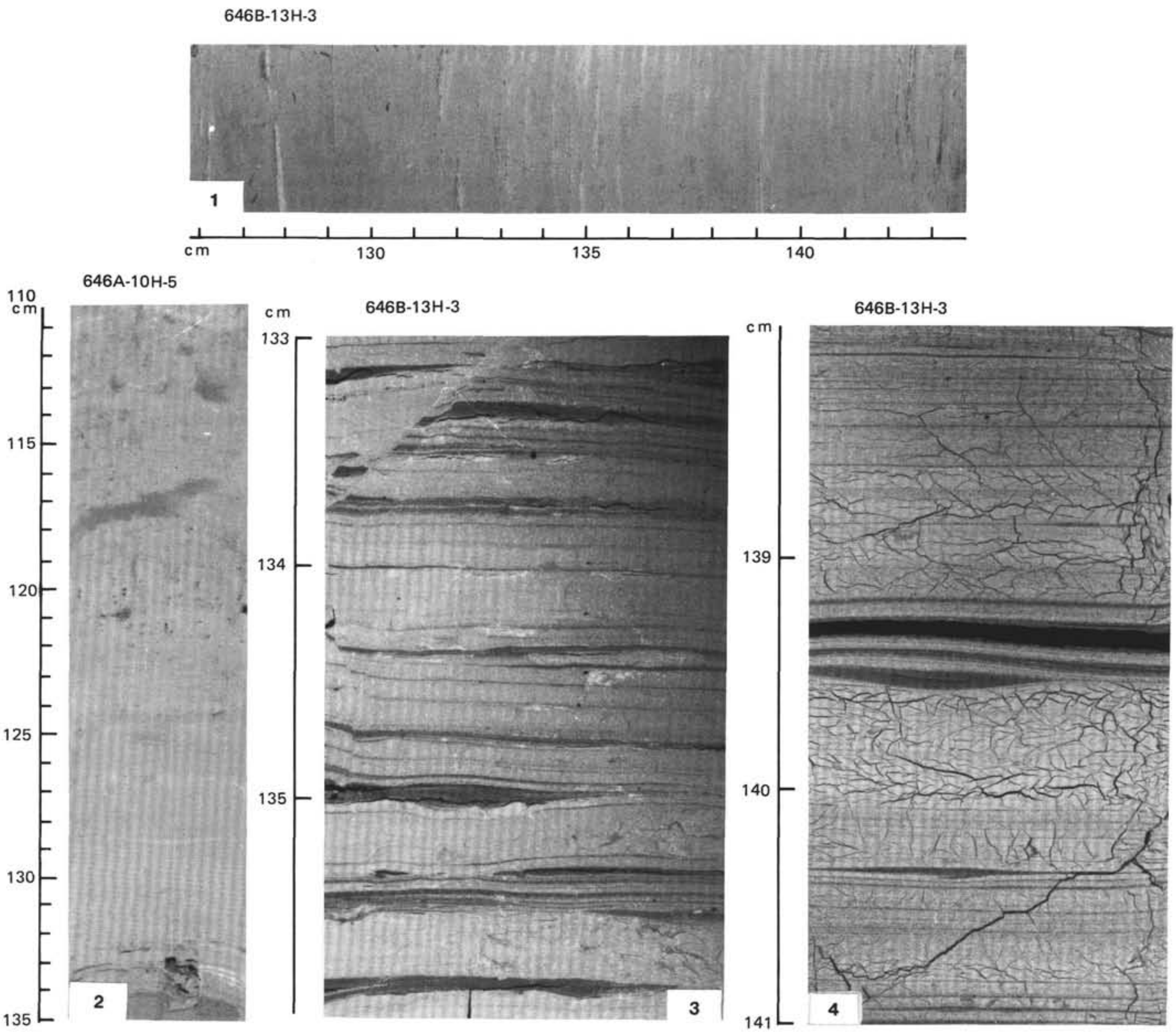

Plate 2. Laminated detricarbonate silts and silty muds at Site 646. To allow quick comparison with Figure 2 stratigraphy, core-top depths for cores illustrated in this plate are as follows: 105-646A-10-H, 84.1 mbsf; 105-646B-13H, 111.1 mbsf. **1.** Composite detricarbonate "bed" formed of about 15 silt-mud couplets. The sharp-based basal silt divisions are a lighter gray tone than the detricarbonate muds. **2.** Complete detricarbonate silty mud bed formed of several silt-based couplets and with a burrowed top. The base of the bed is at 135 cm. **3.** Thin-section enlargement of part of the interval shown in photograph 1. The sharp-based turbidites have a laminated or cross-laminated base (dark) overlain by delicate silt-mud laminae. About 10 couplets are shown in this photograph. **4.** Thin-section enlargement of part of the interval shown in photograph 1, starting 2 cm below photograph 3. The bottom of the photograph shows the fining-upward of silt-mud laminae of a turbidite that begins below the field of view. Above this are two turbidites, one with base at 140.3 cm and one starting at 139.5 cm.

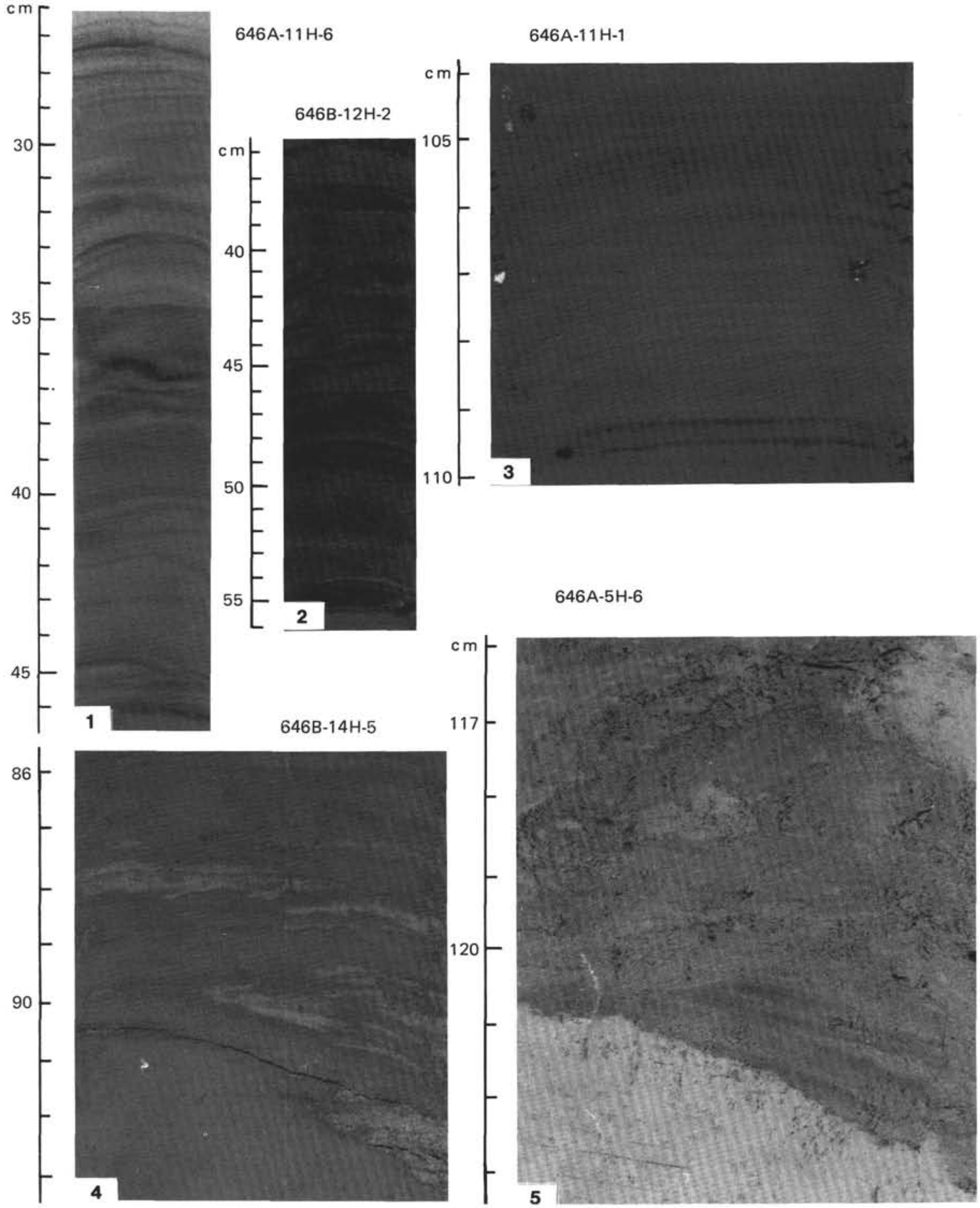

Plate 3. Siliciclastic cross- and parallel-laminated silts at Site 646. To allow quick comparison with Figure 2 stratigraphy, core-top depths for cores illustrated in this plate are as follows: 105-646A-11H, 93.8 mbsf; 105-646B-5H, 33.8 mbsf; 105-646B-12H, 101.4 mbsf; 105-646B-14H, 120.8 mbsf. **1**. X-radiograph of an ungraded, laminated silt bed. **2**. Core photograph of a laminated silt bed. Note that structures are less clear than on the X-radiograph in photograph 1. **3**. Core photograph of parallel-laminated silt. **4**. Core photograph of cross-laminated silt lenses interlayered with mud. **5**. Scour-and-fill cross-lamination in sharp-based silt bed.