

**IODP Expedition 323:
Pliocene-Pleistocene paleoceanography and climate history of the Bering Sea**

Site U1340 Summary

2 August 2009

Background and objectives

The primary objective of drilling at Site U1340 (Site BOW-12B) was to study high-resolution Pliocene and Pleistocene paleoceanography in the southernmost part of Bering Sea at a topographic high location on the Bowers Ridge where relatively good calcium carbonate preservation is expected. The Bowers Ridge is well situated to study the past extent of water mass exchange with the Pacific Ocean through the adjacent Aleutian passes such as Amukta, Amchikta and Buldir Passes. Of particular interest is the ability to examine the influence of the warm Alaskan Stream water mass entry into this region, which influenced the distribution of the past sea-ice coverage. While the productivity in the Bering Sea in general is very high with respect to the other parts of the global oceans, the expected productivity at this site is lower than at Site U1339, which has substantially greater influence from the nearby Bering Shelf and was exposed during the glacial low stands. Drilling at this site with relatively shallow water depth should provide us with the ability to study physical and chemical changes in upper water mass conditions. A good example is the low dissolved oxygen concentration conditions which caused the formation of laminated sediments at a site on the Bering Shelf at similar water depths. The vertical structure of past water masses can be made by comparing results at this site with the other planned drilling sites on Bowers Ridge (U1341, w.d. = 2177 m; U1342, w.d. = 837 m).

Site U1340, at the Bowers Ridge, can also be used to study the impact of subseafloor microbes on biogeochemical fluxes in the highest surface ocean productivity areas of the drill sites in the Bering Sea. Samples to study the organic-fueled subseafloor respiration and its impact on biogeochemistry at the highly productive region of the previous Site U1339 will be compared to analyses at the Bowers Ridge sites, including Site U1340, although the high resolution sampling that occurred at Site U1339 is not planned for Site

U1340. The Bowers Ridge drilled sediments will be used to determine subseafloor cell abundance and to investigate the link between the mass and characteristics of subseafloor microbes and the extent of export productivity from the surface ocean.

Scientists from DSDP Leg 19 found Recent to Upper Miocene diatom ooze interbedded with silt-rich diatom ooze, and diatomaceous silt at Site 188. They also found calcareous nannofossils in the upper 120 m and planktic foraminifers in the upper 300-400 m. In the interval between 580 and 638 m they encountered mudstone. Sedimentation rates are approximately 100 m/m.y. A piston core study from the same general region provided the sedimentation rate of 80 m/m.y. Thus, prior to drilling, the entire Pleistocene to the Pliocene and possibly Miocene sections were expected.

Operations

We arrived at Site U1340 (Site BOW-12B) on 22 July 2300 after a 1.5 day, 344 nm, transit from Site U1339. Hole U1340A was spudded at 0520 hours. A total of four holes, one relatively deep and three shallow, were drilled and cored employing APC and XCB at a water depth of 1306 m on the Bowers Ridge. A complete set of site specific tide tables were provided by the science party for Site U1340, and were used to make adjustments relative to initial mudline core and for each successive core on each hole. The APCT3 temperature tool was deployed four times. Overall recovery for Site U1340, using the APC and XCB coring systems was 91.0%.

Hole U1340A

Position: 53° 24.0008' N Latitude, 179° 31.2973' W Longitude

Seafloor: 1306 m DRF (APC calculated depth)

Penetration Depth: 603.6 m CSF-A

Coring Systems: APC w/ non-magnetic/standard core barrels and XCB

Objective: Recover complete geologic section—seafloor through ~700 m

Result: Reached 603.6 m CSF with 100% recovery during APC portions of the hole. XCB recovery averaged 61%.

Hole U1340A was spudded at 0520 hours on 23 July 2009. Hole U1340A was cored to 603.6 m DSF employing both APC and XCB with 100% recovery during APC portions of the hole and XCB recovery averaged 61%. APC coring continued through Core

U1340A-17H to a depth of 1461.9 m DRF using non-magnetic coring assemblies and with the FLEXIT orientation tool installed. The standard steel coring assemblies were used from Core U1340A-18H through U1340A-42H. APC coring was terminated after Core U1340A-42H after two successive short, incomplete strokes of the core barrel. The XCB coring system was then deployed at Core U1340A-43X and coring continued with the XCB system to Core U1340A-62X. After three straight zero recovery runs, the APC coring system was redeployed. Coring with the APC system through Core U1340A-67H was successful in recovering ~25 m of very sandy sediment. The XCB system was re-deployed and the hole was terminated after Core U1340A-71X when the XCB cutting shoe spacer sub failed, leaving a portion of the sub and XCB cutting shoe at the bottom of the hole. The drill string was pulled back to the seafloor at 2103 hours on July 25th officially ending the hole. Shear pressures were consistent throughout the coring process at 2800 psi. Recovery for Hole U1340A using the APC coring system was 105% with 398.8 m recovered. Recovery for Hole U1340A using the XCB coring system was 61% with 136.7 m recovered. Combined recovery for Hole U1340A using both APC and XCB coring systems was 88.7%.

Hole U1340B

Position: 54° 24.0002' N Lat, 179° 30.9815' W Long (~350 m East of Hole U1340A)

Seafloor: 1308.5 m DRF (APC calculated depth)

Penetration Depth: 53.9 m CSF-A

Coring Systems: APC w/ non-magnetic equipment and orientation

Objective: Obtain continuous sediment cores to ~50 m to determine if slumping is occurring in a similar fashion to Hole U1340A.

Result: Objective achieved.

Hole U1340B officially began when the bit cleared the seafloor at 2103 hours on July 25th ending Hole U1340A. The vessel was offset 350 m east of Hole U1340A. The top drive was picked up and the drill string was spaced out placing the bit at 1305.4 m DRF or 5 m above the “corrected” PDR depth of 1310.4 m DRF. The first APC barrel was pressured up and fired and the barrel recovered 6.4 m of core and an official seafloor depth was established at 1308.5 m DRF. Hole U1340B was spudded at 2340 hours on July 25th. Non-magnetic coring assemblies and the FLEXIT core orientation system were used through Core U1340B-6H. Hole U1340B ended at 0400 hours on July 26th when the

bit cleared the seafloor. Shear pressures were consistent throughout the coring process at 2800 psi. Average core recovery for the APC was 103%. Total depth of Hole U1340B was 1362.4 m DRF or 53.9 m CSF.

Hole U1340C

Position: 53° 23.8113' N Lat, 179° 31.2975' W Long (300 m South of U1340A)
Seafloor: 1304.7 m DRF (Offset from Hole U1340D)
Penetration Depth: 36.8 m CSF (based on offset from Hole U1340D)
Coring Systems: APC w/ non-magnetic equipment and orientation
Objective: Investigate for slumping sediments in Cores U1340C-2H and 3H. Continued coring if no slumping is found.
Result: Slumping Sediments encountered, hole abandoned.

Hole U1340C officially began when the drill string cleared the seafloor at 0400 hr July 26th. The ship was offset 300 meters south from Hole U1340A. A new PDR (precision depth recorder) depth was established and the bit was placed at 1313 m DRF to optimize the core breaks between Hole U1340A and Hole U1340B. The APC was deployed and Hole U1339C was spudded at 0620 hr on July 26th. Unfortunately a mistake in the corrected PDR depth resulted in first core being taken well below mudline. The 9.5 m of core recovery with the APC Core U1340C-1H failed to establish the seafloor depth. APC coring continued through Core U1340C-3H to a depth of 1341.5 m DRF using the FLEXIT core orientation system and non-magnetic coring assemblies. With the exception of the first core shear pressures were consistent throughout the coring process at 2800 psi. Overall core recovery for the APC was 105.3%. The drill string was pulled clear of the seafloor at 0835 hr on July 26th officially ending Hole U1340C.

Hole U1340D

Position: 53° 23.8004' N Lat, 179° 31.2974' W Long (20 m south of Hole U1340C)
Seafloor: 1304.7 m DRF (APC calculation)
Penetration Depth: 26.3 m CSF
Coring Systems: APC w/ non-magnetic equipment and orientation
Objective: Confirm slumping on Holes U1340A, U1340B and U1340C and recover mudline missed on Hole U1340C.
Result: Objective 100% achieved. Slumping sediments found, hole abandoned. Recovered mudline core and completed interval to 26.3 m CSF

Hole U1340D officially began when the drill string cleared the seafloor at 0835 hr July 26th. The ship was offset 20 m from Hole U1340C at 180°. This hole was spudded at 0905 hr on July 26th and the 7.3 m recovered with Core U1339D-1H established a seafloor depth of 1304.7 m DRF. Three APC cores were shot to a depth of 26.3 m CSF. APC coring through Core U1340D-3H used the non-magnetic coring assemblies with FLEXIT orientation. Shear pressures were consistent throughout the coring process at 2800 psi. APC core recovery was 103.5%. The drill string was then pulled and secured for transit. Once the drill collars were racked back and the rig floor was secured for transit, control was transferred from DP to the bridge. The ship was placed in cruise mode at 1534 hr on July 26th for the scheduled 6 hour (65 nm) transit to Site U1341 (BOW-14B).

Official APC coring totals for Site U1340 include 83 total cores, 712.3 m penetrated, 648.1 m recovered, for 91% recovery.

Lithostratigraphy

The sediments recovered at Site U1340 are a mix of biogenic, volcanoclastic, and siliciclastic sediments. Authigenic dolomite also occurs as an accessory sediment type. In general, the color of the sediment reflects its lithologic characteristics: sediment composed of siliciclastic sediment or mixed lithologies tends to be very dark greenish gray to dark gray, while diatom ooze tends to be olive gray to olive or dark gray. Volcanoclastic ash layers are dark gray to black or shades of light gray to white and rarely weak red. Intervals showing soft sediment deformation were observed between Cores U1340A-3H and -8H-2. Three lithologic units were defined at Site U1340.

Unit I is composed of alternating beds of diatom ooze and diatom silt with minor amounts of mixed and volcanoclastic sediment that is Pleistocene in age. The most prominent sedimentary structure in Unit 1 is soft sediment deformation of laminated and bedded diatom ooze and diatom silt. Intervals with soft sediment deformation were observed: Cores 323-U1340A-3H to 323-U1340A-8H-2, and -11H, -12H, -14H, and -15H; Cores 323-U1340B-3H to -6H; 323-U1340C-2H and -3H; and all cores of Hole

U1340D. Folded and tilted bed boundaries are clearly visible in these cores, suggesting the occurrence of synsedimentary slumps as a potential mechanism for the deformation. Distinct volcanoclastic layers ranging in thickness between a few millimeters to 3 cm thickness occur throughout the unit. Volcanic ash is a common secondary or trace lithologic component. A major component of the sediment in Unit 1 is biogenic and predominantly composed of diatoms with generally good preservation. Diatom frustules hosting pyrite framboids were observed. Terrigenous particles are also a major component in Unit 1. The most abundant terrigenous grain types are silt-sized feldspar, quartz, clay, mica and rock fragments. Some pebbles are composed of basalt, and pumice or scoria, indicating a volcanic source. Bioturbation varies from slight to strong throughout all holes and is typically characterized by a mottling defined by color changes. The main lithologies are olive to dark gray diatom ooze and dark gray to dark greenish gray diatom silt with variable amounts of dispersed vitric ash, isolated pebbles, distinct ash layers as well as bioturbated ash/diatom ooze layers and laminated intervals. The light colored sediments (olive) tend to contain predominantly biogenic components, while the dark colored sediments (gray) tend to contain sub-equal proportion of siliciclastic and biogenic components. The volcanic ash layers are typically black, light gray and rarely weak red. Unit 2 comprises diatom ooze with minor amounts of diatom silt, mixed and volcanoclastic sediment that is Pliocene in age. The unit differs from Unit 1 in having significantly more diatom ooze and less interbedded diatom silt and fewer laminated intervals. A layer of gravel was recovered at 380 m CSF-A at Hole U1340A. This is directly below an interval of frequent deposition of gravel-sized clasts: ~220 m to 360 m CSF-A. This gravel-rich interval overlaps the base of Unit 1 and the top of Unit 2. Unit 3, which is further divided into Subunits 3A and 3B, comprises diatom-bearing sponge-spicule-rich ashy-sand; sponge-spicule-rich diatom ooze, diatom ooze and minor amounts of volcanoclastic and siliciclastic sediment of Pliocene age. Core disturbance was observed in all sections collected in Unit 3. The sediment was described as a slurry with water-rich areas at the core surface and along the liners.

Mixed and siliciclastic lithologies in Unit 1 correlate well with magnetic susceptibility changes. The increase occurred at approximately 260 m CSF-A, dated to around 2.6 Ma

and may reflect an increase in sea ice- or glacial ice-rafted debris delivered to the site after the onset of large glacial-interglacial cycles. The rounded shape of many of the gravel-sized grains suggests that their source was a coastal environment and therefore favors the hypothesis that they were deposited as a consequence of sea ice rafting. Relatively large clasts, interpreted as dropstones, were observed most frequently between 360 and 220 m CSF-A (~3.6–1.8 Ma), and their occurrence overlaps with the onset of increased siliciclastic components, coeval with a subtle increase in GRA. This may reflect the onset of Northern Hemisphere glaciation after 3.6 Ma (Mudelsee and Raymo, 2005). The occurrence of extensive intervals with soft sediment deformation related to slumping is somewhat unexpected, as the slope of Bowers Ridge is only slightly inclined at the drill sites. An alternative explanation for the triggering of sediment mass movements could be the seismogenic activity of the Bowers Ridge, which is representing a buried subduction zone, and is relatively close to the volcanic Aleutian arc. Another possibility could be water loss during mineral phase changes in deeper sediments, which may result in less cohesive sediment packages prone to deformation. Between 400 m CSF-A and the bottom of the core (~3.8 Ma), a very high sedimentation rate occurred. The primarily biogenic component of Unit 2 and Subunit 3B may reflect warmer, highly productive Pliocene conditions or a higher sea level.

Micropaleontology

Core catcher samples from Site U1340 are dominated by diatom microfossil assemblages with high diversity. Seventeen datums have been identified in Hole U1340A. Cores 323-U1340A-1H-CC to approximately 34H-CC exhibit a broadly linear sedimentation rate. Thereafter, the sedimentation rate appears to increase drastically with the last three datums all giving the same age of 3.8 to 4 Ma. Siliceous microfossils show consistent occurrences throughout the section, and are mainly composed of high latitude pelagic species indicating changes to surface water productivity. Calcareous microfossils are mostly confined to the top of the section above around Core 323-U1340A-23H-CC for nannofossil, and Core 323-U1340A-31H-CC for foraminifers. Reworked calcareous nannofossil specimens mostly of Miocene and Paleogene ages were found in some samples. The planktic foraminifer fauna does not change radically throughout the

Pleistocene (above 200 m CSF-A) and is dominated by *Neogloboquadrina pachyderma* (sinistral), a subpolar–polar species together with the subpolar species *Globigerina bulloides*, *Globigerina umbilicata*, and *Neogloboquadrina pachyderma* (dextral). Benthic foraminifers are largely characteristic of those found within or near the oxygen minimum zone in high latitude regions. Dinoflagellates consistently occur throughout the section, indicating changes to the productivity and ice cover of the surface waters.

Over 40 species of benthic foraminifera were recovered in 83 samples. Out of over 40 species benthic foraminifera species recovered in 83 samples resemble those from oxygen depleted zones on the Umnak Plateau and elsewhere. Abundance and diversity fell markedly below 282.17 m CSF-A at Hole U1340A, with samples either barren or consisting of a monospecific agglutinated assemblage. Ostracodes were looked for in core catcher samples, but no specimens were found.

Diatoms are the dominant microfossil in all holes, and show good preservation throughout. The LOs of *Proboscia curvirostris*, *Thalassiosira jouseae*, and *Proboscia barboi* were identified at 37.60 m CSF-A for all three species, giving a composite estimated age of 0.3 Ma, based on the result from a piston core from Site ES on the northern Emperor Seamount. The age of 0.9 Ma was assigned at 161.24 m CSF-A by the LO of *Actinocyclus oculatus* and is followed by the first common occurrence (FCO) of *Proboscia curvirostris* at 1.8 Ma. The last common occurrence (LCO) of *Neodenticula Koizumii* was determined at 323-U1340A-25H-CC giving an age of 2.1 Ma. *Neodenticula Koizumii* and *Neodenticula kamtschatica* occur jointly between 323-U1240A-46X-CC and -57X-CC, corresponds to the NPD Zone 8 of 2.7 – 3.9 Ma. The FO of *Neodenticula koizumii* and dominance of *Neodenticula kamtschatica* above 323-U1240A-56X-CC defines this zone as the NPD7 Bb of 3.9 Ma. Diatom assemblages are mainly composed of pelagic species throughout the Pleistocene and late Pliocene. Several significant abundance peaks of a high productivity indicator occur throughout the Upper and Lower Pliocene Period. In general, few coastal water diatoms, including *Chaetoceros* spores, and freshwater diatoms were observed below the Upper Pleistocene, which may be explained by the distant location of this site to continental influence.

Despite of low abundances of silicoflagellates and ebridians two LOs were obtained. The LO of *Dc. subarctios* (0.74 Ma) fits conformably with those of other siliceous microfossils as well as that of paleomagnetism. The LO of *Ebriopsis antiqua antiqua* (2.47-2.48 Ma) is placed at 305.47 m CSF-A.

Consistently abundant to common radiolarians with good to moderate preservation occurred in the upper interval (ca. <200 m) whereas basically few abundances with moderate to poor preservation occurred in the lower interval (ca. >200 m). The radiolarian stratigraphy spans from the *Botryostrobus aquilonaris* Zone (Late Quaternary) to the *Dictyophimus bullatus* Zone (Middle Pliocene), with a missing *Stylatractus universus* Zone (between 0.4 Ma and 0.9 Ma) is due to the absence of *S. universus*. Eleven radiolarian datums derived in the subarctic Pacific were identified at this site.

All samples contain poorly to well preserved palynomorphs. The concentration of terrestrial palynomorphs is low to moderate in most samples. Fresh water palynomorphs (*Pediastrum*, *Botryococcus* and tintinides) occur only in the upper part of the sequence from 42 to 186 m CSF-A. Reworked palynomorphs are generally accompanied by a high number of wood microfragments. Very abundant dinoflagellate cysts occurred only in the upper 200 m CSF-A and lower abundance occurred below. The LO of *Filisphaera filifera* (1.7 Ma) was determined at 216 m CSF-A. The Gonyaulacale *Operculodinium centrocarpum* co-dominates the assemblage together with *Brigantedinium* spp. in the core catcher samples from the uppermost cores. *O. centrocarpum* is closely related to seasonal sea ice cover. All accompanying taxa, except extinct species (*Filisphaera filifera* and *Batiacasphaera minuta*) are known to be abundant in polar and circumpolar regions.

Paleomagnetism

The inclinations measured on Site U1340 sediments average almost 70° over the entire depth range of the cores. The site axial dipole inclination is about 72°. Several distinct

intervals of reversed inclinations are interpreted to be polarity epochs. The declinations, after correction with the FLEXIT tool to orient the declination data with North, suggest that there are multiple polarity intervals in the uppermost 17 cores at Hole U1340A, but the FLEXIT corrections are too poor to be of much detailed use in assigning polarity boundaries. The inclinations provide an initial guide to polarity zonation in Hole U1340A; we could discern the Brunhes, Jaramillo, Olduvai, and Gauss normal polarity Chrons. Polarity boundaries and paleontological age estimates are generally in agreement.

The NRM intensities largely remain at the same level throughout most of Hole U1340A. The NRM and Chi intensities vary over more than an order of magnitude on a meter scale. We interpret this mostly to be due to variable flux of detrital sediment versus biogenic sediment flux (mostly diatoms at this site). The large changes in NRM intensity also appear to be associated with notable detrital (and presumably magnetic) grain size changes. Both of these variations make the relative paleointensity estimates, determined by normalizing the cleaned NRM (20 mT) by magnetic susceptibility, questionable in interpretation. The relative paleointensity variability is quite large, but most of it is strongly correlated with NRM and magnetic susceptibility variability, and probably not mostly due to geomagnetic field variability. As at our last site, we see no notable evidence for the presence of magnetic field excursions in any of the cores.

Stratigraphic Correlation

The composite depth scale and splice at Site U1340 is complete from 0.0–47.7 m (CCSF-A). This splice is tentative because of some evidence for soft-sediment deformation in some of the cores, based on observed sedimentary structures, data features that do not appear to correlate between holes, and in some cases sections that appear to be repeated within a single hole. An interval that contains a distinctive pink ash appears to be present three times in Hole U1340C; twice in Core U1340C-2H, and once in Core U1340C-3H. This appearance of the same sedimentary interval at different subseafloor depths, and replication of section within a single hole, is consistent with visual evidence for tilted beds and non-conformable surfaces. We suggest that sediment deformation has produced

thickened and non-correlative intervals in the depth interval from ~20 to ~45 CCSF-A in Holes U1340B and U1340C, and perhaps also in Holes U1340A and U1340D. We are not confident that the full sedimentary sequence is represented in the composite splice. We tentatively splice Core 323-U1340B-4H as the bottom interval of the splice, which includes the least disturbed intervals through the interval of inferred slumping. Affine Growth Factors in the spliced interval have values of 1.14 in Hole U1340A and 1.18 in Hole U1340B, which are within the normal range typical of many drill sites. The remaining cores at Site U1340 are not tied to the splice but are appended to the bottom of the splice with a constant affine value of 7.31.

Geochemistry

At Hole U1340B nine interstitial water samples ranging from 2.9 to 53.3 m CSF-A (all depths refer to CSF-A) were retrieved by the whole-round squeezing technique. Interstitial water chloride concentrations varied between 528 mM and 570 mM while downhole salinity remained constant at 36 g/kg. Alkalinity increased from 2.9 m to 18 m while only a subtle increase was seen below. DIC showed a similar trend as alkalinity with a maximum concentration at 42.3 m. pH remained unchanged throughout, averaging 7.7. The dissolved sulfate concentrations slightly decreased. Hydrogen sulfide was detected at low concentrations, averaging 4.4 μM . Ammonium concentrations increased with depth, respectively. Phosphate concentrations gradually increased throughout the upper ~12 m followed by a gradual decrease to 53 m.

Methane was the only hydrocarbon gas detected in Holes U1340A and U1340B. Concentration of methane ranged from 0 to 3.1 ppmv and from 2.2 to 6.6 ppmv, respectively. Ethane and other volatile hydrocarbons were not detected. Fourteen core catchers (CC) from Hole U1340A were used for the preliminary analysis of solid-phase total inorganic carbon (TIC), total organic carbon (TOC), total nitrogen (TN) and total sulfur (TS). Calcium carbonate contents in Hole U1340A ranged from 0 to 3.6 wt%. A part of increased CaCO_3 contents between 300 and 400 m corresponds to the intervals where authigenic dolomite and calcite was observed in sediments. TOC and TN contents range from 0.25 to 1.19 wt% and from 0.02 to 0.09 wt%, respectively. TOC decreased

below 400 m. TS contents ranged from 0.09 to 0.42 wt%. Undetectable methane, deep SO_4^{2-} penetration, and low values of DIC, alkalinity, NH_4^+ and PO_4^{3-} suggest extremely low microbial activity as compared to Site U1339 despite similar TOC content.

Microbiology

Samples for abundance of prokaryotes were collected adjacent to interstitial water whole-cores at the same resolution. Samples were fixed for further shore-based analyses.

Physical Properties

Core from all holes were placed on the fast or STMSL track and scanned for magnetic susceptibility and GRA bulk density and on the WRMSL for GRA, MS, and P-wave scanning. Because of noisy data, non-contact resistivity values were not recorded. P-wave velocity and sediment shear strength measurements were not determined on working section halves. MS values spike irregularly, with values ranging from 500-1300 units in the upper 250 m CSF-A, but values were relatively low and invariant below ~250 m CSF-A until 525 m CSF-A when they increased sharply to above 1000 units, registering a thick tephra unit. Bulk density determinations reveal high excursions and an apparent rhythmic pattern of higher values alternating with lower ones. The average reading in the tephra-bearing diatom silt of Unit 1, surface to ~360 m CSF-A, is $\sim 1.4 \text{ g/cm}^3$. Within Unit 1, bulk density decreases with depth to $\sim 1.38 \text{ g/cm}^3$ at ~360 m CSF-A. Below a depth of ~384 m CSF-A and a shift to XCB coring, values lowered additionally to $\sim 1.32 \text{ g/cm}^3$. At Hole U1340A, NGR counts/s, which principally reflect clay mineral abundance, decreases with depth from near surface readings averaging ~ 20 counts/s to about 10 counts/s at a depth of ~380 m CSF-A and below. Presumably, the downhole decrease in NGR counts reflects increasing relative abundance of siliceous biogenic tests and debris of Lithostratigraphic Unit 2.

The P-wave velocity profile for Hole U1340A is variable but generally increases from a near-surface velocity of $\sim 1.52 \text{ km/s}$ to $\sim 1.55 \text{ km/s}$ at ~280 m CSF-A. This section corresponds to Lithostratigraphic Unit 1. In the underlying Unit 2, and in particular below the transition from APC to XCB coring at ~384 m CSF-A, average P-wave

readings exhibit only a subtle continuation of a down-section increase in velocity of about 10 m/s, from ~1.55 to ~1.56 km/s at the bottom of Hole U1340A at ~604 m CSF-A possibly because the diatomaceous ooze section of Unit 2 that included tephra beds is mechanically stronger and less yielding to compaction than overlying diatomaceous silt beds of Lithostratigraphic Unit 1.

The depth distribution of MAD wet bulk density is closely similar to that traced by the WRMSL GRA sensor. The MAD profile documents a slight downward trend of decreasing density, from ~1.42 g/cm³ near the seafloor to ~1.40 g/cm³ at a depth of ~360 m CSF-A. Below this depth, which marks a switch to XCB drilling and a ~25-m-thick section of poor core recovery (~360 to 384 m CFS-A), a low average density of about 1.32 g/cm³ is recorded. But bulk density increases farther downhole to about 1.4 gm/cm³ at the bottom of Hole U1340A at ~604 m CFS-A. Perhaps, a water-rich and partially load-bearing section signaled by the recovery of gravely and sandy beds in the upper part of Lithostratigraphic Unit 2 separates the upper decreasing and lower increasing trends in bulk density.

Porosity and water content profiles at Hole U1340A are similar and exhibit three contrasting trends. For porosity, the upper trend from seafloor to a depth of ~350 m CFS-A displays an average value near 74% that remains virtually constant with depth. The middle trend, which begins below the transition from APC to XCB drilling at ~384 m CFS-A and the zone of poor recovery from ~360–384 m CFS-A, document a shift to a higher average porosity value near 80%, below which the average decreases progressively to ~66% at a depth of ~550 m CSF-A. Porosity measurements decrease to about 75% at the base of Hole U1340A at ~604 m CFS-A (Fig. 3). Hydraulically, the middle porosity sections appear to be separated from the upper one by a permeability barrier in the zone of poor core recovery between ~360–384 m CFS-A. This surmised barrier occurs at the level of a gravel-bearing sequence within the diatom ooze section of lithologic Unit 2. Isolation of the middle trend from the basal one is coincident with lithologic Unit 3, a coarse ashy layer overlying the diatom ooze of Unit 4.

The average grain density decreases down section from near surface values of $\sim 2.61 \text{ gm/cm}^3$ to $\sim 2.5 \text{ g/cm}^3$ at the bottom of Hole U1340A at $\sim 604 \text{ m CSF-A}$. Wide excursions, some of which are so low (below 1.5 g/cm^3) or high (above 2.9 g/cm^3) that measuring error are suspected, occur about the mean, which is $\sim 2.45 \text{ g/cm}^3$. The down section decreasing values appear to reflect an increase in biogenic silica, chiefly diatom frustules, with respect to terrigenous mineral debris and tephra.

Thermal Conductivity

Thermal conductivity (Tcon) was measured on one section, most typically Section 1, of each core collected at Holes U1340A, U1340B, U1340C, and U1340D, and for some cores, Tcon was recorded on a second section. Seemingly incongruous, Tcon decreases downhole from 0.88 W/mK near the surface to $\sim 0.77 \text{ W/mK}$ at $\sim 580 \text{ m CSF-A}$ just above the bottom of Hole U1340A. Excursion to high readings between 1.07 and 1.08 W/mK occur above a depth of $\sim 275 \text{ m CSF-A}$. They are not obviously linked to the occurrence of ash layers revealed by magnetic susceptibility measurements (see Lithostratigraphy and Stratigraphic correlations chapters). A similar downhole trend in decreasing Tcon readings was observed at Site U1339 on Umnak Plateau. It is supposed that the down-section decrease in thermal conductivity reflects an increasing content of siliceous biogenic component with respect to terrigenous material, and, at Hole U1340A, in particular for sediment older than about 2.5 Ma , roughly the new ice-age defining Pliocene/Pleistocene boundary.

Downhole Measurements

The measured temperatures ranged from 5.67°C at 70.4 m DSF to 9.79°C at 165.4 m DSF , and fit closely a linear geothermal gradient of $43.4 \text{ }^\circ\text{C/km}$. The temperature at the seafloor was 2.8°C , based on the average of the measurements at the mudline during all the APCT-3 deployments. A simple estimate of the heat flow can be obtained from the product of the geothermal gradient by the average thermal conductivity ($0.851 \text{ W/m}^\circ\text{C}$), which gives a value of 36.9 mW/m^2 , within the range of previous measurement in the area. Alternatively, if the thermal regime is purely conductive, then the resulting linear fit of the temperature gives a slightly higher heat flow value of 37.8 mW/m^2 .

Sedimentation Rates

Sedimentation rates in the upper Late Pleistocene section appear to be 13–17 cm/k.y. However, below about 30 m (CSF-A) there is evidence of soft sediment deformation, which could have caused post-depositional thickening of the section. From about 150 m (CSF-A) through about 330 m (CSF-A), sedimentary structures indicative of deformation was almost completely absent and the sedimentation rate was 7–9 cm/k.y. Below 330 m (CSF-A) to the bottom of the hole, sedimentation rates were probably at least 24 cm/k.y.