IODP Expedition 400: NW Greenland Glaciated Margin

Site U1606 Summary

Background and Objectives

Site U1606 (proposed Site MB-17A) was cored at position 74°13.9380′N, 61°2.2426′W. water depth 653 meters below sea level (mbsl) on the middle section of the northwest Greenland shelf. The site targets the transition from preglacial contourite drift sediments into glacigenic deposits of earliest Trough Mouth Fan progradation (Seismic Unit 1), marking the first advance of the North Greenland Ice Sheet onto the continental margin. The drilling target was at 411 m core depth below seafloor, method A (CSF-A) near the base of Mega-Unit B above Horizon C1, coring a succession that is complementary to Site U1608. The uppermost 200 m CSF-A at Site U1606 aims to capture a stratigraphic record of the preglacial to glacial transition that hypothetically corresponds to the Pleistocene/Pliocene boundary (Knutz et al., 2019). Below 200 m CSF-A, Site U1606 targets a 220 m thick sedimentary unit characterized internally by a uniform bundle of tilting strata that converges updip against an erosional scarp defined by Horizon C1. The seismic geometries imply accumulation of sedimentary drift deposits over a significantly truncated section of Mega-Unit C (Knutz et al., 2015). The lower sedimentary unit of Site U1606 has a corresponding section at the base of Site U1608.

Operations

Hole U1606A

The vessel transited 44 nmi from Site U1605 to Site U1606. The thrusters were lowered and secured and the ship was fully in dynamic positioning (DP) mode at 2200 h on 13 September 2023. Ice monitoring began and the vessel made the final approach to the site slowly as ice vacated the area. The rig crew made up a rotary core barrel (RCB) bottom-hole assembly (BHA) in preparation for Hole U1606A, and the drill string was partially lowered while we waited on ice to clear the site. By 0230 h on 14 September we positioned the vessel over the site and Hole U1606A was spudded at 0415 h, tagging the seafloor at 652.65 mbsl. Cores U1606A-1R to 20R advanced from 0 to 182.4 m CSF-A and recovered 30.14 m (16%). At 1030 h on 15 September ice moved within 3 nmi of the vessel and we raised the drill string to 24.6 m CSF-A by 1215 h. The ice was slow moving (nearly stationary) and was expected to linger over the site for more than a day while moving closer to the vessel. The decision was made to pull out of Hole U1606A and move to proposed Site MB-07B (Site U1607). The drill string was tripped up, with the bit at the surface at 1424 h. The drill floor was secured for transit and the thrusters were raised and secured for transit at 1500 h on 15 September.

Hole U1606B

The vessel transited the 6.6 nmi from Site U1608 back to Site U1606 on 30 September and arrived at 1715 h. The thrusters were lowered and secured and the ship was fully in DP mode at 1738 h. The vessel was positioned 710 m northeast of Hole U1606A along the seismic line. The rig crew made up an RCB BHA and the drill string was tripped to near the seafloor. Hole U1606B was spudded at 2125 h, tagging the seafloor at 656.4 mbsl. Cores U1606B-1R to 39R advanced from 0.0 to 350.0 m CSF-A and recovered 164.44 m (47%). We tripped the pipe out of the hole, clearing the seafloor at 0110 h on 3 October and ending Hole U1606B.

Hole U1606C

The vessel was offset 181 m southwest of Hole U1606B along the seismic line and Hole U1606C was spudded at 0245 h. The hole was drilled ahead to 25 m CSF-A before removing the center bit and dropping an RCB core barrel. Cores U1606C-2R to 18R advanced from 25.0 to 186.7 m CSF-A and recovered 45.31 m (28%). We tripped the pipe out of the hole, clearing the seafloor at 0355 h on 4 October and ending Hole U1606C.

Hole U1606D

The vessel was offset 598 m southwest of Hole U1606A along the seismic line and Hole U1606D was spudded at 0625 h on 4 October. The hole was drilled ahead to 13.6 m CSF-A before removing the center bit and dropping an RCB core barrel. Cores U1606D-2R to 14R advanced from 13.6 to 132.1 m CSF-A and recovered 7.83 m (7%). We then tripped the pipe out of Hole U1606D, clearing the rig floor at 0815 h on 5 October. The drill floor was secured for transit and the thrusters were raised and secured for transit at 1206 h, ending Hole U1606D and Site U1606.

Principal Results

Lithostratigraphy

The stratigraphy of Site U1606 is divided into four lithostratigraphic units. Site U1606 was drilled along a ~1.3 km long southwest-to-northeast transect and targeted seismic stratigraphic packages with varying thicknesses at each hole; therefore, the Lithostratigraphic Units (LSU) are not laterally continuous and, in some sites, not present as a result of stratal pinchout. Named sedimentary lithofacies include 1) laminated or bioturbated mud with or without dispersed sand, 2) calcareous mud and sand, 3) stratified or bioturbated sandy mud with and without dispersed clasts, 4) stratified or bioturbated muddy sand and sand, with and without dispersed clasts, 5) interlaminated to interbedded sand and mud, and 6) muddy coarse sand, diamicton, and intraclast conglomerate.

LSU I was recovered in Holes U1606A and U1606B and contains unlithified brown mud to sandy mud, overlying LSU II of sandy diamicton ranging from clast-poor to clast-rich, also recovered only in Holes U1606A and U1606B. LSU III is formed of sandy mud and muddy sand with dispersed clasts and has two subunits distinguished by the degree of bioturbation and stratification. LSU IIIA was recovered in all holes of Site U1606 and contains weakly to strongly stratified sandy mud and muddy sand with dispersed clasts. LSU IIIB is identified only in Holes U1606A and U1606C and is characterized as moderately bioturbated stratified sandy mud to muddy sand with dispersed clasts. LSU IV is defined by alternating bioturbated mud and sandy mud (LSU IVA and LSU IVC) with interbedded mud and sand (LSU IVB and IVD). LSU IVA is present in both Holes U1606B and U1606C, whereas LSU IVB, IVC, and IVD are only present in Hole U1606B. Overall, the sedimentary succession collected at Site U1606 is consistent with an ice-proximal, subglacial or proglacial glaciomarine depositional environment with highly variable periods of potential bottom-current reworking.

Micropaleontology

Core catcher samples and additional split-core samples from Holes U1606A and U1606B were examined for foraminifera, diatoms, dinoflagellate cysts, and other palynomorphs. Holes U1606C and U1606D were low recovery and cored the same sequence and thus were not sampled routinely shipboard for biostratigraphic purposes, apart from two test samples for diatom analysis. Subsequent examination of the cores from all holes suggests considerable lithostratigraphic differences that might warrant full paleontological study in the future. The additional samples from working half sections were taken from the upper 1.5 m CSF-A of soft soupy muds of Core U1606A-1R to provide Holocene reference assemblages, and mudline samples from Hole U1606A were also examined. Samples for sedimentary ancient DNA (sedaDNA) were collected in Hole U1606B.

The sandy muds and muddy sands, with variable clast contributions typical of Hole U1606A, contain sparse but reasonably well-preserved calcareous microfossils. Where foraminifera appear, only benthic species occur, and these remain as trace to rare occurrences, except for Sample U1606A-11R-CC-PAL (~94 m CSF-A) where they are rare to common in the >63 µm residue. The benthic foraminifera containing interval from Cores U1606A-10R to 13R (84.51–112.65 m CSF-A) is consistent with an age older than >700 ka. Diatoms are observed in ~52% of all samples examined with poor to moderate preservation. The diatom assemblages observed are consistent with Pliocene age and signify Atlantic water influence at Site U1606. The dinocyst assemblages downhole to ~84 m CSF-A are indicative of a Pleistocene or younger age. In Holes U1606A and U1606B, reworked late Pliocene dinocysts are present. The assemblages of Hole U1606B are consistent with a Pleistocene to Pliocene age. Palynomorph preparations revealed varying abundances of in situ dinocysts and reworked terrestrial palynomorphs. The observed microfossil assemblages are typical of cold-water Arctic environments. Other fossil components observed include bivalve mollusk shell fragments, pieces of terrestrial wood and plants, and fragments of an encrusting bryozoan implying abundant marine life on the Greenland shelf.

Paleomagnetism

Pass-through paleomagnetic measurements from Site U1606 were performed using the superconducting rock magnetometer (SRM) to investigate the remanent magnetization on a total of 182 archive section halves. Measurements were not made on core catcher sections or those that were heavily disturbed. All measurements on archive section halves were made at 2 cm intervals, up to a peak alternating field (AF) demagnetization of 20 mT. A total of 144 discrete cube samples were taken from working section halves. Generally, we collected one sample per core section, avoiding visually disturbed intervals, using the parallel saw. Of the discrete samples, 123 were measured on the SRM and stepwise demagnetized up to 40 mT. The inclinations from the filtered 20 mT step archive section half data are generally bimodal, with a much larger fraction of reverse polarity measurements. Magnetostratigraphy at Site U1606 is highly uncertain, and correlation between holes is complicated by prominent lateral changes in the sedimentary units, reflected in the seismic stratigraphy.

Physical Properties

Standard measurements of physical properties were made on cores from Site U1606 using the Whole-Round Multisensor Logger (WRMSL), Section Half Multisensor Logger (SHMSL), and Natural Gamma Radiation Logger (NGRL) track instruments. Discrete measurements were also made for moisture and density (MAD) analysis, thermal conductivity, and *P*-wave velocities on the *P*-wave caliper system.

Prominent variations in physical property values occur at similar depths in natural gamma ray (NGR) and magnetic susceptibility (MS) and are associated with major lithological changes in the cores; however, the low recovery intervals within this site produce a highly fragmented record of physical properties. A positive correlation is found between NGR counts and MS at Site U1606 and the correlation between these physical properties distinguishes six physical properties units (PP Units I–VI) of Site U1606. In PP Unit I (0–170 m CSF-A) only scattered values related to low recovery were obtained and no trends are discernable. Below, in PP Unit II (170–197 m CSF-A) NGR increases downhole while MS values decrease, which corresponds to the transition from mud to muddy sand within the unit. Density values remain relatively constant across PP Unit II. PP Unit III (197–250 m CSF-A) is characterized by a decrease in NGR downhole while MS values increase and density values remain relatively constant. The upper half of PP Unit IV (250–290 m CSF-A) is dominated by interlaminated sand and mud which transitions to sandy mud in the lower half of the unit. NGR increases downhole in the upper part of PP Unit IV before a sharp decrease to minimum values in the lower part of the unit. Changes in MS and density in PP Unit IV are less pronounced, with MS gradually increasing and density gradually decreasing downhole within the unit. PP Unit V (290–335 m CSF-A) is defined by an increase downhole in MS throughout the unit, which is composed of mud and sandy mud. NGR and density remain relatively constant throughout the unit. PP Unit VI (335–350 m CSF-A) is composed primarily of muddy sand, with the percentage of sand increasing downhole within the

unit. The top of PP Unit VI is marked by a sharp increase in NGR and density and a decrease in MS.

Geochemistry

Samples for headspace gas, interstitial water (IW) chemistry, and bulk sediment geochemistry were analyzed at Site U1606, primarily in Holes U1606A and U1606B. Headspace hydrocarbon gas measurements show low concentrations in the upper 10 m CSF-A of Holes U1606A and U1606B, and below this high concentrations of methane are present to the bottom of Holes U1606A, U1606B, and U1606D (up to 87,400 ppmv). The main findings from IW analysis include low salinity measurements (as low as 12) between approximately 20 and 140 m CSF-A. Gradual downhole increases in salinity, sodium, chloride, and bromide occur below approximately 150 m CSF-A. Elemental analysis of solid material revealed average concentrations of 0.36% organic carbon and 0.05% nitrogen throughout Holes U1606A and U1606B.

Stratigraphic Correlation

Due to the low recovery and the large distance between the holes at Site U1606, the standard procedure for stratigraphic correlation could not be implemented. Physical properties data, including NGR and MS, from all holes at Site U1606 were imported and examined in Correlator v.4. All cores from Site U1606 were cored with the RCB system, and thus gaps and missing intervals were expected. Core disturbances, cores pumped from the liners, and other issues impacting on core quality meant that the stratigraphic coherence of the recovered sequence was variable. Recovery gaps commonly overlap between all holes of Site U1606 in the upper 180 m CSF-A of the record, and only Hole U1606B penetrates significantly below this depth.

Further efforts were made to correlate the record of each hole with the seismic stratigraphy of the area. Physical properties and paleomagnetism together with biostratigraphic and lithological constraints were taken into consideration, and a core-log-seismic correlation was constructed. Despite the uncertainties on the absolute depths, this model provides a means for the further investigation of the Site U1606 record across all holes.

Reference

Knutz, P.C., Hopper, J.R., Gregersen, U., Nielsen, T., and Japsen, P., 2015. A contourite drift system on the Baffin Bay–West Greenland margin linking Pliocene Arctic warming to poleward ocean circulation. Geology, 43 (10):907–910. https://doi.org/10.1130/G36927.1