IODP Expedition 403: Eastern Fram Strait Paleo-Archive

Site U1619 Summary

Background and Scientific Objectives

The Vestnesa Ridge is a roughly east-to-west oriented prominent bathymetric feature situated in the Fram Strait on the western continental margin of Svalbard. Its evolution is linked to the tectonic, sedimentary, and climatic history of the region, making it a focal point for multidisciplinary scientific research. The 100 km long ridge is a sediment drift generated by persistent bottom currents associated with the West Spitsbergen Current (WSC) that developed over oceanic crust since the Fram Strait opening. While the chronology of the Vestnesa Ridge sediment record deposited since the last glacial is well-established and regionally correlatable, the chronology prior to marine isotope stage 3–4 is limited to extrapolation made through seismic profiles from previously drilled sites on the Yermak Plateau (Ocean Drilling Program [ODP] Site 912) and south of the Molloy transform fault (ODP Site 909).

The sedimentation and geological development in this area has been heavily influenced by the Pliocene–Pleistocene glaciations, especially the ice sheet extent over Svalbard and the Barents Sea and the Arctic Ocean sea ice extent. Depositional facies representing a range of glaciogenic and bottom currents depositional processes are well-documented in the recent sedimentary record along the western Svalbard continental margin and the Vestnesa Ridge. The presence of gas hydrates and associated fluid migration are additional controls on the sedimentary record of the Vestnesa Ridge, although more so in the central and eastern areas of the ridge (Site U1618) than in the western extension. The West Vestnesa Ridge contains small, apparently inactive pockmarks, although multidisciplinary investigations point to the presence of methane in the subseafloor.

Site U1619 (proposed Site VRW-03A) on the Vestnesa Ridge west termination was chosen as the northernmost site in Expedition 403. The site is well-situated to provide a record of both high-resolution variability and long-term changes in the northward penetration of North Atlantic waters transported by the WSC at the gateway to the Arctic. The more distal setting of Site U1619, compared to Site U1618, also provides the opportunity to laterally trace glaciogenic deposits originating from the Svalbard Barents Sea Ice Sheet, as well as to examine the history of Arctic sea ice extent into the Fram Strait. For these reasons, the sediment drift at Site U1619 is ideal for paleoceanographic and paleoclimatic studies that can complement research from prior scientific ocean drilling sites further to the north (e.g., ODP Sites 910 and 912 on the Yermak Plateau) and to the south (e.g., ODP Site 908 on the Hovgaard Ridge and ODP Site 909 in the Molloy Basin).

Operations

The vessel completed the 36.3 nmi transit to Site U1619 in 3.2 h with an average speed of 11.3 kt. The thrusters were down and secure and the vessel switched from cruise mode to dynamic positioning control at 1545 h local time (UTC + 2 h) on 23 June 2024, starting Site U1619 and Hole U1619A. A beacon was deployed and a depth reading with the precision depth recorder was taken on arrival.

A total of 5.27 d were spent on Site U1619, penetrating a maximum depth of 627.9 meters below seafloor (mbsf). The cored interval of 627.9 m resulted in a recovered length of 728.35 m (116% recovery). Site U1619 consists of only one hole on Seismic Line CAGE20-5-HH-10-2D. We collected 85 cores in total, with 13% advanced piston corer (APC) use (11 cores), 13% half-length APC (HLAPC) use (11 cores), and 74% extended core barrel (XPC) use (63 cores). To minimize magnetic overprinting on the cored sediment, nonmagnetic collars and core barrels were used for all APC and HLAPC coring. Hole U1619A had intervals where the sediments significantly expanded due to the presence of gas, resulting in recoveries often exceeding 100%. To mitigate the impact of expansion and the potential for core disturbance, and to release the pressure, holes were drilled into the liner, both by the drill crew on the rig floor and by the technical staff on the core receiving platform. In addition, most XCB cores were advanced by 6–8 m to allow for gas expansion of the sediments within the liner. Hole U1619A was terminated at 629.9 mbsf before sea ice began to move into the area. A free-fall funnel was deployed on 28 June at 1245 h in hopes that the ship could reoccupy the hole, but it appeared that the ice would be in the area for at least 10 d, thus the hole and site were abandoned. Ultimately, the ice conditions throughout Expedition 403 remained unfavorable, preventing a return to the site.

Principal Results

The sediments throughout Hole U1619A are primarily siliciclastic, mainly composed of silty clay, clayey silt, clay, and sandy mud, with fewer intervals of clayey sand, sandy clay, sandy silt, silt, and silty sand. One interval of calcareous rich (10%–30%) sediment was observed in Core U1619A-3H. Several intervals of biosiliceous rich sediments were observed in Core 19F, and biosiliceous bearing (5%–10%) sediments were observed in Cores 22F and 34X. These lithologies vary in color, with biogenic bearing to biogenic rich sediments appearing dark greenish gray, while siliciclastic sediments are most commonly gray, dark gray, greenish gray, and black. These sediments contain varying amounts of authigenic mineral precipitants, detrital clasts, laminations, bioturbation, and dark patches, which are used to define lithologic units for this site. Site U1619 is subdivided into two lithostratigraphic units, with Unit I further subdivided into Subunits IA and IB. Small (<1–2 cm) to large (>2 cm) clasts are identified throughout most cores from visual core description and X-radiograph observations, and they range in abundance from dispersed (<1%) to common (1%–5%) and abundant (5%–30%).

Site U1619 was examined for calcareous nannofossils, foraminifers, diatoms, and dinoflagellate cysts (dinocysts). None of these microfossil groups is consistently present throughout the sediment column, and several levels are barren. Calcareous nannofossils appear intermittently across the entire sequence within prolonged barren intervals. Diatoms are almost barren except for the top of Hole U1619A and isolated intervals below. Foraminifers are present in the upper part of the hole and in intermittent intervals downcore. Dinocysts are present throughout the sediment column but are absent occasionally. All groups combined contribute to a first biostratigraphic and paleoenvironmental assessment and an age-depth model for Site U1619. Summary key events from all groups, together with paleomagnetic data, indicate that Site U1619 recovered late Miocene/early Pliocene to latest Pleistocene sediments.

Paleomagnetism investigation of Site U1619 focused on measurements of natural remanent magnetization (NRM) before and after alternating field (AF) demagnetization of archive half sections and vertically oriented cube samples. All archive half sections were measured except for a few that had significant visible coring disturbance as well as core catchers. Some archive half sections with high magnetic susceptibility (MS) were too strong for the NRM to be measured on the superconducting rock magnetometer and caused flux jumps even when the track speed was slowed by 10×, thus compromising our ability to collect quality data in these intervals. However, the intensity often was reduced after AF demagnetization and measurements could then be made. APC and HLAPC archive half sections were measured before and after 10 and 20 mT peak AF demagnetization. As XCB cores do not use nonmagnetic core barrels and are more susceptible to the viscous isothermal remanent magnetization drill string overprint, XCB archive half sections required higher AF demagnetization steps to remove this overprint. These measurements were supplemented by measurement of MS and anhysteretic remanent magnetization on all samples. The Site U1619 magnetic stratigraphy indicates that we recovered a sequence capturing the entire Pliocene and Pleistocene. The base of recovery captured sediments deposited in the latest Miocene during Chron C3r (lower Gilbert).

The physical properties measured at this site included MS, gamma ray attenuation (GRA) bulk density, natural gamma radiation, *P*-wave velocities, and moisture and density (MAD). There is generally a good correspondence between data collected at higher resolution on the MS loop sensor and data collected at lower resolution on the MS point sensor, with the MS point measurements picking up additional peaks in MS that were missed during the averaging in loop sensor measurements. There is also good correspondence between GRA bulk density and discrete MAD sample measurements. Due to the presence of clasts and gas, *P*-wave velocity data are not considered reliable, and there is no detectable signal in discrete or logger data below ~20 mbsf. Thermal conductivity generally increases with depth, in agreement with a decline in sediment porosity. A notable feature of Site U1619 is the prevalence of peaks with MS values orders of magnitude higher than the background. The outsized peaks are infrequent in the upper part of the record, appear at ~150 mbsf, and become more prominent below ~250 mbsf. These MS maxima are likely associated with authigenic Fe-sulfides similar to those observed at Site

U1618 and likely indicate diagenetic alteration. MS is generally low in Lithostratigraphic Subunit IA, indicating this subunit lacks a strong postdepositional alteration signal.

Only a single hole was occupied at Site U1619 and therefore stratigraphic correlation was not possible. The 85 cores reached a depth of 627.9 mbsf and were positioned in stratigraphic order relative to their advance and curated length when recovery was greater than 100%. This resulted in a curated length of 728.35 m. The recovery below ~150 mbsf is strongly affected by gas expansion leading to growth rates of ~1.18. In general recovery at Hole U1619A was very good, often >100%. Subsequent cores were appended by their expansion, assuming minimal coring gaps between cores except for several cores with <100% recovery. Despite being a site with a single hole, the very good recovery and minimal gaps provide a good record for long-term reconstructions.

Samples for interstitial water (IW) chemistry, bulk sediment geochemistry, and headspace gas were analyzed at Site U1619. The main findings from IW analysis are reflective of a gas hydrate and free gas system, diagenetic reactions resulting in the release and consumption of various measured parameters, and fluid flow. Additionally, a few measured analytes in the IWs appear to be correlated with changes in lithology units. There are some high peaks of $CaCO_3$, possibly derived from authigenic carbonate, and total organic carbon/total nitrogen ratios indicate that the organic matter is primarily of marine origin. Methane concentrations peaked sharply at 57 mbsf due to microbial methanogenesis, and ethane and heavier hydrocarbons (C_2–C_6) indicated nonbiological diagenesis with increasing depth. The Vestnesa Ridge sediment drift is situated near the Molloy transform fault and Molloy Ridge and above an extensive gas hydrate system. The dynamics of this gas hydrate and free gas system are assumed to be controlled by proximity to spreading centers and hydrothermal circulation. Specifically, there are extensive variations in gas supply and migration, as well as hydrate formation and dissociation, attributed to multiple factors. The IW geochemistry, bulk sediment geochemistry, and headspace geochemistry are reflective of the impact of a gas hydrate and free gas system.

To test for the oldest recoverable ancient DNA at this site, a total of six sedimentary ancient DNA samples were taken in Hole U1619A, from 398 to 403 mbsf. Additionally, two positive and five negative chemical tracer control samples were taken to track possible contamination from drill fluid. Paleomagnetic measurements suggest that the sampled interval is of Pliocene age.

In Hole U1619A, in situ formation temperature was measured every third core (U1619A-4H, 7H, 10H, and 13F) using the advanced piston corer temperature (APCT-3) probe. After switching to XCB coring, in situ formation temperature was measured before Cores 29X and 45X using the Sediment Temperature 2 (SET2) probe. Temperature increased almost linearly with depth, and the slope of linear regression provides a typical geothermal gradient for the oceanic sediments compared. For Hole U1619A, the heat flow in the sediments and the temperature at the seafloor were calculated using the thermal conductivity measured in Cores 1H–84X and the in situ formation temperature measurements.