IODP Expedition 341: Southern Alaska Margin

Site U1419 Summary

Background and Objectives

Site U1419 (proposed Site KB-2A) is located at 687 m water depth on a relatively flat bank on the continental slope above Khitrov Basin and Ridge. We informally refer to the feature as Khitrov Bank ("KB"). The site is within the influence of the near-surface Alaska Coastal Current and at depths possibly influenced by deeply rooted surface eddies and North Pacific Intermediate Water. The drilling objectives at the site are to develop a high temporal resolution, proximal sedimentary record of late Pleistocene glacial dynamics and paleoceanography. A primary objective is to constrain the timing of glacial events of the Pacific side of the northern Cordilleran ice sheet (NCIS) to test its relation to changes of the larger ice sheets of the Northern and Southern Hemispheres and other global-scale climate effects. An allied goal is to understand the role of north Pacific sea-surface temperatures and subsurface ocean circulation as a possible control on the glacial system over late Pleistocene time, with the potential for decadal-to-centennial resolution in the glaciated and laminated intervals. The proximity of Site U1419 to regions of seasonally high surface productivity offers an opportunity to assess the relative roles of productivity and intermediate water circulation on hypoxia in the northeast Pacific, and their importance in the global carbon cycle. The potential for a highly resolved radiocarbon and oxygen isotopic chronology also may permit documentation of the interrelationship between paleomagnetic intensity and secular variation in the Pacific sector in comparison with records from the Atlantic sector.

This location is ~30 km west of the of Bering Trough mouth that may have been the terminus of the Bering Glacier at the last Glacial Maximum (LGM). The site was surveyed during Cruise EW0408, including a jumbo piston core (~11.5 m long) that contains a record of late-glacial (~17.5 ka) to Holocene hemipelagic and glacimarine sedimentation. Seismic reflection data reveal variations in seismic facies that likely reflect the time-varying input of glacigenic sediment interspersed with biogenic-rich hemipelagic facies. Processed CHIRP data, coincident with multichannel seismic (MCS) profiles, reveal that an upper acoustic transparent layer corresponds to the upper ~8 m of postglacial sediment in Core EW0408-85JC, which dates to younger than 14.7 ka. It is hypothesized that in the CHIRP line and in MCS Line GOA3201 the highly reflective intervals represent coarse-grained glacimarine sediments, while underlying less reflective, acoustically layered sediments represent finer-grained interglacial or interstadial events, when the Bering Glacier terminus retreated relative to the shelf break and ice-rafting of coarse sediment was reduced or absent.

Principal Results

At Site U1419, Holes U1419A–U1419E were drilled to total depths of 193.0, 113.0, 107.1, 103.7, and 75.5 m CSF-A, respectively. Core recovery and refusal depths were significantly affected by frequent lonestones and diamicts. For Holes U1419A–U1419E full length (9.7 m) APC refusals were encountered at 98.4, 81.8, 78.7, 80.16, and 69.0 m DSF, respectively; half-length (4.7 m) APC refusals were encountered at 118.5, 114.03, 108.6, 114.15, and 98.76 m DSF, respectively. XCB coring using the soft-formation cutting shoe was used in only Hole U1419A from 118.5 m DSF to 189.68 m. A total of 101 cores were recovered at Site U1419. A total of 473 m of core over a 517.9 m interval was recovered using the APC systems (91% recovery). The cored interval with the XCB system was 74.4 m with a recovery of 14.86 m of core (20%). APC coring depths in Holes U1419B through U1419E were carefully planned with the aid of the stratigraphic correlators, but poor recovery required five holes to attain essentially complete recovery of ~100 m CCSF-B.

The composite depth scale at Site U1419 was constructed from 0.0–205.79 m CCSF-A. The shipboard splice extends from the mudline to 112.10 m CCSF-D. Weather was calm and ship heave was negligible while coring Site U1419, but the relatively lonestone-rich ice-proximal environment proved challenging for core recovery and for inter-hole correlation. An additional depth scale (CCSF-B) was created to compress and shift the correlated cores back to produce the equivalent drilled interval. Where appropriate, results are reported in this length-corrected, composite depth scale.

The sediment recovered at Site U1419 contains fourteen facies. The dominant facies are dark gray to dark greenish gray mud and diamict, which together account for over 95% of the core recovered. Specific lithofacies include massive mud with and without lonestones, silt, interbedded silt and mud, sand, interbedded sand and mud, interbedded mud and diamict, clast-poor diamict, clast-rich diamict, diatom ooze, biosiliceous ooze, calcareous/carbonate bearing mud, volcanic ash, and volcaniclastic mud and sand. These facies are inferred to reflect deposition from suspension fall out, sediment gravity flows, ice rafting, variable marine productivity, and volcanic eruptions.

The main lithologies of the diamict clasts and lonestones recovered at Site U1419 are, in order of decreasing abundance: siltstone, argillite, sandstone, basalt, granitoid, and chert. The petrology of clasts is similar to that found onshore in the St. Elias Mountains and Chugach Mountains located along the southern coast of Alaska. The rare volcanic ash and volcaniclastic-bearing sand at Site U1419 indicate that the location was proximal enough to either the Aleutian or Wrangell volcanic belts to have occasional influxes of pyroclastic detritus. Smear slides and XRD analysis indicate similar bulk mineralogy downhole, although there are some variations in relative XRD diffraction peak intensities, which may indicate slight variations in mineral content.

Based on facies associations, two Lithostratigraphic Units have been defined. The contact between these Units at Site U1419 is gradational. Unit I largely consists of an olive gray to dark greenish gray diatom ooze to diatom-rich mud, a dark gray to dark greenish gray mud with lonestones, and a clast-rich diamict. The clast content increases at depths greater than ~90 m CCSF-B, forming intervals of mud with abundant clasts. Subordinate lithologies in Unit I include dark gray interbedded sand and mud, thin sand beds with sharp lower contacts, interbedded silt and mud, and volcanic ash. Unit II is a dark gray muddy clast-poor diamict interbedded with dark gray laminated mud and thin coarse sand beds. A few meter-thick intervals of diatom and biosiliceous ooze also are observed. Detailed description of Unit II is limited by incomplete recovery below 114 m CCSF-B. The exact timing of the observed lithologic and compositional transitions requires the development of a detailed chronology at Site U1419.

Microfossil abundance and preservation at Site U1419 varies depending on skeletal composition. Calcareous microfossils (planktic and benthic foraminifera and calcareous nannofossils) are well-preserved and continuously abundant in Site U1419 cores. A total of 14 planktic foraminifera species were encountered at Site U1419; faunal assemblages were dominated by polar to subpolar species. Within the interval from ~80 to 90 m CCSF-B, diatom resting spores and planktic and benthic foraminifera have an abundance peak and the benthic foraminifer *Eubuliminella exilis* dominates the assemblage, suggesting a strong environmental change in the water column and at the sea floor during the time represented by that interval, relative to most of the rest of the recovered record.

Siliceous microfossil preservation and abundance is less consistent. Radiolarian faunas are moderately preserved in the upper 100 m CCSF-B and their abundances fluctuate from rare to abundant. Generally cold-water radiolarian taxa dominate the assemblages. At depths >100 m CCSF-B, most samples examined were barren of radiolarians. The diatom preservation and abundance trends are similar; however, their preservation and abundance is lower than the radiolarians in the upper 100 m CCSF-B. Cold-water diatom species also dominate the assemblage at Site U1419 and are most abundant in the uppermost 10 m CCSF-B and in the interval from 75 to 90 m CCSF-B. Sea-ice related, as well as warm- and temperate-diatom species are observed downhole; however, these species were a relatively minor component of the assemblage and ranged between present and rare. The most likely diatom biozone recognized at Site U1419 is NPD 12 [present – (0.3 ± 0.1) Ma]. The last occurrence (LO) of *Proboscia curvirostris* (D120; 0.3 ± 0.1 Ma) and the LO datum of radiolarian *Stylocontharium acquilonium* (0.4 Ma) were not encountered (i.e., these species were not observed).

The natural remanent magnetization (NRM) intensities of the APC (Holes U1419A–U1419E) and XCB (Cores U1419A-21X to -29X) cores were strong before AF demagnetization (10^{-1} A/m), but were significantly weaker after demagnetization (10^{-2} to 10^{-4} A/m). Intensities vary at both the meter and decameter scale with discrete intervals of very low intensities corresponding with intervals of biosiliceous ooze and diatom-rich mud. Because inclinations generally indicate normal polarity, it is likely that the recovered sediment is exclusively within the Brunhes Chronozone and younger than 0.781 Ma.

Physical property analyses at Site U1419 included measurements on the multisensor logging tracks and sampling for discrete measurements. Whole-round GRA density averages ~1.93 g/cm^3 in the APC cores and displays down-hole recurring variability on the order of ~0.2 g/cm^3. Two intervals of relatively low (<1.8 g/cm^3) GRA density occurred between ~0–6 m and ~80–87 m CCSF-B. After corrections for variable sediment volume within the core liner, specific magnetic susceptibility averages around ~68 cm^3/g down-hole. An interval of high-amplitude variability of specific magnetic susceptibility between 55–90 cm^3/g is found at depths <80 m CCSF-B. The whole-round loop magnetic susceptibility largely co-varies with GRA bulk density from ~0–6 m and ~80–90 m CCSF-B, but a shift to anti-correlation at finer scales is observed from 6–80 m and 90–120 m CCSF-B, suggesting fundamental changes in lithofacies between these intervals. Compressional wave (*P*-wave) velocity was measured on the whole round multi-sensor track (WRMSL). A near continuous record of velocities was captured in Holes U1419C, U1419D, and U1419E between ~5–25 m CCSF-B and showed velocities <1600 m/s. At depths greater than ~25 m CCSF-B, WRMSL *P*-wave velocity measurements were compromised due to the gassy nature of the recovered sediment.

Discrete *P*-wave velocity and vane shear strength were analyzed, and samples were taken for moisture, density, and porosity measurements from Hole U1419A. Void spaces within the unconsolidated sections and gas expansion, as well as gaps in core recovery, resulted in only a limited characterization of *P*-wave velocities; although all discrete measurements at this site were taken within the dominant lithology of the recovered interval. Velocity values show no significant overall trend with depth, though an interval of higher velocity is observed at ~120 m CCSF-B where values increase to ~1800–2100 m/s.

NGR measurements show recurring down-hole variations between 14 and 43 counts per second (cps) with a mean and standard deviation of 32 and 4, respectively. Down-core variability in raw NGR values closely parallel changes in GRA bulk density. Two notable intervals of reduced raw NGR (<30 cps) occur between ~0–6 m and ~80–87 m CCSF-B, corresponding to the uppermost and lowermost part of Lithostratigraphic Unit 1, respectively. Moisture and density (MAD) discrete values correspond well with GRA bulk densities measured on the WRMSL for Hole U1419A. MAD densities increase down hole from ~1.5–1.6 g/cm^3 at the seafloor to ~2.2–2.4 g/cm^3 at ~120 m CCSF-B. The interval between ~120 m and ~140 m CCSF-B was not recovered. Below 140 m CCSF-B, density increases from ~2.0–2.1 g/cm^3 to 2.2 g/cm^3 by ~180 m CCSF-B. Porosity measured on discrete samples generally decreases with depth. Between ~55 and 100 m CCSF-B, the values show more variance, which is more than seen in comparable depth intervals of the grain density values. Shear strength indicates that sediments range from very soft (0–20 kPa) to stiff (up to 79 kPa). Generally, shear strength increases with depth at a constant rate. An anomalous interval of elevated shear strength (~60–79 kPa) is present at ~115 m CCSF-B. This interval coincides with an increase in both *P*-wave velocity and density, and a decrease in porosity.

Routine headspace gas analyses were carried out on samples from Hole U1419A, and 20 samples were analyzed for carbonate, carbon and nitrogen. A total of 22 interstitial water samples were taken for pore water characterization. Total organic carbon (TOC) (0.4–1.0 wt%), total nitrogen (TN) (0–0.1 wt%) and carbonate contents (1.5–4 wt%) are within the range exhibited by Holocene to late glacial sediments at this location. Organic carbon to total nitrogen (C/N) ratios ranged between 10 and 22. Chlorinity, salinity, and sodium profiles document a significant freshening of pore waters with depth. The biogeochemical processes at Site U1419 follow the catabolic sequence, with the exception of manganese reduction that is apparently completed shallower than the depth of the uppermost pore water sample (~3 m CCSF-B). Total sulfate depletion was reached at around 20 m CCSF-B and methane production occurred below 20 m CCSF-B (mostly 10,000–40,000 ppmv), indicating a sulfate-methane transition zone at ~20 m CCSF-B. Ammonium and alkalinity both exhibit broad maxima between roughly 20 and 90 m CCSF-B, suggesting that most organic matter degradation is occurring within the methanogenic zone. This process also seems to release organic matter-derived bromide, boron and phosphate to the pore waters.

Seismic lines GOA3101 and GOA3102 cross Site U1419. At a gross scale, seismic character across both profiles changes at ~997 ms twtt from laterally continuous subhorizontal reflectors (Seismic Units A–B) to generally more chaotic facies with intermittent semi-continuous units below Seismic Unit B (Seismic Units C–K). Seismic Unit A is defined by two high-amplitude, continuous reflectors between the seafloor and ~937 ms twtt. According to a preliminary shipboard travel time-depth conversion, this Seismic Unit correlates with a gray diatom ooze interval with relatively low *P*-wave velocity and density and high magnetic susceptibility that comprises the top ~6 m CCSF-B of the core. Seismic Unit B includes conformable, subhorizontal, continuous reflectors. The corresponding interval of the cores (~5–55 m CCSF-B) consists of gray mud with lonestones, occasional sand layers, and diatom-bearing muds. Seismic Unit C is defined by high-amplitude, semi-chaotic reflectors with some truncations. The lower portion of Seismic Unit C appears to correlate with an interval of low magnetic susceptibility and low density from ~80–90 m CCSF-B, which is comprised of diatom ooze and mud with lonestones. Seismic Unit D (~1045–1095 ms twtt) includes two packages of high amplitude, semi-continuous reflectors, which correspond to an interval of high density and *P*-wave velocity in the recovered sediment between ~113 and ~120 m CCSF-B. This is a muddy clast-poor diamict that is interbedded with laminated mud and thin coarse sand beds. The boundary between Seismic Units C and D likely correlates to the boundary between Lithostratigraphic Units I and II.