IODP Expedition 341: Southern Alaska Margin
Site U1421 Summary

Background and Objectives

Site U1421 (proposed Site GOAL-17A) is located at 721 m water depth on the continental slope seaward of the Bering Trough mouth. Whereas Site U1420 targeted strata above an inactive thrust fault, Site U1421 is positioned to sample correlative strata on the limb of an actively deforming structure, where more deeply buried seismic sequences on the shelf are observed slightly closer to the seafloor. The site is located downslope of the Bering Trough above the youngest two thrusts of the Pamplona Zone where they cut obliquely across the slope. Also, as with Site U1419, this site is within the influence of the near-surface Alaska Coastal Current. The drilling objectives at this site seek to capitalize on good preservation of carbonate microfossils and associated geochronologic methods that can be used to develop a chronostratigraphy of a proximal sedimentary record of late Pleistocene glacial dynamics. A secondary objective is to recover material for provenance studies.

Principal Results

At Site U1421, Holes U1421A–U1421C were drilled to total depths of 702.7, 6.2, and 38.2 m CSF-A, respectively. Core recovery and refusal depths were significantly affected by frequent lonestones and diamicts. For Hole U1421A, full-length (9.7 m) APC refusal was encountered at 65.5 m DSF; half-length (4.7 m) APC refusal was encountered at 96.4 m DSF. XCB coring was used in only Hole U1421A from 96.4 m DSF to 702.7 m. In Holes U1421B and U1421C, full-length APC cores were collected. A total of 92 APC cores were recovered at Site U1421 and recovered 114.47 m of core over a 140.8 m interval (81% recovery). Sixty-six XCB cores penetrated 606.3 and m recovered 61.54 m (10%). The overall recovery for Site U1421 was 24%. APC coring depths in Holes U1421B and U1421C used stratigraphic correlation in an attempt to obtain as complete a section as possible.

The composite depth scale at Site U1421 was constructed from 0 to 695.72 m CCSF-A. The splice consists of one complete and continuous interval from the mudline to 33.21 m CCSF-D. Weather was calm and ship heave was negligible while coring Site U1421, but the relatively lonestone- and gravel-rich ice-proximal environment

severely limited core recovery and quality. Intervals of core disturbance, incomplete recovery, and use of the half-length APC coring system all presented complications in the development of composite record.

The sediment recovered at Site U1421 contains nine facies. The dominant facies are dark gray to dark greenish gray mud and diamict. They account for over 95% of the core recovered. Specific lithofacies include massive mud with and without lonestones, interbedded mud and diamict, clast-poor diamict, clast-rich diamict, diatom ooze, mud with diatoms/biosilica, calcareous/carbonate bearing mud, and mud and diamict with volcanic ash. These facies are inferred to reflect deposition from suspension fall out, sediment gravity flows, ice rafting, and variations in marine productivity.

The main lithologies of the diamict clasts and lonestones recovered at Site U1421 are, in order of decreasing abundance: siltstone, sandstone, and basalt. 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. Smear slides indicate similar bulk mineralogies downhole.

Based on facies associations, two Lithostratigraphic Units were defined. Unit I (0–57 m CSF-A in Hole U1421A) is a very dark gray to dark greenish gray mud, interbedded with diatom bearing mud and diatom rich mud. The number of lonestones varies from dispersed to abundant below 6.4 m CSF-A. One interval of olive-colored thin laminae was deposited above the uppermost lonestones. Unit II (57 to 702.7 m CSF-A) is very dark gray silty clast-rich diamict interbedded with clast-poor diamict and mud with abundant clasts. Most common clast lithologies are siltstone, sandstone, basalt, and argillite. The Unit I/II boundary is marked by an increase in GRA bulk density from 1.9 to 2.2 g/cm^3 where it remains high throughout the clast-rich intervals within Unit II.

Siliceous microfossils occur infrequently at Site U1421 while calcareous microfossils are continuously present. Diatoms at Site U1421 are within the biostratigraphic Zone NPD 12 (0–0.3 Ma) throughout the record. Radiolarians found in Sample U1421A-77X-CC (616.33 m CSF-A, median depth) are in the *Botryostrobus acquilonaris* Zone (0–0.5 Ma). However, in Sample 341-U1421A-46X-CC (343.59 m CSF-A, median depth), we recorded the LO of *Lychnocanoma sakaii* suggesting that sediments are

older than 0.03 Ma. The oldest collected sediments are between 0.03 to 0.3 Ma. Benthic foraminifera appear to be a mixture of transported specimens, largely shallow water neritic and *in situ* specimens typical of middle neritic to upper bathyal depths in the Gulf of Alaska. *Elphidium* spp. specimens are often fragmented, further suggesting that they have a transport history. Relatively more radiolarian and diatom taxa typically found in shallow water (neritic) are observed in the lower part of the section. Deeper water (>500 m) radiolarians increase in proportional abundance between 300 and 400 m CSF-A. Neritic radiolarian and planktic foraminifera species are typical for subarctic faunas. The ratio of cold water to temperate water planktic foraminifera species fluctuates, suggesting some changes in temperature in this record.

The natural remanent magnetization (NRM) intensities of the cores from Site U1421were relatively strong before AF demagnetization (10^{-2}~10^{-1} A/m), but were weaker after demagnetization (10^{-2} to 10^{-3} A/m). Intensities were higher in the APC than in the XCB recovered intervals. Development of a the shallow splice and placement of all Holes on a CCSF-A depth scale allows comparisons to be made of the APC recovered intervals, and intensities are consistent between holes and vary at both the meter and decimeter scale. Because inclinations indicate generally normal polarity it is thought that the recovered sediment is exclusively within the Brunhes Chronozone and younger than 0.781 Ma.

Physical properties were measured on all cores from Hole U1421A, B, and C. GRA bulk density shows down-core increase within the depths of APC coring with slight drops at ~20 and ~50 m CSF-A in Hole U1421A. NGR measurement varied between 14 and 41 counts per second illustrating down-hole increase above ~96 m CSF-A. *P*-wave velocity values from the track delineated between ~1500–~2200 m/s. After switching from APC to XCB coring, *P*-wave velocity of the core sections below ~96 m CSF-A were not measured on the track system. Discrete *P*-wave measurements measured on the working-half sections ranged from ~1450–1975 m/s. *P*-wave values show significant scatter, with a slight increasing downhole trend. Shear strength measurements ranged from ~5–80 kPa and generally increase downhole, with increasing scatter observed starting at Core U1421A-6H. Moisture and density measurements show generally increasing bulk density and decreasing porosity from ~0–50 m CSF-A in Hole U1421A. Below ~50 m CSF-A in Hole U1421A, bulk

density values vary from 1.9–2.4 g/cm^3 and porosities range from 28%–45% with no significant trend.

At Site U1421, 26 interstitial water samples were taken, with sampling resolution in the deeper part of the Hole becoming irregular due to spotty core recovery. Samples were immediately analyzed for alkalinity, pH, salinity and chlorinity. The complete sample set of Site U1421 was analyzed by IC analysis for cations and anions, by ICP-AES for minor elements, and by spectrophotometry for ammonium and phosphate. In addition, 64 headspace samples were analyzed for hydrocarbon gases, and in total 44 discrete sediment samples were analyzed for total carbon, nitrogen, carbonate, and TOC contents. Alkalinity values are generally between 9–15 mM, with maxima at ~48 m CSF-A and ~441 m CSF-A. Overall, both chlorinity and salinity are low, with minima recorded at ~40–70 and 485 m CSF-A. Methane concentrations are highly variable, ranging between the detection limit and 34,000 ppmv. Peaks in methane occurred around 57 m CSF-A (up to 20,000 ppmv) and around 276 m CSF-A (up to 34,000 ppmv), while in large parts of the record, concentrations were below 5,000 ppmv. Carbonate contents are below 2 wt% in most samples, but there are a few isolated peaks (3–13 wt%) that appear to be related to mud-rich lithologies. TOC contents are low overall, but accumulation rates are high, and C/N ratios indicate variable contributions from terrigenous organic matter. Down-core profiles of ammonium, alkalinity, and methane reflect moderate organic matter remineralization overall, with zones of higher degradation likely related to the increased presence of more labile marine organic matter.

Two tool strings were deployed in Hole U1421A on the basis of potentially unstable borehole conditions and limited time at the end of the expedition: the Sonic-Induction tool string and the Versatile Seismic Imager (VSI) tool string. The Sonic-Induction tool string, initially deployed in the previous hole (U1420A), was composed of the Enhanced Digital Telemetry Cartridge (EDTC), Hostile Environment Lithodensity Sonde (HLDS) without neutron source, Dipole Shear Sonic Imager (DSI) and Phasor Dual Induction-Spherically Focused Resistivity Tool (DIT) respectively measuring total gamma ray, borehole diameter, sonic velocity and resistivity. The Sonic-Induction tool string was able to reach a total depth of 697.3 mbsf. The second tool string was the VSI tool string, run without the Hostile Environment Natural Gamma

Ray Sonde (HNGS) due to concerns about borehole instability. The VSI tool string was able to reach a total depth of 697.3 mbsf. With the exception of some thin washouts, borehole diameter varied smoothly and rarely exceeded 18 inches, the limit of the HLDS caliper arm. The character of the borehole wall in Hole U1421A on the shelf is a distinct change from the rugose character observed at the deeper-water sites (U1417 and U1418). Above 500 m WMSF, borehole diameter ranges from 10 to 17 inches, with an average diameter of ~15 inches. The hole was nearly in-gauge below ~500 m WMSF, with the exception of a washed-out zone between 583 and 591 m WMSF. High coherence in sonic waveforms was observed in the compressional velocity (Vp) and flexural velocity (Vs) tracks. Gamma ray data was logged through the entire hole. The gamma ray measurement is highly attenuated when the tool is inside the bottom hole assembly (above ~96 m WMSF), however while the log signal is attenuated and there is a slight vertical offset, there is still a reasonable agreement between gamma ray from logs and cores and similar trends are shown in both data sets. The Vertical Seismic Profile using the VSI tool provide data for establishing a link between core and log data (recorded in depth) and seismic surveys (recorded in two-way travel time). Six of the nine VSP depth stations yielded travel times ranging from 1.278 s two-way time below sea level at 284.7 m WMSF to 1.641 s at the deepest station at 687 m WMSF.