IODP Expedition 341: Southern Alaska Margin
Site U1420 Summary

Background and Objectives

Site U1420 (proposed Site GOAL-15C) is located at 259 m water depth within the Bering Trough, a shelf-crossing trough formed by the Bering Glacier advancing across the shelf during glacial periods. The drilling objectives at this site are to drill through several regional seismic reflection packages on the outer continental shelf site that can place these seismic units within a lithostratigraphic and chronostratigraphic context. Doing so allows to test the fundamental hypothesis of the expedition that the St. Elias Orogen has undergone a perturbation associated with the expansion of ice sheets following mid-Pleistocene transition (MPT) that has markedly changed the patterns and rates of deformation and exhumation in the orogenic wedge. The drill site penetrates through an angular unconformity at shallow sub-seafloor depths (180–200 m expected) that has been suggested to be the first occurrence of grounded glaciers reaching the outer shelf edge. Below this angular unconformity are the waning folds of a portion of the Pamplona Zone, which is a fold-and-thrust belt that has accommodated some of the tectonic shortening caused by the underthrusting of the Yakutat Terrane beneath North America to form the St. Elias orogen. Previous mapping suggests that the folding within the Pamplona Zone beneath the Bering Trough waned by the time of a seismic reflection at ~1.4 s twtt. The lack of significant deformation in the sequences above this reflector indicates that the underlying faults were abandoned prior to the angular unconformity, possibly due to loading by sediments.

The drilling objective at the Site is to address the hypothesis that the onset of ice streams has resulted in correspondingly high erosion rates that could markedly alter orogenesis. Drilling targets are the angular unconformity and 1.4 s twtt reflectors. Retrieval of sediments from the seafloor to 1.4 s twtt will provide age control, which is lacking for this location, thus determining sediment accumulation rates that can be used to test the hypothesis. Cored sediments can also provide provenance records that can be used to test the hypothesis that the locus of erosion is within the windward side of the orogen coincident with the glacial equilibrium line altitude, the zone of maximum glacial erosion.

Principal Results

At Site U1420, Hole U1420A was drilled with the RCB coring from Core U1420A-1R through -106R (1020.8 m CSF-A). Recovery over the entire hole was problematic because of the presence of numerous rock clasts that continually jammed the core catchers and prevented core recovery. A total of 106 rotary cores were taken over a 1020.8 m interval and recovered 139.91 m of core (14%). Recovery from 58.2 to 448.5 m CSF-A was less than 10% but improved below 448.5 m CSF-A, where several cores were collected with recovery between 30%–94%.

The limited sediment recovered at Site U1420 contains seven facies. Numerous drilled rocks and washed clasts were recovered in the hole without a supporting matrix lithology. The dominant facies are very dark gray to dark gray clast-rich and clast-poor diamicts. Additional facies include massive mud with and without lonestones, mud with diatoms/biogenic silica, calcareous/carbonate bearing mud, and volcaniclastic mud and diamict. 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 drilled rocks, washed pebbles, clasts within the diamict, and rare lonestones contained in the sediment are, in order of decreasing abundance: sandstone, siltstone, basalt, and granitoids. The granitoid group includes intermediate and felsic intrusive rocks. Argillite, rhyolite, and metasandstone represent minor lithologies. 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 volcaniclastic-bearing mud at Site U1420 indicates that the location was proximal enough to either the Aleutian or Wrangell volcanic belts to have periodic influxes of pyroclastic detritus. Smear slides and XRD indicate similar bulk mineralogies downhole, although there are some variations in relative XRD diffraction peak intensities, which may indicate slight variations in mineral content.

Based on characteristic facies associations, three Lithostratigraphic Units have been defined. The contacts between Units are not observed due to the poor core recovery. Lithostratigraphic Unit I consists of very dark gray muddy, clast-rich diamict interbedded with clast-poor diamict with angular to rounded clasts ranging in size from granule to pebble. The diamict beds are massive and have mainly silt and clay matrixes with some outsized sand grains. Core recoveries within Lithostratigraphic Unit II ranged from 0%–8%. The majority of the section in Unit II was not recovered. The material that was recovered mostly contains washed pebbles as well as cylindrical shaped drilled rocks with abraded surfaces. Lithostratigraphic Unit III consists of very dark gray clast-rich, muddy diamict and a very dark gray to dark gray clast-poor, muddy diamict interbedded with very dark gray to dark greenish gray mud with or without clasts. Drilled rocks occasionally occur coincident with low core recovery. These lithostratigraphic units are interpreted as reflecting sedimentation in a dynamic setting primarily influenced by grounded ice and/or glacimarine processes with intervals of biogenic accumulation.

Microfossil abundances are generally low at Site U1420A. Diatoms and radiolarians are only observed in three intervals. Thus, age constraints are few, but suggest an age younger than 0.7 Ma. Benthic and planktic foraminifera are better preserved and occur throughout the record. Diatom occurrence is mostly low and preservation varies strongly, but is mostly poor. The diversity of the diatom community is low and mainly consists of Pleistocene to Holocene species. Cold-water species are the most abundant and coastal and benthic diatoms are observed. Radiolarians are mostly barren except for three intervals, and the fauna is mostly marked by the presence of cold, shallow water radiolarians, except for below ~750 m CSF-A where the assemblage is marked by relatively high abundances of deep-water species. Planktic foraminifera were present, sometimes in high abundance, and the preservation was generally good. Planktic foraminifers are mostly associated with cold-water conditions. Benthic foraminifera were present to abundant and preservation varied between good and poor. Changes in the composition of the benthic foraminiferal fauna suggest changes in water depth ranging from inner neritic to upper bathyal.

The natural remanent magnetization (NRM) intensities of the cores were strong before AF demagnetization (10^{-2}~10^{-1} A/m), but were weaker after demagnetization (10^{-2} to 10^{-3} A/m). 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 property analyses included measurements on the multisensor logging tracks and sampling for discrete measurements. Whole-round GRA density averages ~1.8

g/cm^3 in the RCB cores and displays down-hole variability on the order of ~0.3 g/cm^3, but values are affected by the variable diameter of the recovered sediment in the cores. Specific magnetic susceptibility averages ~54.3 cm^3/g, with several successions of variability between 25–70 cm^3/g below 550 m CSF-A, appearing to increase below ~940 m CSF-A. Due to poor core recovery, *P*-wave measurements using the *P*-wave caliper (PWC) tool only were obtained below ~449 m CSF-A, where values show no significant overall trend with depth and vary widely, sometimes within the same core section—likely due to the varying amounts and lithology of clasts in the diamict. Though values generally range from ~1500 to ~2000 m/s, occasional high values with velocities >2200 m/s were also observed. Low-frequency variability in mass-normalized NGR activity is limited in the recovered cores, although an increase in activity below 940 m CSF-A parallels changes in normalized magnetic susceptibility and may reflect a change in lithology. Moisture and density (MAD) values range from 2.0–2.4 g/cm^3 between ~40 and 440 m CSF-A. Below ~440 m, MAD values vary from ~2.0–2.4 g/cm^3 to ~2.1 g/cm^3 with no obvious overall trend with depth. Grain density values consistently display wide variance from ~2.7 to 3.0 g/cm^3 and do not appear to correspond with lithology. Porosity measured on discrete samples generally decreases with depth. However, there are some ~10–20 m thick intervals of large variations in porosity (~22%–45%) where the higher values correspond with muddy lithologies. Porosity is ~25%–30% in the clast-rich diamict facies. Void ratio values mimicked porosity with depth, averaging ~0.4. Only four shear strength measurements were obtained, all shallower than 40 m CSF-A. All measurements were taken in the dominant lithology of the recovered sediment and were low (~20 kPa).

Routine headspace gas analyses were carried out on samples, and 41 samples were analyzed for carbonate, carbon and nitrogen. A total of 20 interstitial water samples were taken for pore water characterization. Due to strongly recovery/lithology-influenced interstitial water sample spacing, the resulting down-core profiles of chemical parameters are discontinuous and need to be interpreted with caution. Total organic carbon (TOC) (0.4–0.9 wt%), total nitrogen (TN) (0.01–0.07 wt%) and carbonate contents (1.2–4.2 wt%) have no overall down-core trend. Organic carbon to total nitrogen (C/N) ratios ranged between 11 and 77, consistent with dominantly terrigenous organic matter input, with the highest values recorded between ~600 to 800 m CSF-A. Alkalinity (<12 mM) and phosphate (<4 µM) have low concentrations, while ammonium concentrations are relatively high (up to 2.5 mM). Sulfate concentrations ranged from 2.2 to 7.6 mM, with the maximum concentration recorded at 10.7 m CSF-A. Total sulfate depletion was not observed, although sulfate reduction likely occurs within the uppermost 40 m of the sediment, and methane production occurred mostly below 410 m CSF-A (1,700–33,000 ppmv). Ethane was present in samples starting at 244.9 m CSF-A, and concentrations remained very low throughout Hole U1420A (<5 ppmv). Chlorinity, salinity, and sodium profiles document a significant freshening of pore waters in all recovered samples with respect to the overlying seawater. The freshening is particularly extreme in the upper 40 m, and in the interval between ~760 and 900 m CSF-A, and likely has an additional yet unconstrained effect on other pore water parameters as well (e.g., sulfate, magnesium, potassium).

Due to concerns about borehole stability based on poor core recovery and challenging coring conditions, only one logging tool string was deployed in Hole U1420A. This Sonic-Induction tool string was designed to provide the highest priority measurements to meet science objectives with the lowest risk to logging tools. The string comprised 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) and measured total gamma ray, borehole diameter, sonic velocity and resistivity. Due to a bridge or collapsed borehole, the tool was only able to log from ~90 to 290 m WSF. The caliper measurement indicates that the borehole diameter exceeded 18 inches, the limit of the HLDS caliper arm, in the upper and lower sections of the logged interval. Borehole size was smaller (~15 inches) between ~140 and 200 m WMSF. Even with this large aperture, the data seem to be of good quality as the measurements showed relatively consistent variability throughout the logged interval. The logged interval was assigned to a single logging unit based on the minimal measurements recorded and the limited depth interval of the logging data in the context of the entire drilled depth. However, on the basis of distinctive changes in resistivity and velocity measurements, Logging Unit 1 has been sub-divided into five Subunits. Logging Subunit 1B is distinguished by abrupt decreases in gamma ray and resistivity measurements. The deep resistivity curve likely measured formation, whereas the shallow and medium curves mostly likely reflect the resistivity of the borehole fluid given the large borehole diameter.

Gamma ray, resistivity, and velocity (Vp) all increase at the Subunit 1B/1C boundary, whereas gamma ray decreases and resistivity and Vp increases across the Subunit 1C/1D boundary. All three of these logs then decrease and the caliper increases in Subunit 1E. Overall, resistivities in Hole U1420A are generally greater than 3.0 Ωm, with the deepest resistivity curve showing values greater than 8 Ωm in Logging Subunit 1D. Relatively high velocities (~1700 to >2500 m/s) were measured within this shallow logged interval from ~92 to 282 m WMSF.

Each of the seismic profiles that cross Site U1420 exhibits a distinct change in stratal architecture across the regional unconformity. At Site U1420, the seismic packages above the angular unconformity are acoustically semi-transparent and semi-chaotic, containing erosional surfaces that likely are related to glacial advance-retreat cycles. According to the twtt-depth conversion using both the PWC and extrapolated sonic log values, the shallowest of these surfaces likely corresponds with the boundary between Lithologic Units I and II. Lithologically, Unit I is characterized by a massive clast-rich diamict whereas Lithologic Unit II consisted primarily of washed pebbles and drilled clasts of varying lithologies. Logging Units 1a to 1d show changing velocity, natural gamma, and resistivity that appear to correlate with changes in seismic facies. Logging Unit 1e coincides with the uppermost aggradational packages that are truncated by the angular unconformity. Below Logging Unit 1e (~282 m WMSF) we observe increasing disparity between *P*-wave velocities measured by the *P*-wave caliper and those extrapolated from the sonic log. This velocity discrepancy creates potential errors in twtt calculation up to ~200 ms and post-cruise analysis will be essential for further core-log-seismic interpretations.