IODP Proposal Cover Sheet

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Prince William Sound Subduction and Climate

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Title	Understanding megathrust earthquake hazards and post-LGM climate change along the southern Alaska margin through scientific drilling
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Keywords	Alaska, megathrust, paleoseismology, climate, landslides
Area	Prince William Sound, Alaska

Proponent Information

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Country	United States

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Abstract

Southern Alaska is a preeminent location to address central IODP challenges, with sedimentation rates providing exceptional resolution of time-varying processes. The Prince William Sound region of Alaska experienced a Mw 9.2 earthquake in 1964 and is the best modern example of a glaciated subduction margin. We aim to develop a paleoseismic and paleoclimate record to address: 1) megathrust earthquake recurrence, the completeness of marine paleoseismic records, mechanical conditions governing tsunamigenic splay faulting, and submarine landsliding; 2) distal-proximal timing, synchroneity, and abruptness of Cordilleran Ice Sheet dynamics linking to nearby IODP Exp. 341 drilling, and extending the highest resolution site U1419 to ~150,000 years to compare deglacial dynamics across two glacial terminations, and understand the dynamics of Cordilleran ice growth. Seismic data indicate likelihood of collecting good stratigraphic sequences through Marine Isotope Stage 3 in Prince William Sound and to MIS 6 in Junken Trough and Kayak Slope, to test emerging hypotheses about abrupt climate and ice sheet change, and ice-ocean-sediment interactions in large marine terminating outlet glaciers.

We propose drilling four areas:

(1) Port Valdez - a) Develop a history and mechanistic understanding of large submarine landslides, compare the timing to terrestrial paleoseismic records, and test relationships between frequency and/or volume of landslides during neoglacial times (last 3-4 kya) relative to earlier Holocene; b) Analyze a Holocene climate record to examine the potential causes and impacts of Holocene climate states at high resolution.

(2) Central Prince William Sound Basin - a) Collect a late Pleistocene climate and sedimentary record and establish timing of major ice stream deglaciation; b) develop a potential 10,000-year record of megathrust earthquakes; c) examine a high-latitude record of abrupt MIS 3 climate changes in an ice-proximal setting; d) establish slip rate and variability of a megasplay fault.

(3) Junken Trough - a) Constrain rates and progression of megathrust splay faulting that ruptured in 1964, b) evaluate mechanical properties and fault zone structure by drilling through a modern active splay fault; c) develop ice-proximal climate record through three glacial cycles.

(4) Kayak Slope - Obtain: a) a long (~150,000 yr) continental slope record of deglaciation and climate change extending the well-dated Quaternary record at nearby Site U1419, b) compare/contrast the LGM deglaciation to older transitions (MIS 5-6), and examine ice growth dynamics in the transition from the last interglacial to the last ice age. Compare with nearby Junken Trough, and with other global margins to determine ice stream synchronicity.

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Scientific Objectives

We will develop a high-resolution paleoseismic and paleoclimate record from the last glacial cycle. We will evaluate marine paleoseismic techniques by comparison to terrestrial records, and establish the timing of deglaciation from distal to proximal sites. We will examine megathrust earthquake variability, the mechanical conditions governing the role of potentially-tsunamigenic splay faulting, submarine landsliding, and the relationships among climate change, glacial behavior, and sea level rise after the LGM. We expect to sample MIS 1 to 6 sediments, developing a finely resolved climate history for the subarctic Pacific ocean and testing hypotheses on the role of North Pacific climate and Cordilleran ice in the global climate system to evaluate if late Pleistocene ice retreat was catastrophic or gradual, and synchronous or diachronous compared to previous findings. We propose drilling multiple holes in four locations.
(1) Port Valdez - mechanics and frequency of submarine landslides; proximal Holocene climate; relationship between climate state and large landslide frequency and volume.
(2) Central Prince William Sound Basin - post-LGM climate and earthquake record, with additional constraints on pre-LGM climate and megasplay faulting slip rates.
(3) Junken Trough - rates and progression of megathrust splay faulting; mechanical properties of splay fault zones; development of an ice-proximal record of high-latitude climate and marine-terminating ice streams through multiple glacial cycles.
(4) Kayak Slope - continental slope record of the full last glacial cycle and climate change at high resolution; recover pre-LGM glacial-interglacial climate transitions; sample proxies for water mass dynamics and relation to climate, sea ice, regional productivity, and subsurface ventilation.

Non-standard measurements technology needed to achieve the proposed scientific objectives

Not applicable.

Have you contacted the appropriate IODP Science Operator about this proposal to discuss drilling platform capabilities, the feasibility of your proposed drilling plan and strategies, and the required overall timetable for transiting, drilling, coring, logging, and other downhole measurements?

yes

Science Communications Plain Language Summary

Using simple terms, describe in 500 words or less your proposed research and its broader impacts in a way that can be understood by a general audience.

The region of Prince William Sound, Alaska, USA, is home to dynamic glacial processes and great earthquakes that generate landslides and tsunamis, and it serves as a natural laboratory to understand these systems based on their past behavior, now recorded in layered sediments that can be recovered by drilling. The sedimentary record here has exceptional time resolution due to extremely high rates of glacier-produced sediment delivery into the Sound and neighboring continental shelf and slope. This finely resolved sedimentary record documents past events in the region. This relatively compact and cost-effective drilling program will improve understanding of advances and retreats of marine-terminating glaciers, faulting and earthquakes, and other natural hazards, and test specific hypotheses that will be applicable to global systems.

We propose four distinct scientific drilling locales to capture these records. (1) Port Valdez - mechanics and frequency of submarine landslides; proximal Holocene climate; relationship between climate state and large landslide frequency and volume. (2) Central Prince William Sound Basin - post-ice-age climate and earthquake record, with additional constraints on pre-ice-age climate and earthquakes. (3) Junken Trough - rates and progression of shallow faulting; mechanical properties of splay fault zones; development of an ice-proximal record of high-latitude climate and ice streams through multiple glacial cycles. (4) Kayak Slope - continental slope record of deglaciation and climate change both since the Last Glacial Maximum and previous transitions between climate states including the ice dynamics during both warming (ice loss) and cooling (ice advance), meltwater and sea ice, and effects on marine productivity.

This proposed expedition builds on the results and experience of IODP Expedition 341 (Tectonics, climate, and sedimentation in the Gulf of Alaska), as well as an extensive onland earthquake record, and offshore seismic images of active thrust faults that slipped in the 1964 Mw9.2 great earthquake. The science proposed is of extremely high interest to the public, addressing themes of natural hazards in the Pacific Rim, rates of abrupt climate changes, and impacts of warming on glaciated systems. The location and time interval to be studied are key to issues of climate and sea level influences on early human migration from Asia to North America, especially via the proposed “kelp highway” marine route, which is the most viable route for peopling of the Americas during the Last Glacial Maximum, a topic that attracts broad public interest in new scientific findings.

Proposal History

Submission Type: Resubmission from previously submitted proposal

Review Response

We appreciate a positive evaluation from the SEP and acknowledge their constructive feedback. Below we respond to their primary requests and comments.
SEP requested inclusion of testable hypotheses. We include such for each thematic component and drill site, and emphasize each region addresses multiple hypotheses related to climate and earthquakes.
SEP questioned our proposed chronological approach. We explain and justify how we plan to implement our proposed methods to attain the chronologies necessary to test the hypotheses.
We obtained new Chirp/TOPAS data over the previously proposed Junken Slope sites, and found they were unsuitable. We therefore replace those sites with the “Kayak Slope” sites near Site U1419 to recover an extended late Pleistocene record that addresses our original objectives. The new TOPAS survey shows that the Kayak Slope site is a singularly unique depocenter where previous drilling nearby at U1419 demonstrates recovery potential and drilling safety.
The SEP suggested not drilling the deviated borehole across the Cape Cleare fault and suggested drilling our alternate site on the Patton Bay fault strand. We accepted this suggestion, and with further assessment found a better site on an adjacent profile without the need for deviated drilling.
The review asked for better justification of velocities used, which we added.
The review asked for additional processing and multiple removal of the seismic data. This was not done as the short streamer length of the minisparker data are not amenable to those methods. The review stated the uploaded seismic data was “low resolution”, however, all the uploaded data was at full resolution.
The SEP asked for better documentation of our knowledge of the lateral stratigraphy/3D context at sites where we do not have crossing lines, which we add to the SSDB.
The review stated we needed to clarify why terminus behavior of glaciers is important and suggested we add modeling expertise for ice sheet dynamics. We address both in the revised text and added a proponent with these modeling skills.
There was concern about whether ice-sheet related questions were of global or regional importance. We addressed this by clarifying how the proposed records would advance our basic understanding of ice-sheet stability, and therefore critical to predicting the fate of the Greenland and Antarctic ice sheets in a warming world.
We discussed the drilling plan with the IODP Science Operator. Several concerns were raised: 1) Drilling a deviated hole in Junken Trough was not a possibility, so we abandoned that idea. 2) There would not be enough room on deck to store all the core and our proposed effort was two weeks longer than a normal expedition. We note the need for four APC holes at some sites, based on the challenges inherent in drilling a glaciated margin and our experience with Exp. 341, in which additional holes helped obtain complete records. Moreover, there is not likely to be the 100% recovery as was assumed by the operator given the glacimarine target rocks (see Exp. 341), which will reduce the volume of core to reasonable levels.

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Proposed Sites (Total proposed sites: 19; pri: 10; alt: 9; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
PWSPV-01B (Primary)	61.10790 -146.46833	242	403	0	403	The Port Valdez sediments will contain a proximal record of post-LGM climate change and submarine landslides. With drilling, we will develop a history and an understanding of the mechanics of submarine landsliding, compare this record to the terrestrial paleoseismic history, and evaluate the completeness of the record and the frequency of landslides. We will develop a unique proximal climate record after deglaciation, albeit punctuated by submarine landslide debris, to be compared to more distal sites to understand the timing and rates of deglaciation around the northern Pacific.
PWSPV-02A (Alternate)	61.10764 -146.49375	245	445	0	445	The Port Valdez sediments will contain a proximal record of post-LGM climate change and submarine landslides. With drilling, we will develop a history and an understanding of the mechanics of submarine landsliding, compare this record to the terrestrial paleoseismic history, and evaluate the completeness of the record and the frequency of landslides. We will develop a unique proximal climate record after deglaciation, albeit punctuated by submarine landslide debris, to be compared to more distal sites to understand the timing and rates of deglaciation around the northern Pacific.
PWSPV-03A (Primary)	61.09381 -146.60730	251	391	0	391	The Port Valdez sediments will contain a proximal record of post-LGM climate change and submarine landslides. With drilling, we will develop a history and an understanding of the mechanics of submarine landsliding, compare this record to the terrestrial paleoseismic history, and evaluate the completeness of the record and the frequency of landslides. We will develop a unique proximal climate record after deglaciation, albeit punctuated by submarine landslide debris, to be compared to more distal sites to understand the timing and rates of deglaciation around the northern Pacific.
VAL-01A (Alternate)	61.1147 -146.4419	237	293	0	293	The Port Valdez sediments will contain a proximal record of post-LGM climate change and submarine landslides. With drilling, we will develop a history and an understanding of the mechanics of submarine landsliding, compare this record to the terrestrial paleoseismic history, and evaluate the completeness of the record and the frequency of landslides. We will develop a unique proximal climate record after deglaciation, albeit punctuated by submarine landslide debris, to be compared to more distal sites to understand the timing and rates of deglaciation around the northern Pacific.
VAL-02A (Alternate)	61.1124 -146.4608	238	308	0	308	The Port Valdez sediments will contain a proximal record of post-LGM climate change and submarine landslides. With drilling, we will develop a history and an understanding of the mechanics of submarine landsliding, compare this record to the terrestrial paleoseismic history, and evaluate the completeness of the record and the frequency of landslides. We will develop a unique proximal climate record after deglaciation, albeit punctuated by submarine landslide debris, to be compared to more distal sites to understand the timing and rates of deglaciation around the northern Pacific.
VAL-03A (Primary)	61.0967 -146.5447	246	312	0	312	The Port Valdez sediments will contain a proximal record of post-LGM climate change and submarine landslides. With drilling, we will develop a history and an understanding of the mechanics of submarine landsliding, compare this record to the terrestrial paleoseismic history, and evaluate the completeness of the record and the frequency of landslides. We will develop a unique proximal climate record after deglaciation, albeit punctuated by submarine landslide debris, to be compared to more distal sites to understand the timing and rates of deglaciation around the northern Pacific.
PWSCB-01B (Primary)	60.52442 -146.875115	332	284	0	284	The Central Prince William Sound basin sediments will contain a complete record of post-LGM climate change. This site will also help us test rates and timing of deglaciation in the north Pacific, and sample possible MIS 3 and older interglacial sediments. Preliminary work indicates there is also a high-resolution paleoseimic record, which has the potential of giving us a record of megathrust earthquakes spanning the entire Holocene, and further developing the field of marine paleoseismology.
PWSCB-02A (Alternate)	60.515234 -146.868815	330	263	0	263	The Central Prince William Sound basin sediments will contain a complete record of post-LGM climate change. This site will also help us test rates and timing of deglaciation in the north Pacific, and sample possible MIS 3 and older interglacial sediments. Preliminary work indicates there is also a high-resolution paleoseimic record, which has the potential of giving us a record of megathrust earthquakes spanning the entire Holocene, and further developing the field of marine paleoseismology.

Proposed Sites (Continued; total proposed sites: 19; pri: 10; alt: 9; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
PWSCB-03A (Primary)	60.652097 -146.936269	335	182	0	182	The Central Prince William Sound basin sediments will contain a complete record of post-LGM climate change. This site will also help us test rates and timing of deglaciation in the north Pacific, and sample possible MIS 3 and older interglacial sediments. Preliminary work indicates there is also a high-resolution paleoseimic record, which has the potential of giving us a record of megathrust earthquakes spanning the entire Holocene, and further developing the field of marine paleoseismology.
PWSCB-04A (Alternate)	60.612348 -146.91828	333	177	0	177	The Central Prince William Sound basin sediments will contain a complete record of post-LGM climate change. This site will also help us test rates and timing of deglaciation in the north Pacific, and sample possible MIS 3 and older interglacial sediments. Preliminary work indicates there is also a high-resolution paleoseimic record, which has the potential of giving us a record of megathrust earthquakes spanning the entire Holocene, and further developing the field of marine paleoseismology.
PWSJT-01B (Primary)	59.54248272 -148.1841377	209	274	0	274	This site should penetrate three glacial cycles, which would lead to the development of a high latitude glacial and interglacial climate record. Moreover, timing of LGM deglaciation at this site is critical to understanding of LGM ice sheet collapse was catastrophic or gradual. A chronology here should help to evaluate rates and progression of megathrust splay faulting.
PWSJT-02A (Alternate)	59.53480124 -148.2078545	205	259	0	259	This site should penetrate three glacial cycles, which would lead to the development of a high latitude glacial and interglacial climate record. Moreover, timing of LGM deglaciation at this site is critical to understanding of LGM ice sheet collapse was catastrophic or gradual. A chronology here should help to evaluate rates and progression of megathrust splay faulting.
PWSJT-03A (Primary)	59.62613972 -148.3429446	195	283	0	283	A chronology at this site should help to evaluate rates and progression of megathrust splay faulting on the time span of 10s to 100s of thousands of years. This site should penetrate three glacial cycles, which would lead to the development of a high latitude glacial and interglacial climate record. Moreover, timing of LGM deglaciation at this site is critical to understanding of LGM ice sheet collapse was catastrophic or gradual.
PWSJT-04A (Alternate)	59.62043641 -148.3532876	194	295	0	295	A chronology at this site should help to evaluate rates and progression of megathrust splay faulting on the time span of 10s to 100s of thousands of years. This site should penetrate three glacial cycles, which would lead to the development of a high latitude glacial and interglacial climate record. Moreover, timing of LGM deglaciation at this site is critical to understanding of LGM ice sheet collapse was catastrophic or gradual.
PWSJT-06A (Alternate)	59.6292841 -148.3010139	197	132	628	760	The purpose of this site is to collect samples across a megathrust splay fault with known Holocene rupture in order to evaluate mechanical properties of the fault zone.
PWSJT-07A (Primary)	59.62566265 -148.30998296	194	113	300	413	The purpose of this site is to collect samples across a megathrust splay fault with Holocene rupture in order to evaluate mechanical properties of the fault zone.
KS-01A (Primary)	59.52153564 -144.12280086	713	183	0	183	Obtain: a) a continental slope record of deglaciation and climate change, extending the record at nearby Site U1419, b) recover strata to compare/ contrast the LGM deglaciation to older transitions (MIS 5-6), and examine ice growth dynamics in glacial/interglacial transitions. Specifically, we target the strata anticipated to record the past ~150,000 years. The record will compare locally with Junken Trough, and with other Cordilleran and global margins; c) a further understanding the dynamics of hypoxia within the oceanic oxygen minimum zone, and its relation to climate, sea ice, regional productivity, and subsurface ventilation.
KS-02A (Alternate)	59.52460808 -144.12517087	710	2023	0	2023	Obtain: a) a continental slope record of deglaciation and climate change, extending the record at nearby Site U1419, b) recover strata to compare/ contrast the LGM deglaciation to older transitions (MIS 5-6), and examine ice growth dynamics in glacial/interglacial transitions. Specifically, we target the strata anticipated to record the past ~150,000 years. The record will compare locally with Junken Trough, and with other Cordilleran and global margins; c) a further understanding the dynamics of hypoxia within the oceanic oxygen minimum zone, and its relation to climate, sea ice, regional productivity, and subsurface ventilation.

Proposed Sites (Continued; total proposed sites: 19; pri: 10; alt: 9; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
KS-03A (Primary)	59.48977358 -144.09868805	832	180	0	180	Obtain: a) a continental slope record of deglaciation and climate change, extending the record at nearby Site U1419, b) recover strata to compare/ contrast the LGM deglaciation to older transitions (MIS 5-6), and examine ice growth dynamics in glacial/interglacial transitions. Specifically, we target the strata anticipated to record the past ~150,000 years. The record will compare locally with Junken Trough, and with other Cordilleran and global margins; c) a further understanding the dynamics of hypoxia within the oceanic oxygen minimum zone, and its relation to climate, sea ice, regional productivity, and subsurface ventilation.