IODP Proposal Cover Sheet

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NE Pacific Margin Paleoenvironment

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Title	ICEMAN (cordilleran ICE sheet, Missoula floods And Nearshore environments)
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Keywords	Climate, Cordilleran, Megafloods, Stratigraphy, Circulation
Area	Northeast Pacific margin from Oregon to British Columbia

Proponent Information

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Abstract

Here we propose a suite of 9 drill sites to study the paleoenvironmental history of the northeast Pacific margin between Oregon and southern British Columbia. The paleoclimate history of the North American Pacific Northwest margin remains poorly constrained, in large part due to a paucity of appropriate sedimentary archives available for study. The tectonic environment, prone to seismic activity and with steep continental slopes facilitating submarine mass wasting events, tightly constrains potential site selection for paleoclimate objectives. Nonetheless, such records are critical to furthering our understanding of climate dynamics in the Northeast Pacific and how those regional processes interact with the global climate system. Throughout the Pleistocene, the Pacific Northwest margin hosted the southern margin of the Cordilleran Ice Sheet (CIS), similar in size at its maximum extent to modern-day Greenland. The demise of the CIS in previous glacial/interglacial cycles likely holds important lessons for the sensitivity and response of our last remaining Northern Hemisphere ice sheet to our modern warming climate. During the ultimate retreat of the CIS, and perhaps before, megafloods originating from ice-dammed glacial lakes on the southern margin of the ice sheet profoundly altered the landscape surrounding the Columbia River and the morphology of the adjacent continental margin; the most recent floods left a marine sedimentary signature extending from California to British Columbia. Increasing lines of evidence suggest that the failure of the CIS (perhaps related to these floods) produced a global impact. However the following questions remain:

- What regional environmental conditions are associated with advance/retreat of the southern margin of the ice sheet?
- To what extent did the marine margin of the CIS behave synchronously?
- Was retreat during Termination 1 somehow unique or mechanistically similar to earlier deglaciations?
- What were the phase relationships between advance/retreat of the southern margin of the CIS and other global cryosphere systems through the Pleistocene?

Changes in freshwater routing associated with these processes also likely impacted regional ocean circulation, watermass properties, marine floral and faunal communities, and carbon burial in ways that remain poorly constrained even during the most recent termination and are absolutely unstudied during prior warm intervals. This proposal capitalizes on several promising site survey cores and preliminary seismic data that offer the possibility of recovering continuous late Pleistocene to early Pliocene stratigraphic sections on this margin that will shed important insights on these and other regional paleoenvironmental questions of global significance.

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Scientific Objectives

Specific drilling objectives are:
1. Reconstruct the late Pleistocene behavior of the southern margin of the Cordilleran ice sheet, with particular emphasis on establishing the relationship between changes in regional environmental conditions and its areal extent through multiple glacial/interglacial cycles
2. Place records of Cordilleran ice sheet behavior and regional climate variability into a global context using robust multi-proxy chronologies including foraminiferal stable isotopes but also informed by independent techniques such as radioisotopes, paleomagnetism, and biostratigraphy
3. Establish the regional and far-field effects of freshwater routing from the southern Cordilleran into the Northeast Pacific, ranging from impacts on Northeast Pacific current systems to potentially global climate teleconnections
4. Reconstruct the recent evolution of the Pacific Northwest margin itself, both from the context of sediment accumulation as well as via applying dated stratigraphic horizons in the step basins and regional fan systems to interpretation of tectonic deformation horizons on the continental slope.
5. Reconstruct changes in regional carbon burial, hypoxia, and faunal community responses to changes in regional oceanography and glacial discharge.
6. Compare sedimentary microbial communities with paleostratigraphy, particularly w/re interplay between rapid accumulation of fluvial sediments, carbon burial, and the deep biosphere.
7. At lower resolution, establish regional climate and geomagnetic variability back to the onset of Northern Hemisphere cooling in the late Miocene through the inception of Northern Hemisphere glaciation in the mid-Pliocene.

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

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

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
ICEMN-01A (Primary)	43.2500 -126.3667	2978	560	0	560	This site, location of site survey core Y72-11-1, has late Pleistocene sedimentation rates of ~10 cm/kyr, extending back to MIS-6 in the uppermost 16 m of sediment (Heusser and Shackleton, 1979). Crustal age at this location is estimated to be 5 MYA. As such, this site affords the possibility of recovering a regional environmental record extending back into the mid-Pliocene, perhaps somewhat beyond, capturing the period over which small ice sheets began to form in the Northern Hemisphere and potentially informing on regional climate processes and the sensitivity of North American cryospheric systems in a warmer world analogous to our near-future.
ICEMN-02A (Primary)	44.8367 -125.2417	1999	300	0	300	This site, the location of DSDP Site 175, has late Pleistocene sedimentation rates of ~25-30 cm/kyr, and extends back at least 400 ka in the uppermost 120 m. Although lithology and proxy preservation is promising, recovery rates were poor and remaining materials are desiccated and disturbed. As such, detailed modern analyses of high-resolution environmental changes, depositional structures, and geo/paleomagnetism are impossible. We propose to reoccupy this site via triplicate APC coring to refusal (likely 200-300 m). This site offers the possibility to inform on regional paleoenvironment over the late Pleistocene as well as the tectonic/deformation history of the margin.
ICEMN-03A (Primary)	44.8897 -126.3467	2815	800	0	800	This site is located on an interfluve of lower Astoria Fan. DSDP Expedition 18 drilled 879 meters of sediment here, reaching within 30 meters of bedrock, but only recovering 48% of the section. We propose to reoccupy this site via triplicate APC coring to refusal, targeting the upper 284 meters of section, which consist of horizontally bedded sands and silts intercalated with foraminifera-rich muds, then XCB/RCB to ~800 m. Deposition of this dateable sequence spans multiple 100-ka glacial-interglacial cycles, affording the opportunity to reconstruct how the Cordilleran Ice Sheet and its megafloods varied over a longer timescale than terrestrial studies can reconstruct.
ICEMN-04A (Primary)	45.4583 -125.2320	1959	300	0	300	This site is a step basin on the outer continental slope south of Astoria canyon. Based on the seismic stratigraphy, in conjunction with site survey cores collected in nearby step basins, we feel it probable this basin preserves an exceptional high-resolution record of paleoenvironmental variability physically isolated from energetic/erosive turbidity currents. This site and ICEMN-02A form the deepest/youngest slope step basins occupied in our proposed sites adjacent to the Astoria canyon, and thus offer the possibility to inform on regional paleoenvironment over the late Pleistocene as well as the tectonic/deformation history of the margin.
ICEMN-05A (Primary)	45.8658 -124.8546	826	750	0	750	This site is a step basin on the upper continental slope immediately south of Astoria canyon, for which promising site survey cores and crossing seismic lines have been collected. Similar to Site ICEMN-04A, seismic stratigraphy and lithology indicates the preservation of a high-resolution record of paleoenvironment, physically isolated from most energetic/erosive turbidity currents that travel down Astoria canyon system while benefitting from dilated sediment accumulation rates. As the most shoreward (and hence oldest) of the proposed slope step basin sites, this site reflects the oldest paleoenvironmental record and offers insight into the earliest deformation history of the margin.
ICEMN-06A (Primary)	47.4292 -125.5833	1469	300	0	300	This site is on a slope basin adjacent to Grays Canyon on the Washington continental margin. This canyon system was the conduit of drainage from the Puget Lobe of the Cordilleran Ice Sheet, and as such should contain a record of the behavior of the southwestern margin of the ice (as opposed to the Astoria canyon adjacent-sites, which will contain sediments sourced predominantly from ice sheet drainage east of the Cascade Mountains). We anticipate APC coring to refusal, likely 200-300 m, to collect a high-resolution late Pleistocene sediment sequence.
ICEMN-07A (Primary)	47.5800 -128.9920	2588	400	0	400	This site is the location of legacy site survey core TT029 017-021, which captured an environmental history extending back to the last glacial maximum over ~4 m of accumulated sediment. Oceanic crust at this site is relatively young, 1-2 MYA, but the lower accumulation rates afford the possibility of recovering a stratigraphic section that captures the mid-Pleistocene transition to more intense glaciations of the late Pleistocene and perhaps earlier, providing broader environmental context for megaflooding events routed out the Columbia River drainage. We anticipate refining this target via collection of seismic data and additional survey cores.

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

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
ICEMN-08A (Primary)	48.9745 -127.0357	1228	300	0	300	This site is located near the entrance of the Juan de Fuca strait on a slight mound on the continental slope, avoiding downslope turbidite activity and capturing glaciomarine sediment from Vancouver Island and the Juan de Fuca Lobe of the CIS. This is the location of Marion Dufresne jumbo piston core MD02-2496, producing some of the best studied and most complete records yet published for behavior of the marine margin of the late Pleistocene Cordilleran ice sheet. This site has proven excellent for paleoceanographic reconstructions; we propose to drill after refining the target via collection of seismic data.
ICEMN-09A (Primary)	49.8800 -130.4600	2390	500	0	500	This site is the location of site survey core PAR 850-01, capturing late Pleistocene ice-rafted debris events likely from a CIS lobe extending through Hecate Strait and Queen Charlotte Sound (Blaise et al., 1990). Similar to ICEMN-08A we anticipate expanded glacial and condensed interstadial/interglacial sediments. This site is located on relatively young (1-2 MYA) crust west of Explorer Ridge; lower accumulation rates distant from the margin should allow for recovery of a stratigraphic section complete to the early Pleistocene, capturing intensification of Northern Hemisphere glaciation. We anticipate refining this target via collection of seismic data and additional survey cores.