IODP Proposal Cover Sheet

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Chile Megathrust

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Title	Investigating conditions that lead to Earth's largest earthquakes in south-central Chile		
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Keywords	Chile subduction zone, earthquakes, megathrust	Area	south-central Chile margin

Proponent Information

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Abstract

On the 22nd May 1960 the Mw 9.5 Valdivia earthquake devastated Chile and caused a Pacific-wide tsunami. Investigations into megathrust ruptures since the Valdivia event, have found strong correlation between thick trench fill and great earthquakes, and the 1960 Chile rupture segment is among Earth's settings with this condition. The south-central Chile subduction, however, stands out due to the frequency of such events, which occur at 100 to 150-year intervals. Seismic reflection data indicate a mode of accretion here unlike other accretionary margins that have hosted Mw. 9 earthquakes, such as Alaska or Northern Sumatra, which allows most of the trench sediment to bypass the deformation front. Reflection profiles suggest that since the Early Pliocene only ~30% of the subducted sediment has been accreted to the margin, which is 30-40 km wide, implying that 70% of the sediment has been subducted to greater depth. This behaviour may be due to the presence of unusually well-drained and strong trench sediment that is homogenous because of along-strike sediment transport, but this is largely speculation. Because pelagic or hemipelagic sediment on the Nazca plate seaward of the trench is too thin to cover the rough oceanic basement, we hypothesize that south-central Chile has no deep continuous weak layer within the trench along which a décollement can form and propagate, forcing the décollement to form near the top of the trench strata. This proposal will obtain ground truth information to combine with the seismic imaging to examine why this scenario leads to unusually frequent great earthquakes. We propose 5 drilling sites: two offset sites within the trench to sample the trench wedge and pelagic/hemipelagic section for the lithology and physical properties of the incoming sediment; one wedge toe site to sample the new, shallow décollement and fluid transport along this surface; a site to sample the slope drape and accretionary wedge to constrain age and uplift/subsidence history; and an older upper plate site, to penetrate the margin framework rock, and backstop to modern accretion, which may be as old as Jurassic. Drilling is needed to constrain models of fluid sources and flow patterns, the structural development of the wedge, and fate of subducted trench sediment. Comparing results here to recent IODP results from other megathrust settings (e.g. Northern Sumatra, Japan Trench) will further constrain the conditions leading to megathrust ruptures, and serve IODP's mission of understanding the mechanisms underlying subduction zone earthquakes and tsunami.

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Scientific Objectives

We have developed a drilling plan to examine the conditions that lead to the world's largest earthquakes and tsunami along the south-central Chile margin to determine why this setting is prone to such large events and at high frequency by comparison to other margins. Our primary goals for drilling are:

1) Determine composition and physical properties of the trench sediment that allow an unusually large fraction (and high volume) of sediment to bypass frontal accretion, produce an unusual accretionary style of mostly episodic, basal accretion, and potentially allow large volumes of sediment to subduct into the seismogenic zone.

2) Penetrate the shallow trench strata and frontal accretionary wedge to sample the equivalent sedimentary sections on both sides of the deformation front to examine lithologies, physical properties, pore fluid chemistry and microstructures associated with decollement initiation. These sites will constrain fluid sources and flow patterns associated within the accretionary wedge, decollement, and underthrust sediment.

3) Determine the age, uplift history and fluid flow patterns within the modern accretionary wedge (since the Late Miocene/Early Pliocene) to assess accretion style, uplift history, and wedge dewatering to infer long term margin behavior and compare with current accretion and subduction styles along the lower slope.

4) Determine ages, composition, and tectonic uplift history of the older upper plate that is the margin framework rock and backstop to the modern wedge, to determine the physical properties and condition of the rocks that comprise the bulk of the upper plate and store elastic strain energy.

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

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

Proposal History

Submission Type: Resubmission from previously submitted proposal

Review Response

History for IODP 984-Full – Chile Megathrust
Our pre-proposal (IODP 984-Pre), submitted on April 1, 2020 was reviewed by SEP in July 2020.
SEP review issues:

1. Scientific rationale for drilling targets

We rejected a strike transect because we did not think we could drill enough sites to characterize this vast 1,000 km long rupture. Even if we could test some along-strike variation, we would still be able to address only two of our main hypotheses and our understanding of the unique margin behavior would be much too incomplete. Drilling results with existing seismics can give some assessment of along strike variation.

We describe options for transects using alternative CEVICHE lines. For the most part, only one line has feasible targets. Targets are substantially deeper on other lines and cannot be drilled in a 60-day leg.

2. Geologic background and global uniqueness

Other geophysical observations: We have included more of the relevant publications for this setting. We have added more regional background and included substantially more on other geophysical observations, but not all we wanted with page limits.

Global uniqueness: We committed several pages to the margin's unique characteristics with figures to show our interpretation of margin behavior and how it compares to other settings. We did not specifically address the setting in Columbia/Ecuador because that region involves large basement ridge collision that dominate regional tectonics and this is not the case along our proposed transect.
Inner forearc drilling: Ideally we would include drilling of the inner forearc; however this did not seem feasible for a single drilling leg. Drilling shelf basins requires substantial time, and the large distance to industry exploration wells leaves us in the dark on where the most informative portions of the basin sediments are. Our proposed initial drilling leg would provide a better basis for future drilling on the inner forearc.

3. Methods to address hypotheses

This is a pioneering effort and we have chosen a broad strategy of examining multiple characteristics relevant to the tectonic behavior and characteristics that have been proposed to control earthquake behavior. Drilling here will give us constraints on sediment and rock composition, ages, physical and mechanical properties, and in situ pore pressure that we can use with seismic images to further our interpretation. We will also be able to use drilling results to build hydrogeologic, geomechanical and geodynamic models. For the full proposal we have described in greater detail how drilling results will help us achieve these goals.

Prism toe site: We have decided to adopt this option.

4. Proponent list

We expanded our proponents list to cover geophysics, structure, tectonics, geodynamics, geomechanics, porefluid chemistry, sedimentology, and volcanology. We now include scientist from Germany in addition to those from the US and Chile.
We considered LWD, but it seems unfeasible given the additional JR transit time needed get them out to this remote location. We have contacted the JRSO and they have estimated that our current proposed drilling plan is feasible within a 60 day leg.

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Proposed Sites (Total proposed sites: 10; pri: 5; alt: 5; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
CMT-01A (Primary)	-39.2152 -75.26363	4341	650	20	670	This is the first of two trench drilling sites to examine the lithology, age, sedimentation rate, pore fluid chemistry and physical properties of the trench sediment on the subducting plate. This site will offset from Site CMT-02A by ~ 20 km to sample the lower half of the trench section. CMT-01A will penetrate ~ 20 m into the oceanic crust basement.
CMT-02B (Primary)	-39.21667 -74.95469	4403	600	0	600	This is the second of two trench drilling sites to examine the lithology, age, sedimentation rate, fluid chemistry and physical properties of the trench sediment on the subducting plate. This site will offset from Site CMT-01A by ~ 20 km to sample the upper half of the trench section near the deformation front. The goal is to sample strata that become the decollement slip surface before slip initiates to compare with the incipient decollement at Site CMT-03B.
CMT-03B (Primary)	-39.21871 -74.88004	4094	850	0	850	The primary goal of this site is to penetrate the frontal accretionary wedge to reach the incipient decollement and the shallowest few m of the underthrust sediment. This site will be used to compare with Site CMT-02B, 6 km to the east. This site lies approximately 3 km landward of the deformation front. The goal is to examine the lithology, pore fluid chemistry, and physical properties to determine fluid migration and dewatering of the frontal prism, decollement, and underthrust sediment to assess conditions that cause the shallow decollement.
CMT-04B (Alternate)	-39.22568 -74.57748	2228	1100	0	1100	This site is an alternate to primary Site CMT-05A. The goal is to sample the complete slope cover sediment section and penetrate into the underlying accretionary wedge in the oldest portion of the modern accretionary wedge. The goal is to determine lithology, provenance, age, deposition rate, microstructure, temperature, pore fluid chemistry and physical properties of both the slope cover and accreted sediment. This site will assess the sediment accretion rate, mass balance, deformational style, and hydrogeology.
CMT-05A (Primary)	-39.22619 -74.550095	2031	1350	0	1350	This site will sample the complete slope cover sediment section and penetrate into the underlying accretionary wedge in the oldest portion of the modern accretionary wedge. The goal is to determine lithology, provenance, age, deposition rate, microstructure, temperature, pore fluid chemistry and physical properties of both the slope cover and accreted sediment. This site will assess the sediment accretion rate, mass balance, deformational style, and hydrogeology.
CMT-06B (Alternate)	-39.09252 -74.601522	2386	1250	0	1250	This site is an alternate to primary Site CMT-05A. The goal is to sample the complete slope cover sediment section and penetrate into the underlying accretionary wedge in the oldest portion of the modern accretionary wedge. The goal is to determine lithology, provenance, age, deposition rate, microstructure, temperature, pore fluid chemistry and physical properties of both the slope cover and accreted sediment. This site will assess the sediment accretion rate, mass balance, deformational style, and hydrogeology.
CMT-07A (Primary)	-39.23236 -74.24102	1755	560	0	560	This site will drill through the entire slope cover sediments and penetrate the old (possible Jurrasic) accretionary wedge that forms the backstop to the modern accretionary wedge. The goal is to determine ages, composition physical properties, and hydrogeology of the older accretionary wedge that forms the bulk of the upper plate and stores elastic strain energy during the earthquake cycle.
CMT-08A (Alternate)	-39.23465 -74.13334	1224	650	0	650	This is an alternate site for CMT-07A. This site will drill through the entire slope cover sediments and penetrate the old (possible Jurrasic) accretionary wedge that forms the backstop to the modern accretionary wedge. The goal is to determine ages, composition physical properties, and hydrogeology of the older accretionary wedge that forms the bulk of the upper plate and stores elastic strain energy during the earthquake cycle.
CMT-09A (Alternate)	-39.09832 -74.31441	2259	1250	0	1250	This is a second alternative for CMT-07A. This site will drill through the entire slope cover sediments and penetrate the old (possible Jurrasic) accretionary wedge that forms the backstop to the modern accretionary wedge. The goal is to determine ages, composition physical properties, and hydrogeology of the older accretionary wedge that forms the bulk of the upper plate and stores elastic strain energy during the earthquake cycle.

Proposed Sites (Continued; total proposed sites: 10; pri: 5; alt: 5; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
CMT-10A (Alternate)	-39.22701 -74.52355	1868	1200	0	1200	This site is an alternate to primary Site CMT-05A. The goal is to sample the complete slope cover sediment section and penetrate into the underlying accretionary wedge in the oldest portion of the modern accretionary wedge. The goal is to determine lithology, provenance, age, deposition rate, microstructure, temperature, pore fluid chemistry and physical properties of both the slope cover and accreted sediment. This site will assess the sediment accretion rate, mass balance, deformational style, and hydrogeology.