IODP Proposal Cover Sheet

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Chile Megathrust

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Title	The lithology, structure and tectonic history of the south-central Chile margin and their role in generating the world's largest earthquakes
Proponents	Nathan Bangs, Anne Tréhu, Eduardo Contreras-Reyes, Evan Solomon, Shuoshuo Han, Julia Morgan, Andrei Maksymowicz
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Proponent Information

Proponent	Nathan Bangs
Affiliation	University of Texas at Austin, Institute for Geophysics
Country	United States

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Abstract

The south-central Chile subduction megathrust regularly generates the world's largest earthquakes and tsunami. A recent seismic survey on the R/V Langseth imaged structures along this margin, and by inference, showed characteristics that could help explain the particularly large earthquakes. At the deformation front, the décollement forms at an unusually shallow position near the top of the 1.6 – 3.0 km thick trench sediment section, and ~ 80-90% of the trench sediment subducts under the lower slope. Accretion is primarily by basal underplating rather than the more typical frontal accretion. Consequently, the outer forearc has few structures typically associated with frontal wedges, such as imbricately stacked sediment sequences separated by in-sequence thrusts, or splay faults. Basal accretion appears to be episodic and relatively inefficient. Thus a large fraction (70%) of the 1.6+ km of incoming sediment subducts beyond the upper plate basement and into the seismogenic zone. Here it can produce a smooth, homogeneous megathrust well above the roughness of the subducting oceanic crust, making it capable of building particularly large shear stresses. While these recent results are intriguing, we lack critical lithology, physical property, ages and structural data to understand this tectonic behavior, assess what drives it, and understand how it influences megathrust development and ultimately earthquakes and tsunami.

A critical next step is to drill key elements within the margin. Two sites in the trench, offset by ~ 20 km, can sample the entire incoming trench sediment section to determine what causes the unusually shallow décollement. Trench sediment lithologies and physical properties can be extrapolated beneath the wedge and into the seismogenic zone to assess frictional properties and compare with other settings. Drilling through the upper plate slope cover sequences and into the underlying accretionary wedge in two locations will sample early and late phases of modern accretion. The ages, physical properties, pore fluids, and microstructures will be critical for determining tectonic development, hydrogeology of the megathrust and overlying wedge, and details needed to assess the mass and fluid fluxes into the wedge and seismogenic zone. Mass fluxes associated with the unusual tectonic behavior will reveal whether sediments effectively cover subducting crust roughness. Lastly, a mid-slope site through the slope cover sequences and into underlying accretionary wedge backstop will verify structural components of the margin, determine the age, composition, and infer temporal and compositional heterogeneity of the upper plate basement, and reveal mechanical properties that enable large strain accumulation.

Scientific Objectives

We have developed a drilling plan that is designed to understand the unusual tectonic behavior of the south-central Chile margin, what drives it, and what are the implications for the development of the megathrust and earthquake hazards. 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) Sample subducting sediment lithologies and measure physical properties to determine the frictional properties of these materials, assess how they evolve into the seismogenic zone, and compare them to other subduction zones.

3) Constrain ages and volumes of accreted sediments in order to assess the flux of sediment into the seismogenic zone, as well as the structure and tectonic history of the margin.

4) Determine ages, composition, and state of primary structural components within the upper plate, including the accretionary wedge and mid-slope backstop, for assessing their ability to store elastic strain energy and generate particularly large earthquakes and tsunami.

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

Proposed Sites (Total proposed sites: 9; pri: 5; alt: 4; 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, 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 sampled at Site CMT-02A. CMT-01A will penetrate ~ 20 m into the oceanic crust basement.
CMT-02A (Primary)	-39.21513 -75.01712	4398	500	0	500	Sample the upper half of the trench wedge section to determine lithology, age, deposition rates, and physical properties of the sediment on the subducting plate. These materials will reveal critical details about what controls the shallow formation of the decollement, the tendency for this margin to grow by underplating rather than frontal accretion, and provide the basis to assess how the megathrust frictional properties evolve as these sediments subducted into the seismogenic zone. Site CMT-02A will sample the upper half of the trench section and compliment CMT-01A, which will sample the lower half.
CMT-03A (Primary)	-39.22192 -74.73994	3084	1000	0	1000	Sample the complete slope cover sediment section and penetrate into the underlying accretionary wedge 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-04A (Alternate)	-39.09006 -74.71471	2745	1000	0	1000	An alternate to Site CMT-03A. Sample the complete slope cover sediment section and penetrate into the underlying accretionary wedge 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 complement Site CMT-03A and 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-06A (Alternate)	-39.09313 -74.56626	2733	1225	0	1225	This is an alternative site for Site-05A. This site will complement Site CMT-03A and 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	1050	0	1050	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.