Thermal regime around the Chile Triple Junction based on JAMSTEC MR18–06 cruise 'EPIC'

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The EPIC Cruise: 105 days

• The World’s only active ridge subduction zone = Survey of Chile Triple Junction
• Exploratory study on the connectivity of the oligotrophic environment and ecosystem in the Southeastern Pacific Gyre (SPG)
ABSTRACT: The Chile triple junction (CTJ) is a unique place where a spreading center of mid-ocean ridge is subducting near the Taitao peninsula. Around CTJ, presence of high heat flow on the continental slope and near-trench young granitic rocks on the Taitao peninsula suggests the thermal and petrological impact of subducting ridge on the continental side. The tectonic history of the southeast Pacific since early Cenozoic to the present suggests that ridge subduction continuously occurred along the Chile trench, which migrated northward.

In January 2019, the MR18-06 cruise Leg 2 was conducted at CTJ, as a part of 'EPIC' expedition by using R.V Mirai of JAMSTEC. During the leg, we completed 4 SCS lines, 6 piston coring with heat flow measurements, 2 dredges, and underway geophysics observations, as well as deployment of 13 OBSs. Coring/heatflow sites were located across the ridge axis, HP5 on the seaward plateau of axial graben, HP1/HP2/HP6 on the axis, and HP3/HP7 on the forearc slope near the trench axis. The primary objective of heat flow measurement at CTJ is to better constrain the thermal regime around CTJ by adding new data right above CTJ. The key question is whether CTJ is thermally dominated by ridge activity (magmatic, tectonic, and/or hydrothermal) or by subduction initiation (tectonic thickening, accretion, and/or erosion). The ultimate goal is to model the temperature at the plate interface from the heat flow and other data, and to infer how the thermal regime at CTJ contributes the seismic behavior at the M~9 megathrust zone.

Onboard and post-cruise measurements include; bulk density, porosity, Vp, resistivity, CT images, iTracks element scan, sedimentation rate. The seaward core (HP5) has few turbidites with higher density (~2 g/cc) and low sedimentation rate (SR; 0.2 m/ky), whereas cores on the axis the density are turbidite dominant with lower (1.6~1.8 g/cc) and very high SR (1~3 m/ky). The accretionary prism front cores have the density of 1.6~1.7 g/cc and SR=0.5~1 m/ky. They suggest that the turbidite covers only the axial graben.

Heat flow in the axial graben range 140-210 mW/m², which is lower than on the seaward plateau (370 mW/m²). This apparent controversy may be due to lower magmatic activity and/or high sedimentation rate on the axis. The lower spreading rate (2.6 cm/yr one side) and the rapid convergent rate at the trench (7.2 cm/yr) may suppress sufficient magma supply or hydrothermal circulation. Heat flow on the accretionary prism (230 mW/m²) is higher than borehole or BSR-derived heat flow (~<100 mW/m²). It is suggestive of fluid upwelling along the decollement as proposed in the previous study. Some numerical thermal models will be presented to show the effect of ridge subduction.
MR-18-06: Geophysical/geological Experiments

**Purpose**

Quantifying effects of anomalous heat of ridge on subduction zone processes (e.g., seismicity, magmatism, fluid cycling), based on thermal, seismic and rock structures. Important also for understanding the Earth’s evolution. Revealing thermal, hydrological and sedimentological structure of ridge subduction zone.

(H. Iwamori, pers. Comm.)
Blue circle and bottom-left insert indicates location of our survey.
HP1~Hp7: Heat flow with piston coring
DR1,DR2: Dredge sampling
SCS: Single-channel seismic
Black square: OBS sites
Piston corer with outriggered temperature sensors

Weight (600kg / 800 kg)

Temperature loggers T1 T2 T3 T4 T5 T6 T7 T8

Heat flow probe

Weight (1000 kg)

Temperature loggers T1 T2 T3 T4 T5 T6
All heat flow data obtained during MR18-06 cruise

(Top left) 6 geothermal data. Each dot corresponds to ‘in situ temperature’ that is corrected for the frictional heat upon penetration. The correction was made from measured temperature-time curve (bottom left). Note all geothermal profiles are linear, supporting thermal equilibrium (no seasonal or transient effect recently).

(Right) Thermal conductivity measured on piston core samples using the needle probe method. Higher conductivity group at HP5 (seaward side core) agrees with higher density detected by X-CT.
Heat flow along MR1806-3 (also RC2901-751)

Thick sediment throughout the section.

Probe heat flow HP3 is higher than BSR-derived and HP2 and ODP863 heat flow values.

→ Localized advection along the frontal thrust?
Heat flow along MR1806-1 (also RC2901-750)

Heat flow at HP5 is higher than at HP6 (axis).
→ Low axial magmatic activity and/or rapid sedimentation?

Probe heat flow at HP7 is higher than BSR-derived heatflow values.
→ Localized advection along the frontal thrust?
Heat flow results & interpretation

*Heat flow in the axial graben range 140-210 mW/m², which is lower than on the seaward plateau (370 mW/m²).
  Low heat flow may be due to lower magmatic activity and/or high sedimentation rate on the axis. The lower spreading rate (2.6 cm/yr one side) and the rapid convergent rate at the trench (7.2 cm/yr) may suppress sufficient magma supply or hydrothermal circulation.

*Heat flow on the accretionary prism (230 mW/m²) is higher than borehole or BSR-derived heat flow (~<100 mW/m²).
  It is suggestive of fluid upwelling along the decollement as proposed in the previous study (e.g. Brown and Bangs, 1995).
CT/MSCL data for piston core samples (Depth corrected)

Density (leftmost section): Blue-CT, Orange-MSCL. (MSCL density is NOT depth-corrected)

- Seaward (PC5): High density & Increase with depth; slow spreading rate
- Axis (PC1,2,6): Frequent turbidites; constant density; rapid sedimentation
- Landward (PC3,7): Less turbidite; slight density increase w/depth

Summary plot for all piston core samples.
At each site, we plot bulk density (based on CT number and from Multi Sensor Core Logger=MSCL), P-wave velocity (MSCL), and CT image.
Age-depth for all piston core samples.
Sediment thickness at HP5 ~ 150m (from SCS)
Crust at HP5 was formed ~ 80ky (from spreading rate)
Sed. rate at HP5 ~ 150/80 = 2m/ky
Consistent with that for current axis (1-3m/ky)
Most of sediment at HP5 deposited as axial turbidite

HP5 age curve has a kink at ~ 18 ka
Rapid sedimentation followed by a sudden (?) decrease
Normal faulting & uplift occurred at ~ 18 ka?
Summary

- MGG survey onboard R/V MIRAI was conducted at Chile Triple Junction (CTJ) in Jan 2019
- Heat flow data was obtained at 6 sites
  - Heat flow in the axial graben range 140-210 mW/m², which is lower than on the seaward plateau (370 mW/m²).
  - Heat flow on the accretionary prism (230 mW/m²) is higher than borehole or BSR-derived heat flow (~<100 mW/m²).
- 6 piston core samples recovered at CTJ show the following characters:
  - Seaward (HP5): High density & Increase with depth; slow spreading rate
  - Axis (HP1,2,6): Frequent turbidites; constant density; rapid sedimentation
  - Landward (HP3,7): Less turbidite; slight density increase w/depth
- Present axial valley was probably formed after 20 kyBP (14C age-dating of HP5 core)
- We thank all Japanese and Chilean authorities; the Ministry of Education, Culture, Sports, Science, and Technology of Japan, the Ministries of Foreign Affair of Japan, Chile, Servicio Hidrografico y Oceanografico de la Amada de Chile, for allowing us to work inner and territorial water and the exclusive economic zone of Chile. We appreciate the crew members of MIRAI for their hard works on board and the Chilean national observer and pilots for their best advices concerning the activities and safety navigation. We also thank Kochi Core Center of Kochi University/JAMSTEC for post-cruise measurement on core samples.
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Supplementary slides
All 13 OBSs were landed with small enough tilt that can be corrected by the sensor leveling unit inside of the OBS. Drifts in landed positions were < 200m. The recovery of OBS is currently planned in Jan. or Feb. 2021 by using a Chilean Navy vessel.
Discussion: Evolution of CTJ

Formation of HP5 crust
Present location at HP5 (= PC05) is 2km away from axis
Spreading velocity (one-side) = 25mm/yr

\[ \text{-> The age at HP5 may be:} \]
\[ 2\text{km}/(25\text{mm/yr}) = 80\text{ky} \]