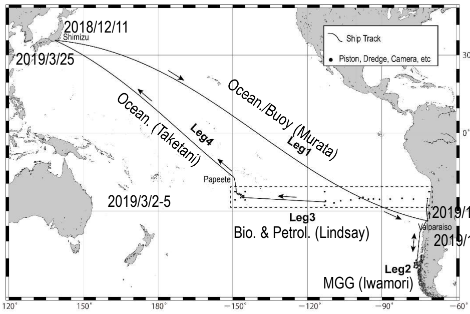
# Thermal regime around the Chile Triple Junction based on JAMSTEC MR18-06 cruise 'EPIC'

Masataka Kinoshita1, Ryo Anma2, Yuka Yokoyama3, Kosuke Ohta4, Yusuke Yokoyama4, Tomoaki Nishikawa5, Natsue Abe6, Hikaru Iwamori1, and Lucia Villar7

1ERI-Utokyo and JAMSTEC (masa@eri.u-tokyo.ac.jp), 2Tokushima University, 3Tokai University, 4AORI-UTokyo, 5DPRI-Kyoto University, 6JAMSTEC, 7Pontificia Universidad Católica de Valparaiso

The EPIC Cruise: 105 days




JAMSTEC R/V Mirai

- 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.

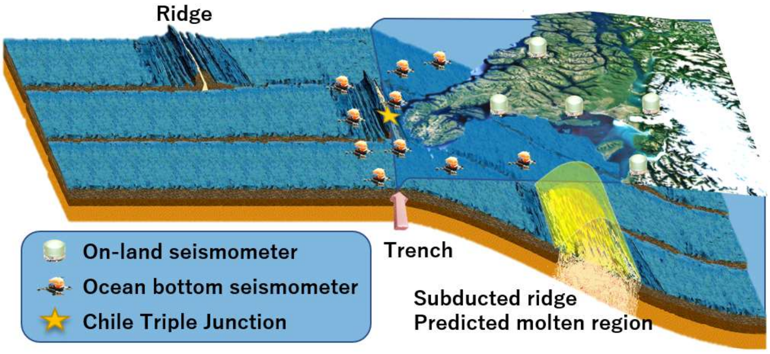
In January 2019, the MR18-06 cruise Leg 2 was conducted at CTJ, as a part of 'EPIC' expedition by using R.V Mirai of JAMSTEC. During the leg, we completed 4 SCS lines, 6 piston coring with heat flow measurements, 2 dredges, and underway geophysics observations, as well as deployment of 13 OBSs. Coring/heatflow 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 object 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 seismogenic behavior at the M~9 megathrust zone.

Onboard and post-cruise measurements include; bulk density, porosity, Vp, resistivity, CT imags, 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/m$^2$, which is lower than on the seaward plateau (370 mW/m$^2$). 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/m$^2$) is higher than borehole or BSR-derived heat flow (~<100 mW/m$^2$). 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

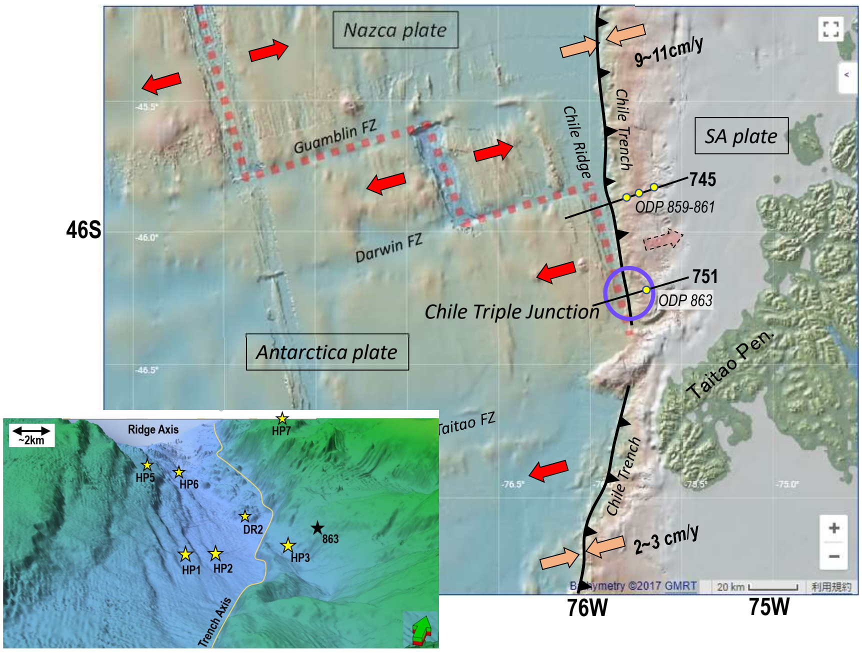
**Purpose**

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.)

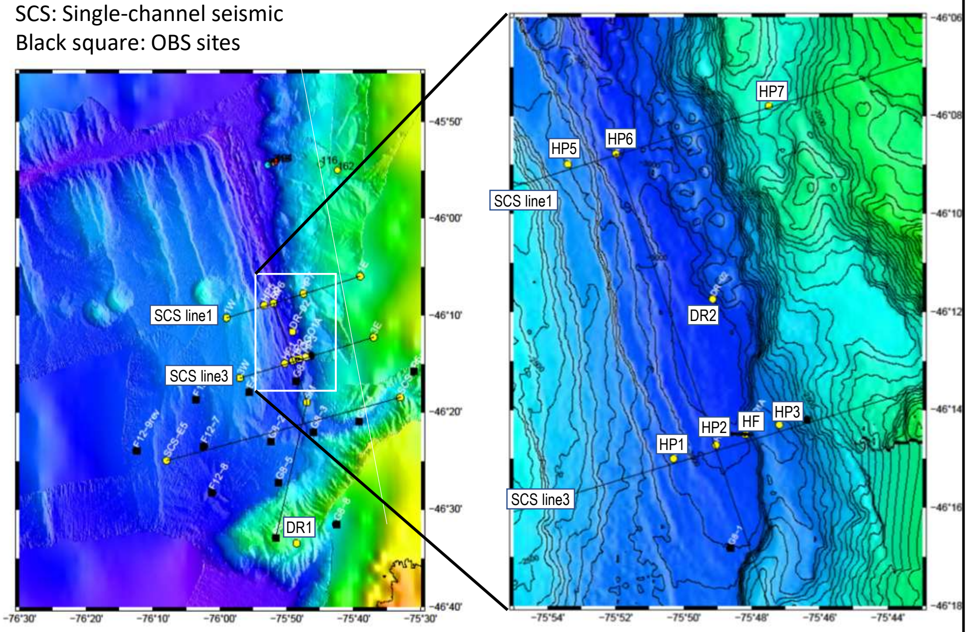
Tectonic Setting around Chile Triple Junction (CTJ)

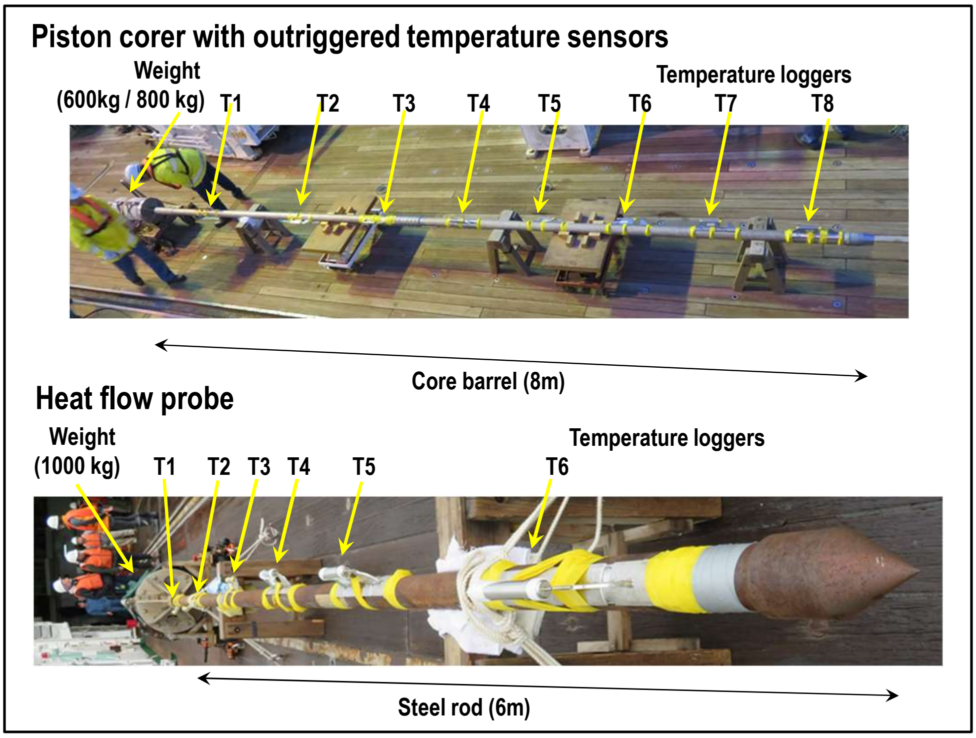


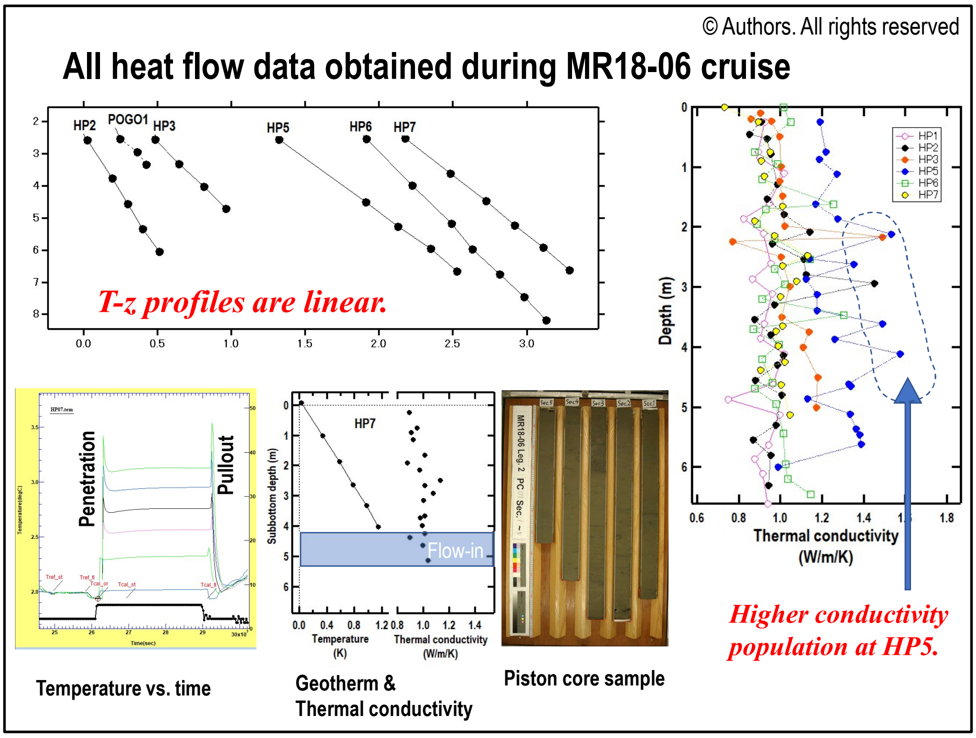

Blue circle and bottom-left insert indicates location of our survey.

HP1~Hp7: Heat flow with piston coring
DR1,DR2: Dredge sampling
SCS: Single-channel seismic
Black square: OBS sites

## MR19-06 Leg2 Survey lines & points



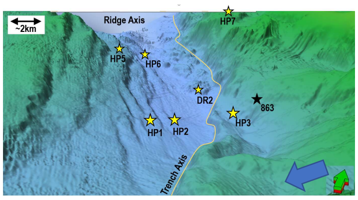

Piston corer with outriggered temperature sensors
Weight
(600kg / 800 kg)
T1
T2
T3
T4
T5
T6
T7
T8
Temperature loggers
Core barrel (8m)
Heat flow probe
Weight
(1000 kg)
T1
T2
T3
T4
T5
T6
Temperature loggers
Steel rod (6m)

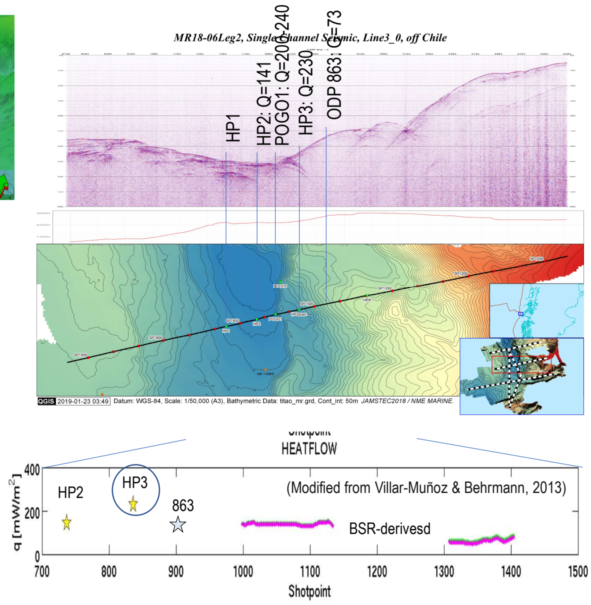



(Top left) 6 geothermal data. Each dot corresponds to 'in situ temperature' that is corrected for the frictional heat upon penetration. The correction was made from measured temperature-time curve (bottom left). Note all geothermal profiles are linear, supporting thermal equilibrium (no seasonal or transient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



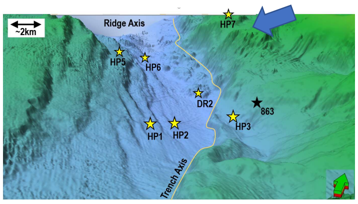

Thick sediment throughout the section.

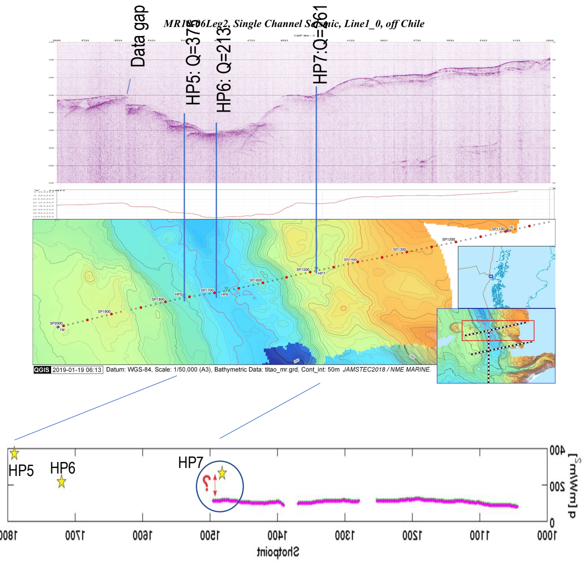
-----------------------------------------

Probe heatflow 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@HP5 is higher than @HP6 (axis).
→ Low axial magmatic activity and/or rapid sedimentation?

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

(Modified from Villar-Muñoz & Behrmann, 2013)

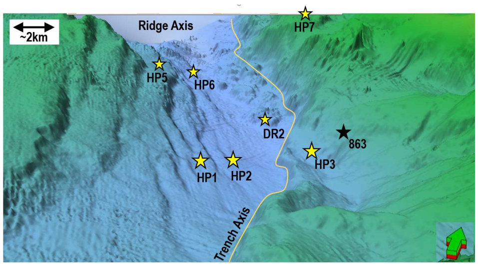
# Heat flow results & interpretation

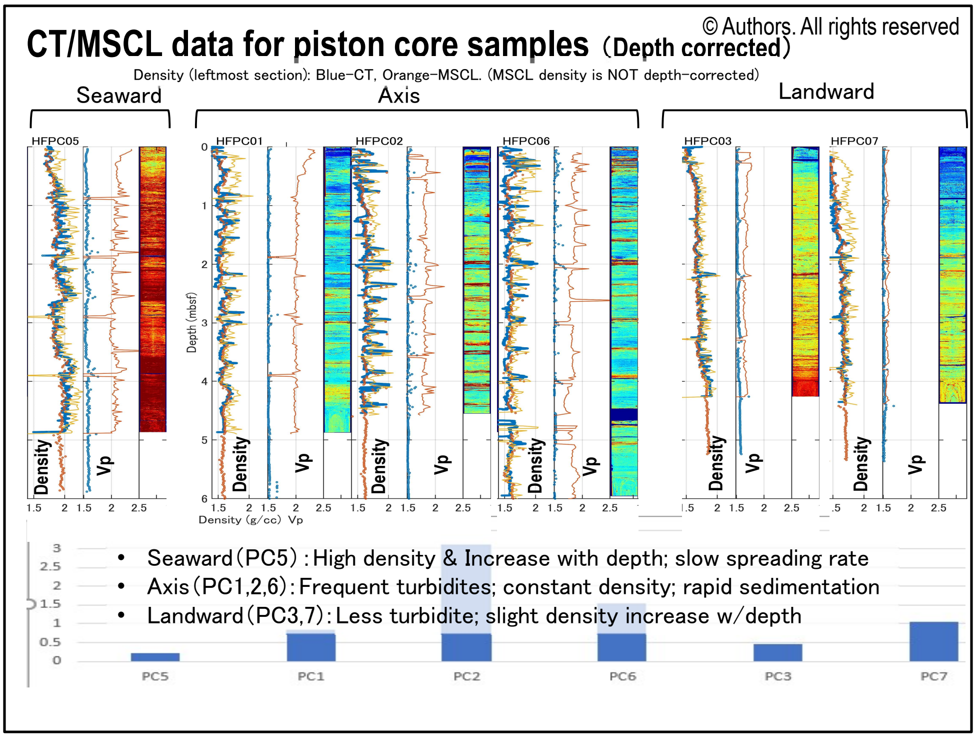
*Heat flow in the axial graben range 140-210 $mW/m^2$, which is lower than on the seaward plateau (370 $mW/m^2$).

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.

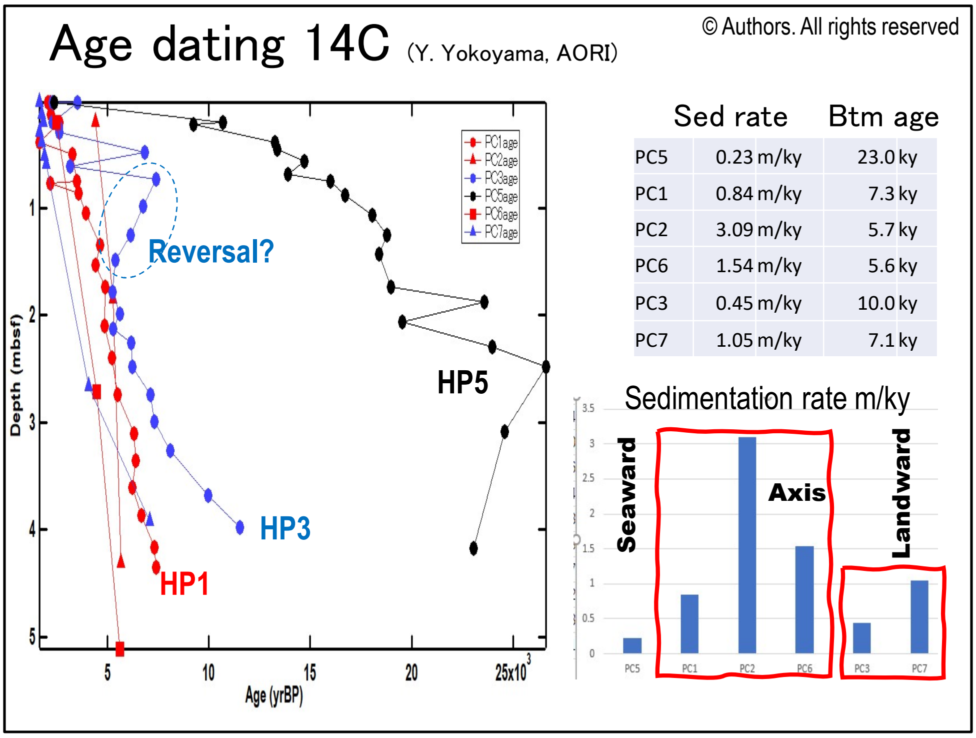
*Heat flow on the accretionary prism (230 $mW/m^2$) is higher than borehole or BSR-derived heat flow (~<100 $mW/m^2$).

It is suggestive of fluid upwelling along the decollement as proposed in the previous study (e.g. Brown and Bangs, 1995).



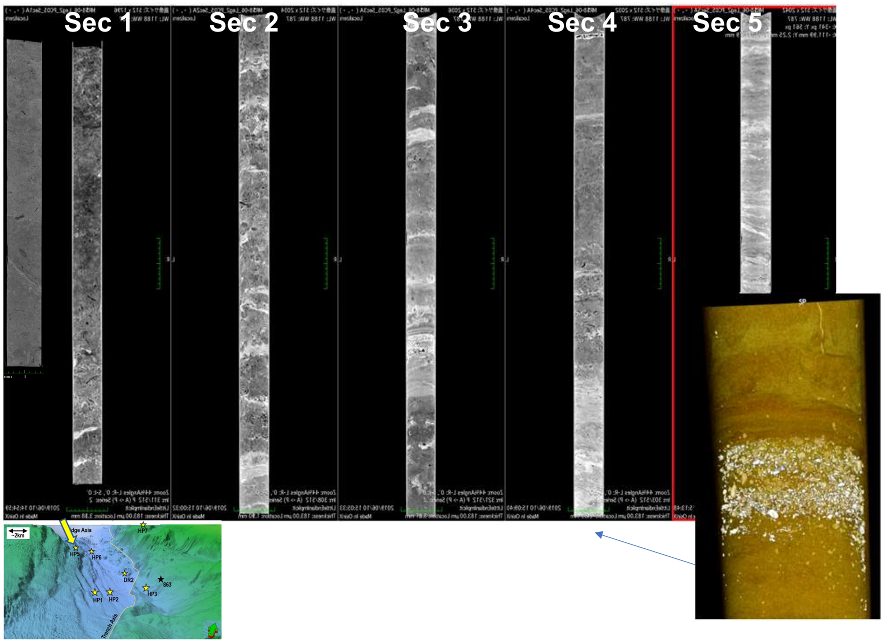



Summary plot for all piston core samples.
At each site, we plot bulk density (based on CT number and from Multi Sensor Core Logger=MSCL), P-wave velocity (MSCL), and CT image.



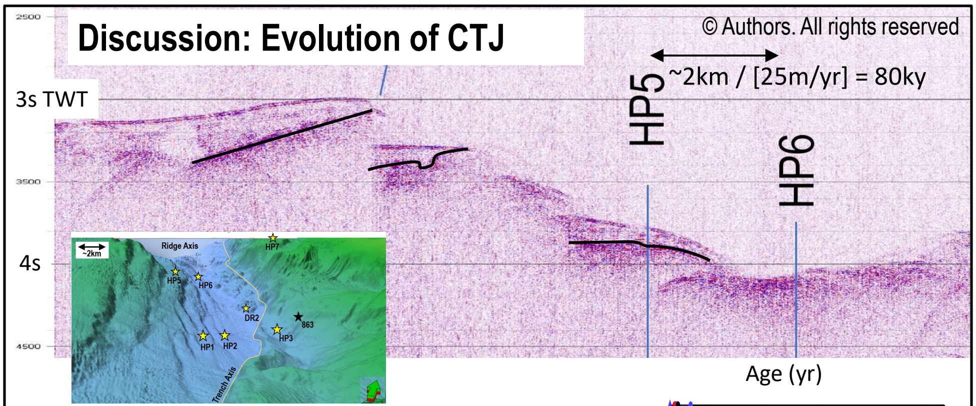

Age-depth for all piston core samples.

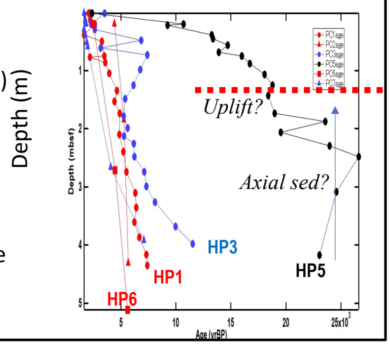
# MR18-06 HP5 CT image



# Discussion: Evolution of CTJ






○ 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?

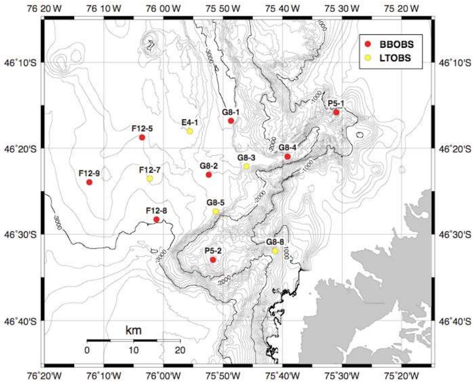
# Summary

- 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)

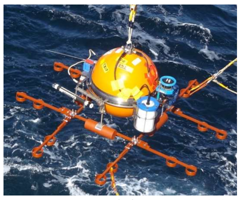

- We thank all Japanese and Chilean authorities; the Ministry of Education, Culture, Sports, Science, and Technology of Japan, the Ministries of Foreign Affair of Japan, Chile, Servicio Hidrografico y Oceanografico de la Amada de Chile, for allowing us to work inner and territorial water and the exclusive 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 than Kochi Core Center of Kochi University/JAMSTEC for post-cruise measurement on core samples.
- FUNDING: Japan Agency for Marine-Earth Science and Technology (JASTEC) for ship operation, SCS survey, piston coring, heat flow dredge and other operations; Earthquake Research Institute, the University of Tokyo for OBS deployment, JSPS grant-in-aid 18H01304 (JPFY 2018-2020) for travel and measurement support.

Supplementary slides

# OBS Deployment




Location map of OBSs. BBOBSs at sites F12-5 and F12-8 are with DPG



BBOBS with DPG (8)

LTOBS (5)

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.

# MR-18-06 Leg2: Tools

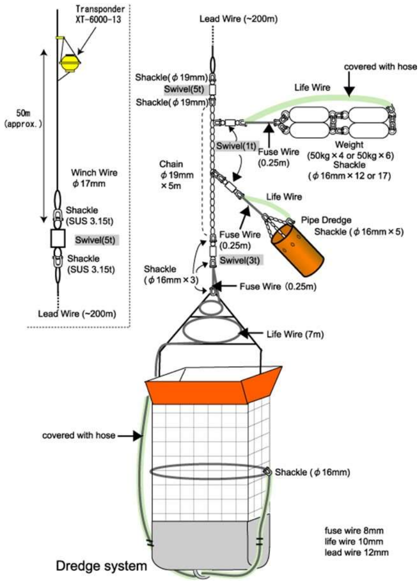
## Single Channel Seismic System (SCS)


Compressor


GI-gun


Streamer Cable

## Dredge system (hard rock sampling system)



Dredge system

# Discussion: Evolution of CTJ

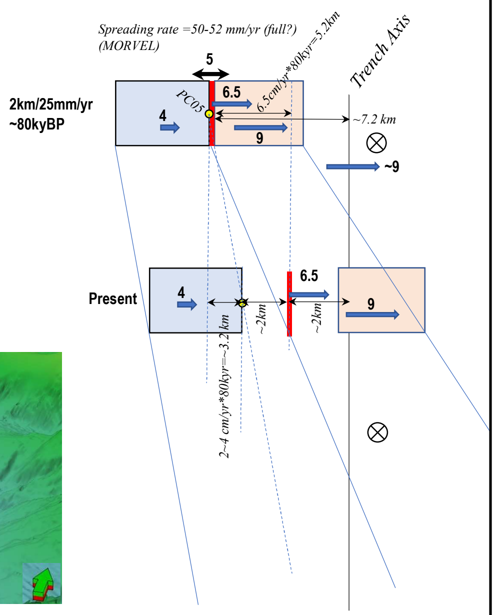
## Formation of HP5 crust

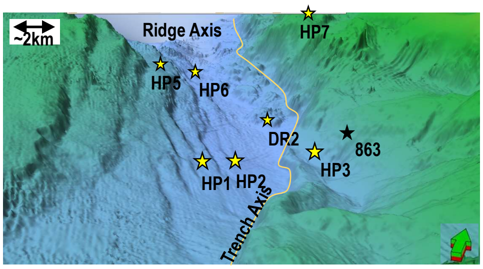
Present location at HP5(=PC05) is 2km away from axis

Spreading velocity (one-side) = 25mm/yr

-> The age at HP5 may be:

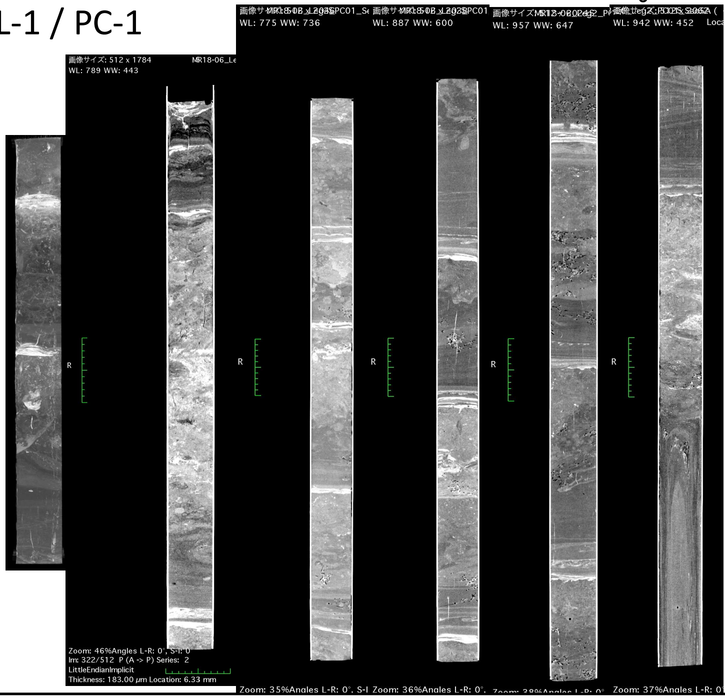
2km/(26mm/yr) = 80ky



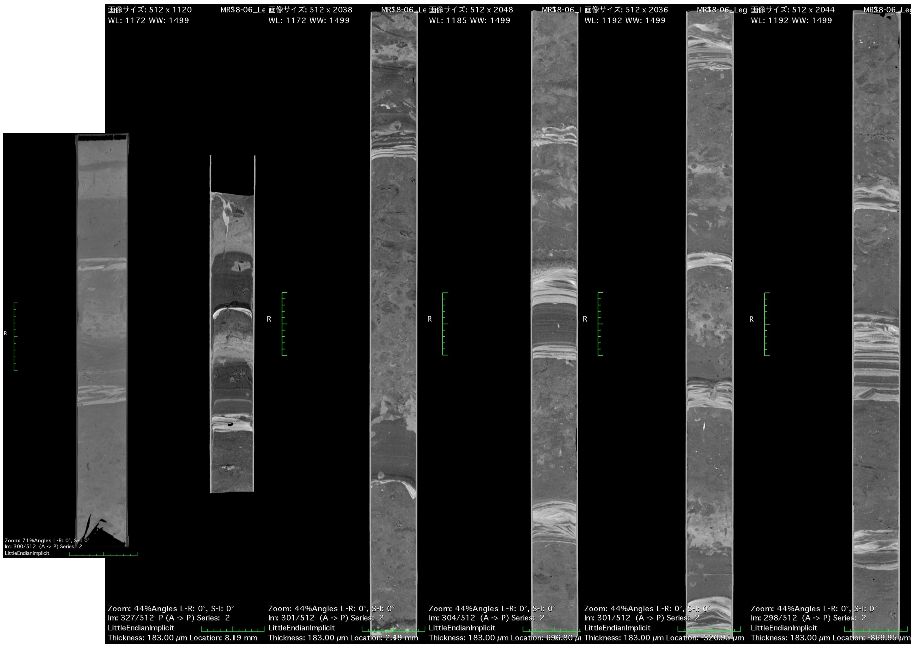
## MR18-06 PL-1 / PC-1





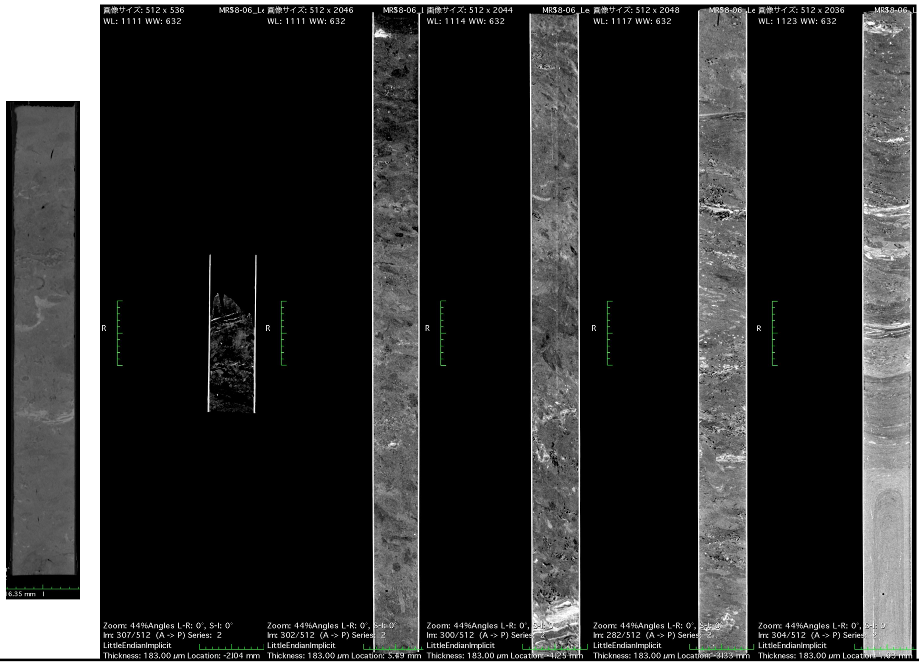
# MR18-06 PL-2 / PC-2





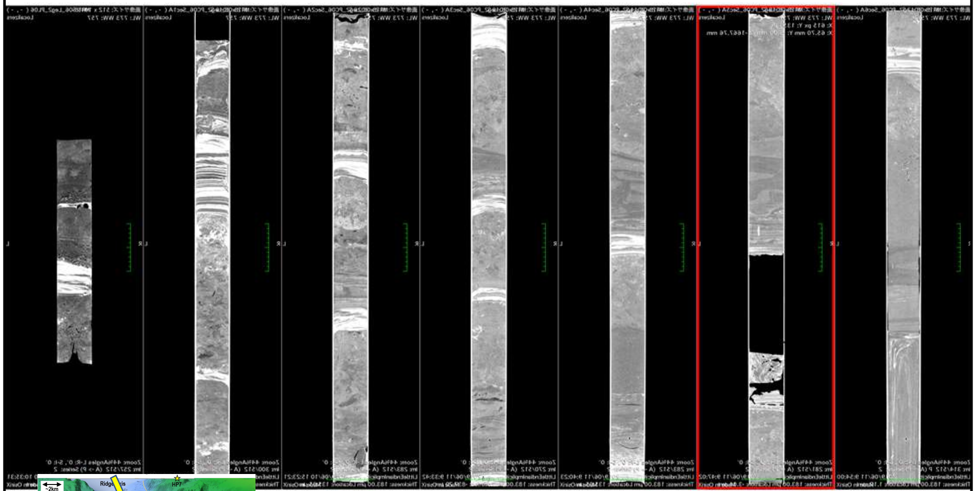
# MR18-06 PL-3 / PC-3

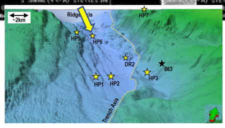




# MR18-06 PL-6 / PC-6







## MR18-06 PL-7 / PC-7