International Workshop
Cutting Edge Technology for Understanding the Earth
2023 January 12th, Tohoku University, Sendai

Scientific and Technological Achievements of the *D/V Chikyu* In the Plate Subduction Zone Drilling

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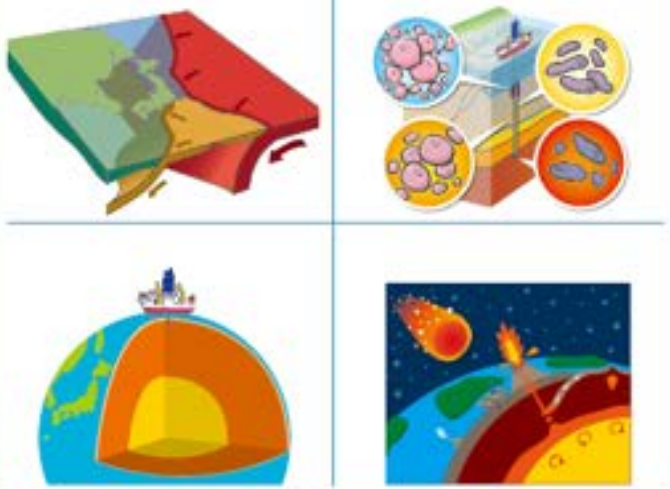
Director, Institute of Ocean Research and Development, Tokai Univ.

The Deep-sea Scientific Drilling Vessel *Chikyu*
The Flagship of IODP since 2007

D/V Chikyu Missions



D/V Chikyu
IODP scientific drilling records
(as of March 2018)

Expeditions: 17 Exp. days: 938

Exp. holes: 102 Drilling: 41km

Cumulative collected core lengths: 5.6 km

Number of cores: 1057 cores

Deepest water depth record:
6,900 m (Exp. 343)

Deepest hole record: 3058.5 m (Exp. 348)

By JAMSTEC

JAMSTEC
Japan Agency for Marine-Earth Science and Technology

IODP=Integrated Ocean Drilling Program
Integrated = Integrated Technology

Integrated Technology=
Core：Geological Sampling
Logging：Physical Property Measurements
Seismic：Seismic Profiling of Geological Structure
Observatory：Borehole Observatory & Cable Network
Experiment：Active Experiment using Borehole
e.g.: Controlled Hydrothermal Mineral Precipitation at the Okinawa Trough

R/V Tanseimaru – *R/V Fred Moore*
Two-ship Seismic Experiment at the Nankai Trough July 1987 (Univ. Tokyo-UTAustin-Univ.Hawaii)

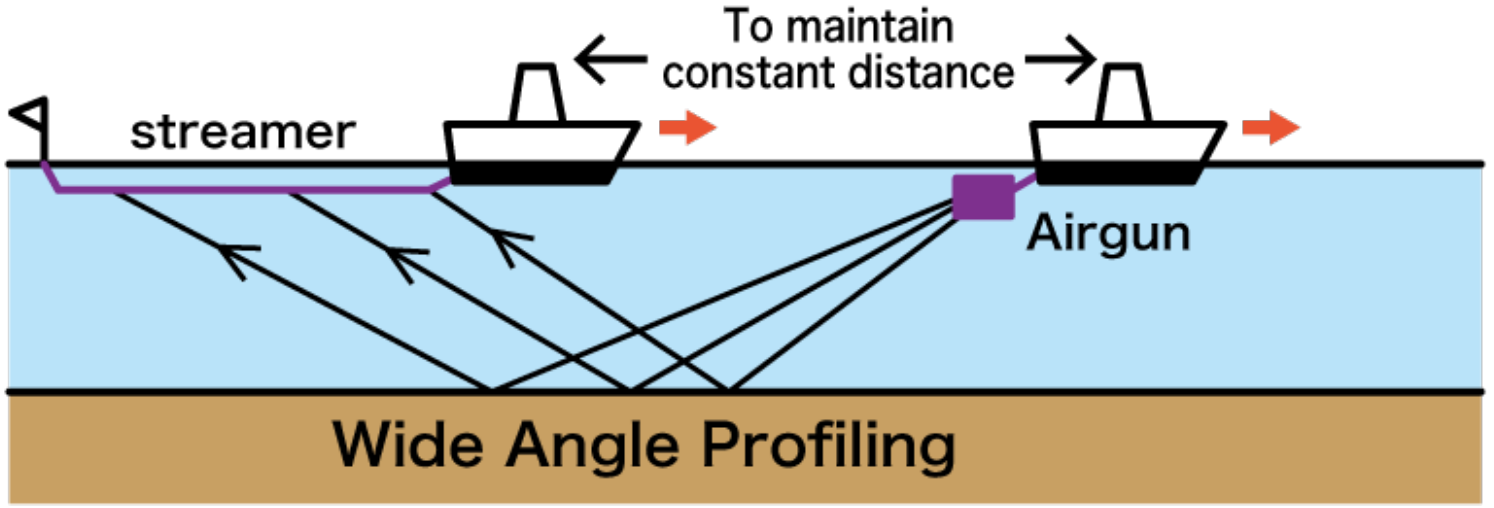
R/V Fred Moore & R/V *Tanseimaru*

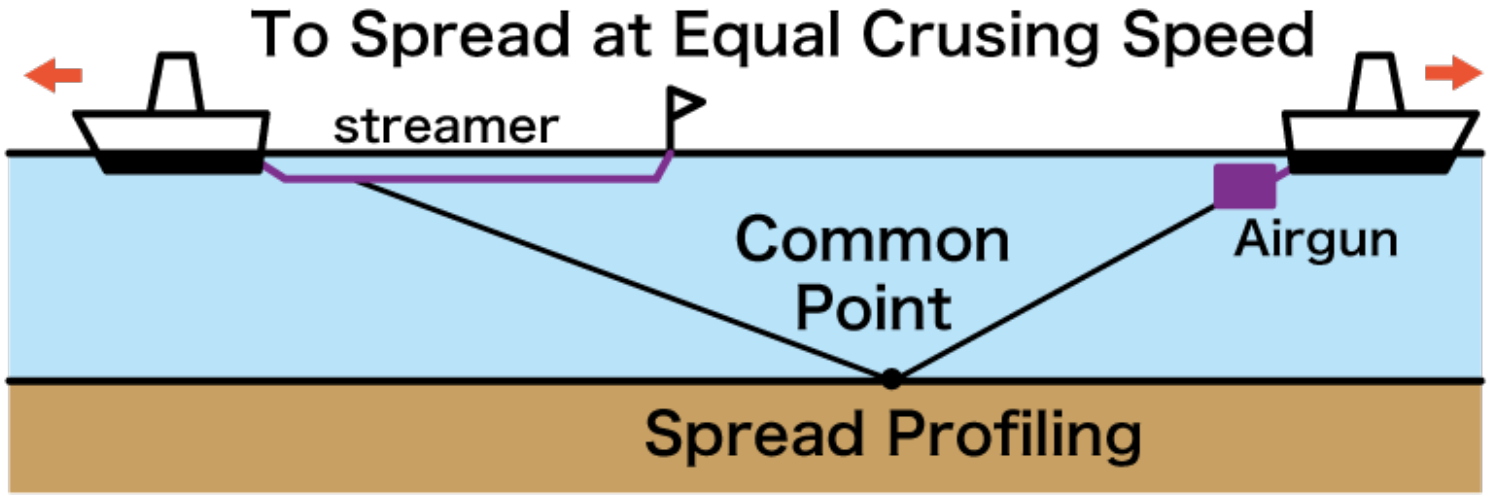
A.Taira on R/V *Tanseimaru*

Prof. Greg Moore & Dr. A. Nishizawa

By A. Taira

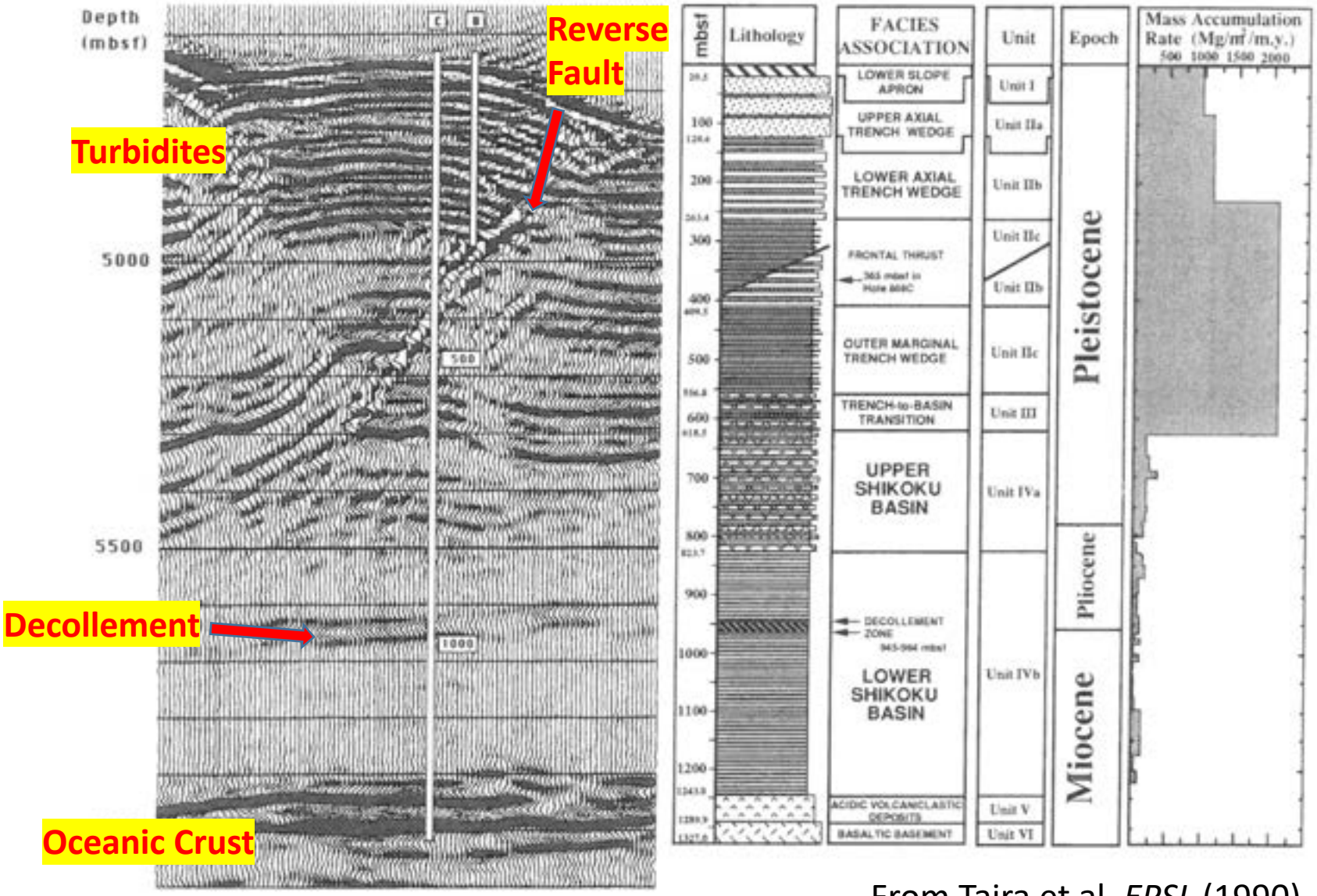
Two-ship Seismic Profiling:
High-quality Velocity Structure Determination





by A. Taira

Correlation of Seismic Profile and Lithology Site 808, Leg 190 Nankai Trough



From Taira et al. *EPSL* (1990)

ODP Nankai Downhole Observatory: ONDO Project
Leg 190, 1990

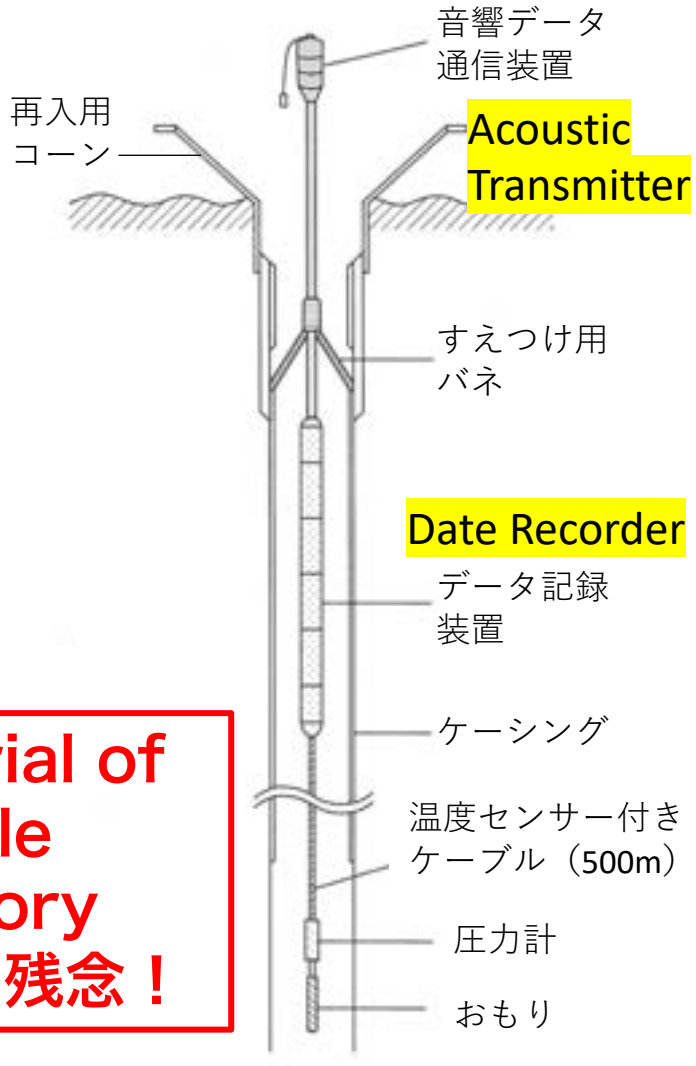
Taira, A. et al. *Proc.ODP* (1990)

Thermistor Cable

Landing Device

Acoustic Data Transmitter

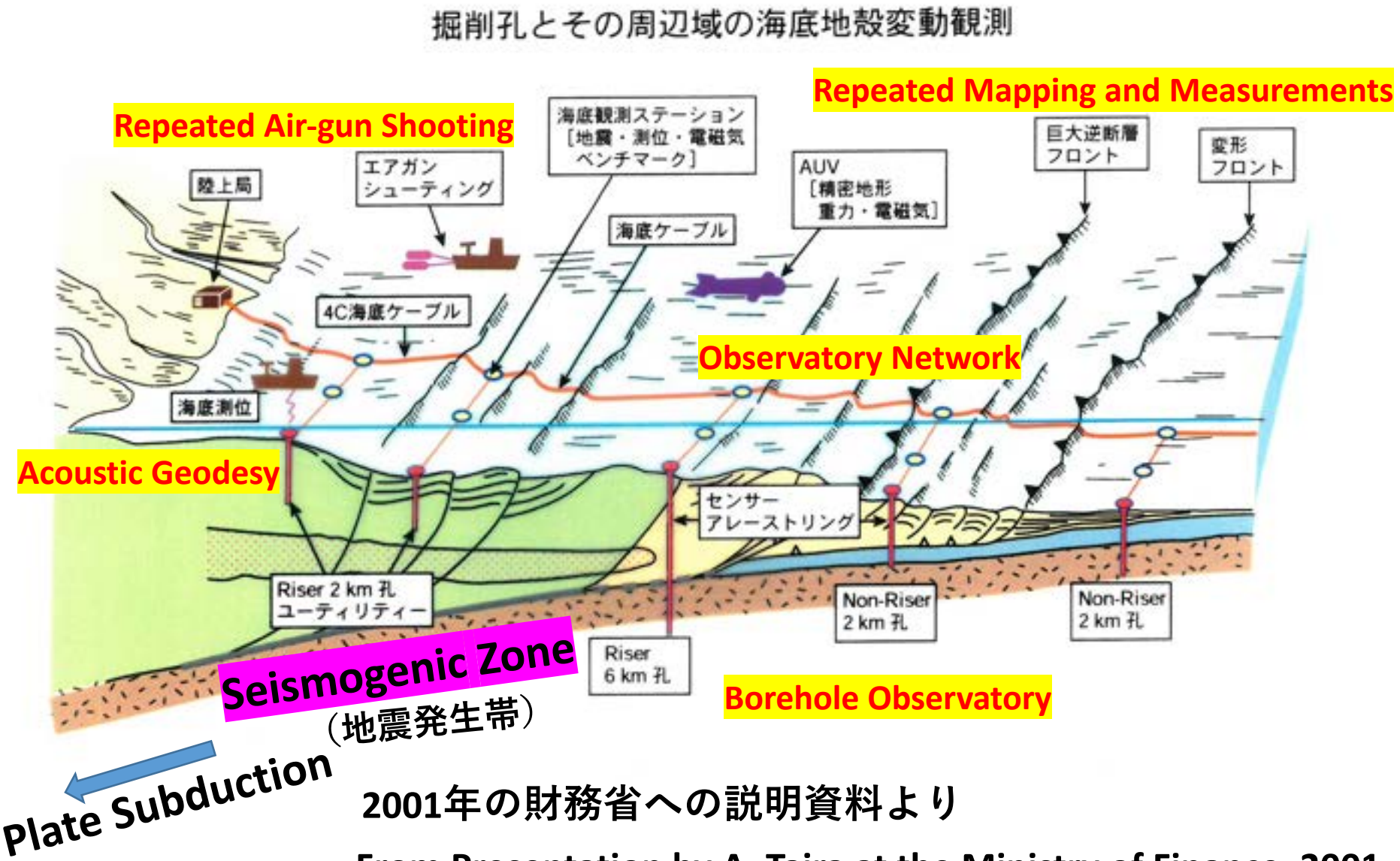
The First Trial of Downhole Observatory But, Failed！残念！



Schematics of ONDO

Chikyu Project Proposal:

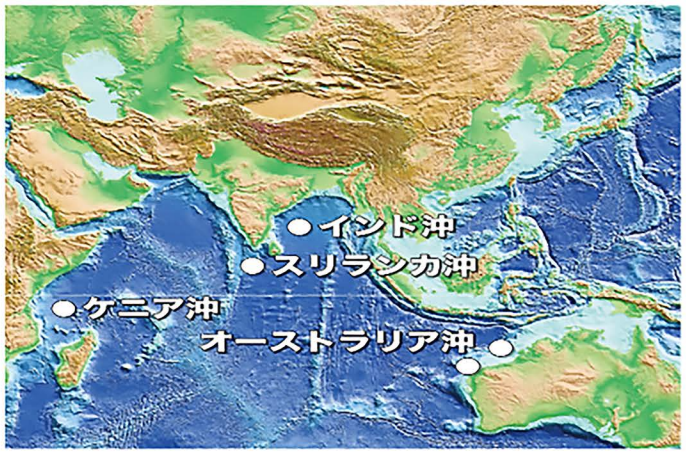
Not Just For Geological Sampling But Monitoring of Earth Interior



2001年の財務省への説明資料より

From Presentation by A. Taira at the Ministry of Finance, 2001

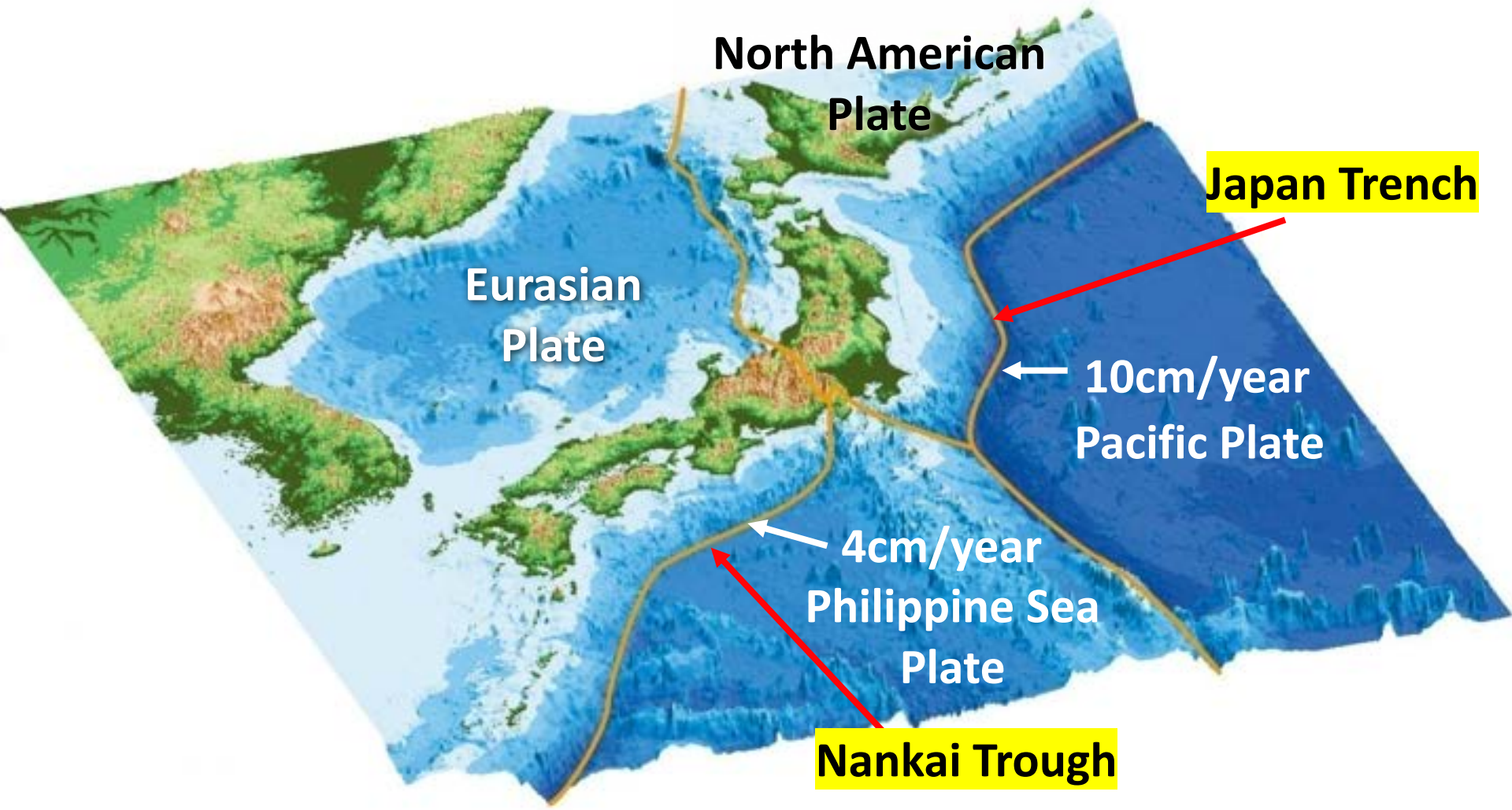
IODP and Other Drilling Sites by the *Chikyu*



(By JAMSTEC)

Drilling for Oil and Gas
海外資源受託掘削

Topography of Japan Islands and Plate Boundaries



by A. Taira

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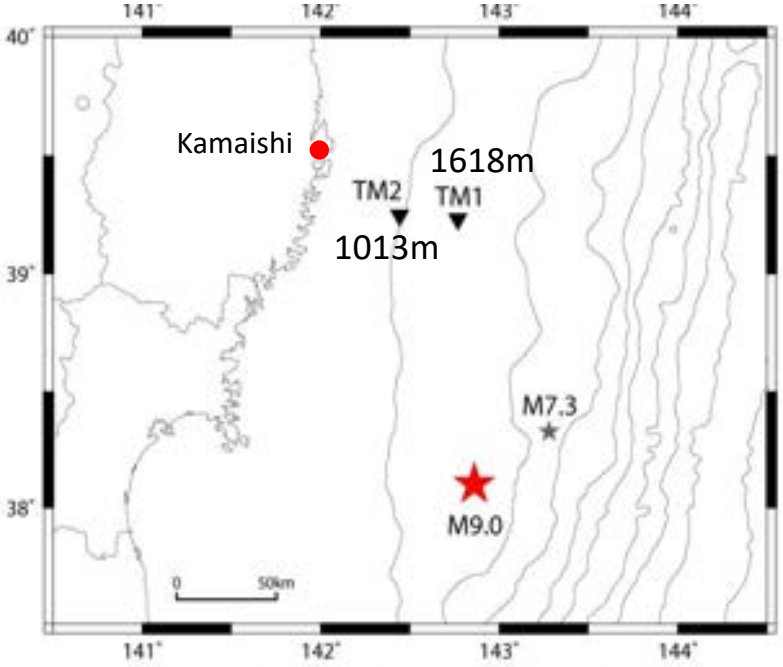
J-FAST
Japan Trench Mega-earthquake Fast-Response Drilling
Exp.343 and Exp.343T
2012

Tsunami washed the Sendai Airport, March 11, 2011

Photo by JiJi press (2011)

Huge Tsunami Observed by Ocean-floor Sensors

The offshore pressure sensors detected the huge tsunami 20 minutes prior to the arrival at the City of Kamaishi.



Wave Height

Kamaishi Ground Motion

Kamaishi Tsunami

14:47

20 minutes

15:21

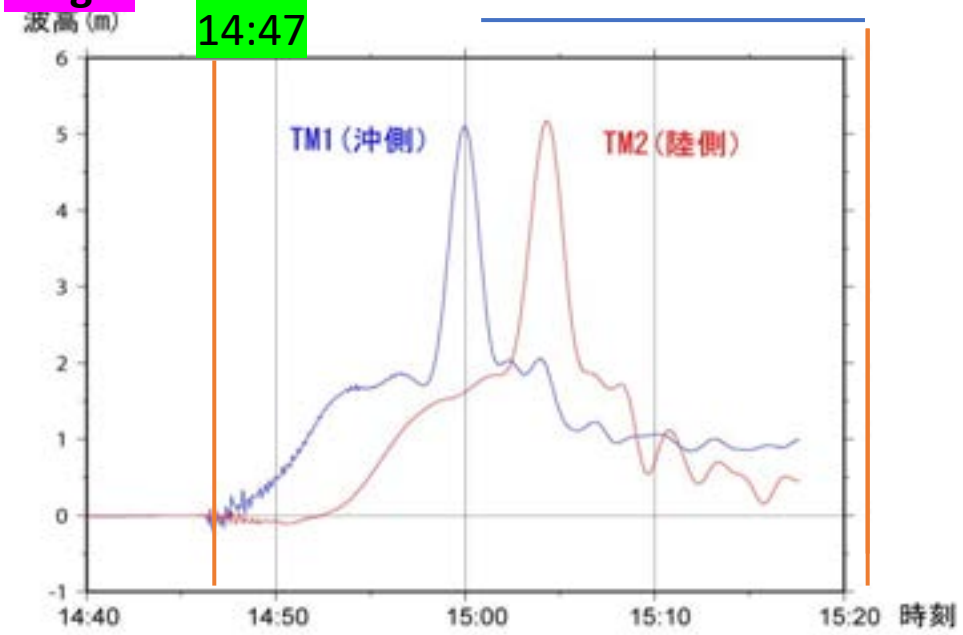


図２　海底水圧計の観測記録。14時46分頃、本震(M9.0)の振動が水圧計に伝わり、TM1(海寄り)では、その時から徐々に海面が上昇している。約２ｍ上昇し、約11分後にはさらに約3m急激に上昇し、合計約5m海面が上昇した。約30km陸寄りに設置されているTM2では、TM1から約4分遅れて同様の海面上昇を記録した。

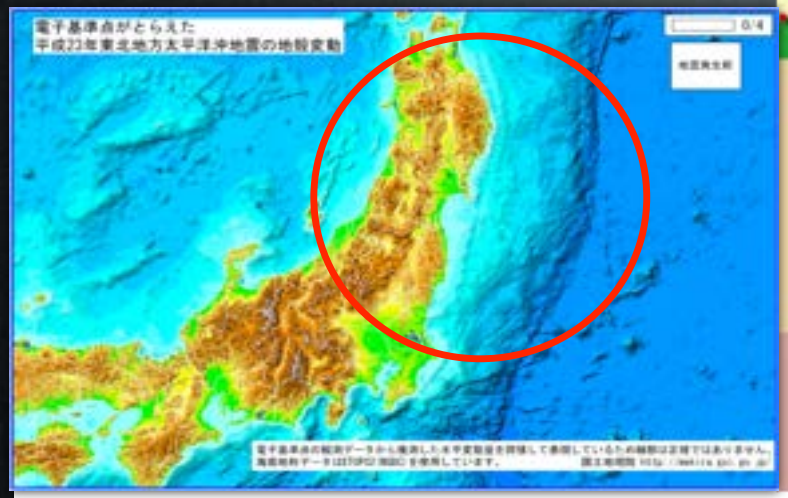
Cable Observation Point: TM1 & TM2
Off the coast of Kamaishi

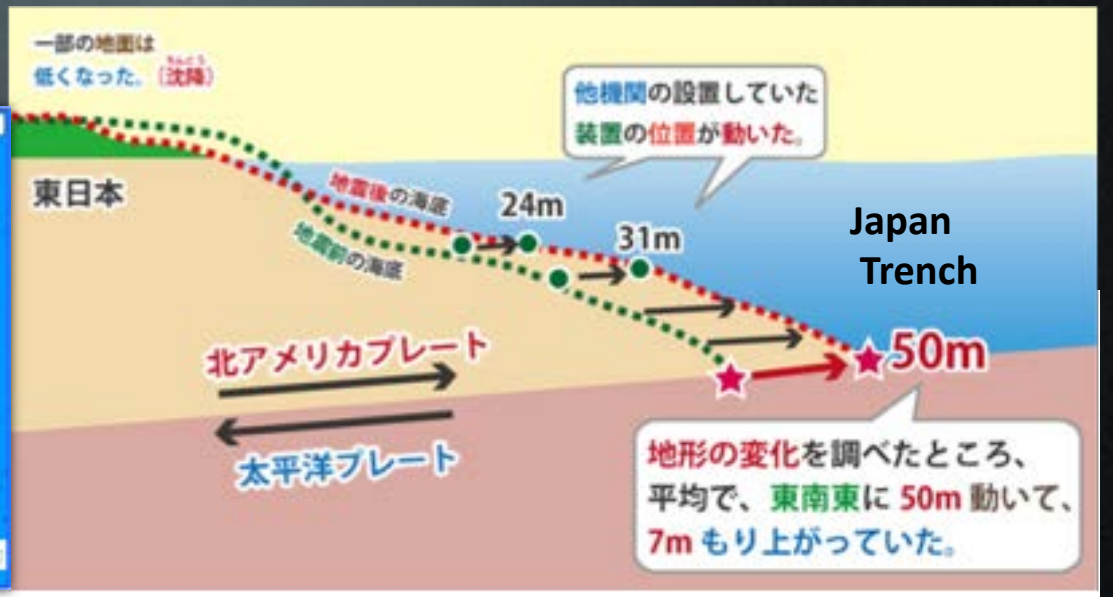
Earthquake Research Institute(ERI), Univ. of Tokyo. (2011),
Maeda et al., *Earth Planets Space* (2011)

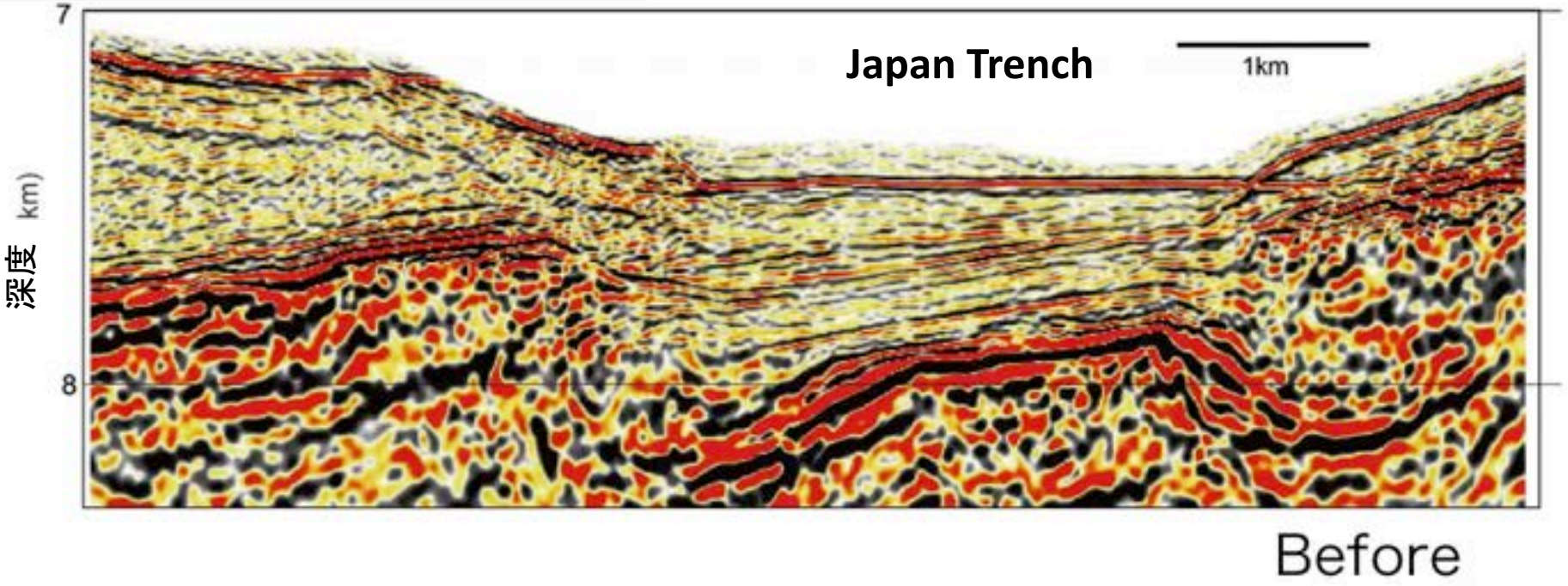
Data were not used for the official warning system

Huge Eastward Motion of Landward Slope and Trench Axis

Slide made by S.Kuramoto
based on National Geographic Inst. Home Page,
Fujiwara et al., *Science* (2011),
Kodaira et al., *Nat. Geosci*. (2012)



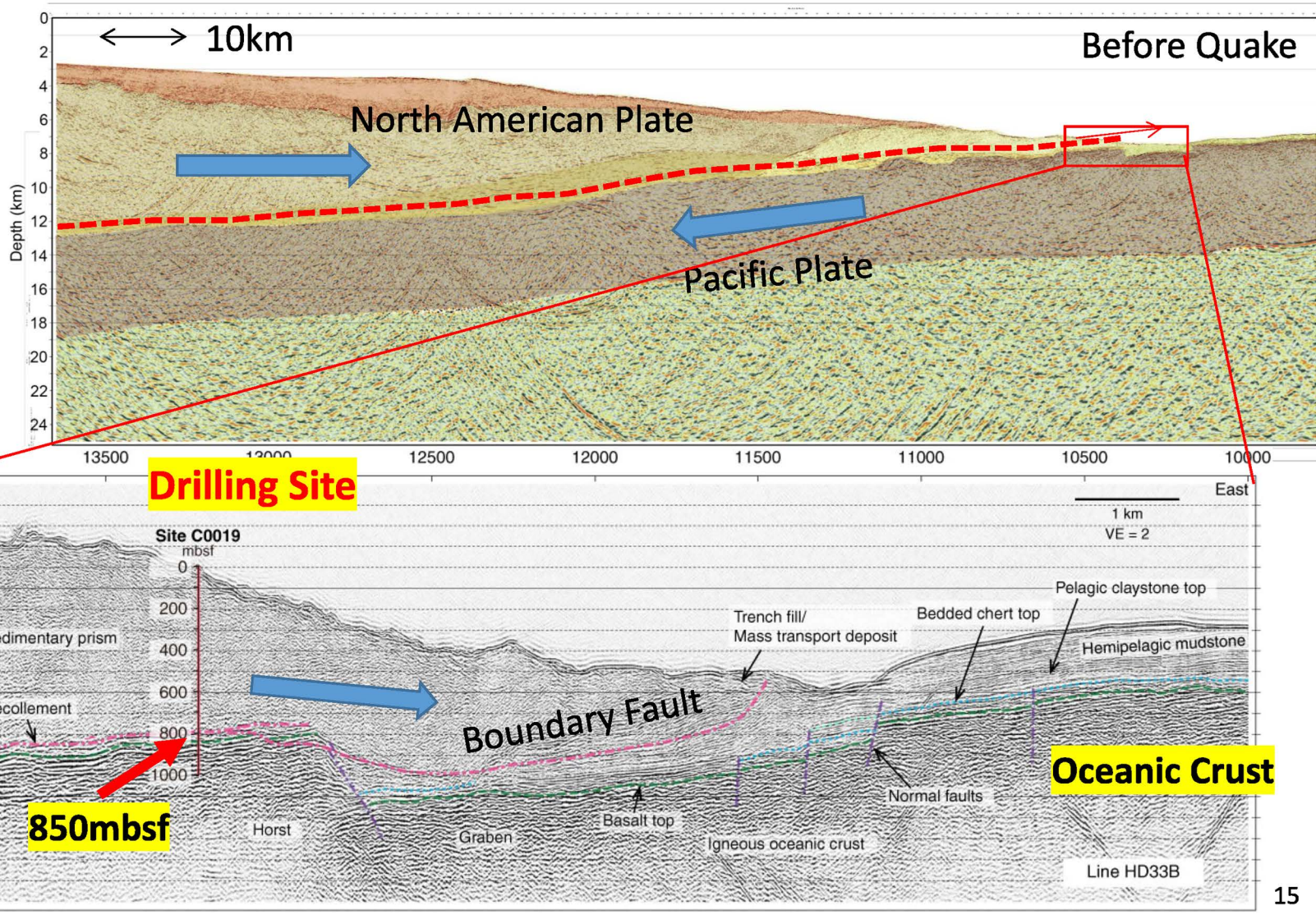




IODP J-Fast Drilling: April-May, 2012

From 6900m water depth to the Plate Boundary Fault Zone

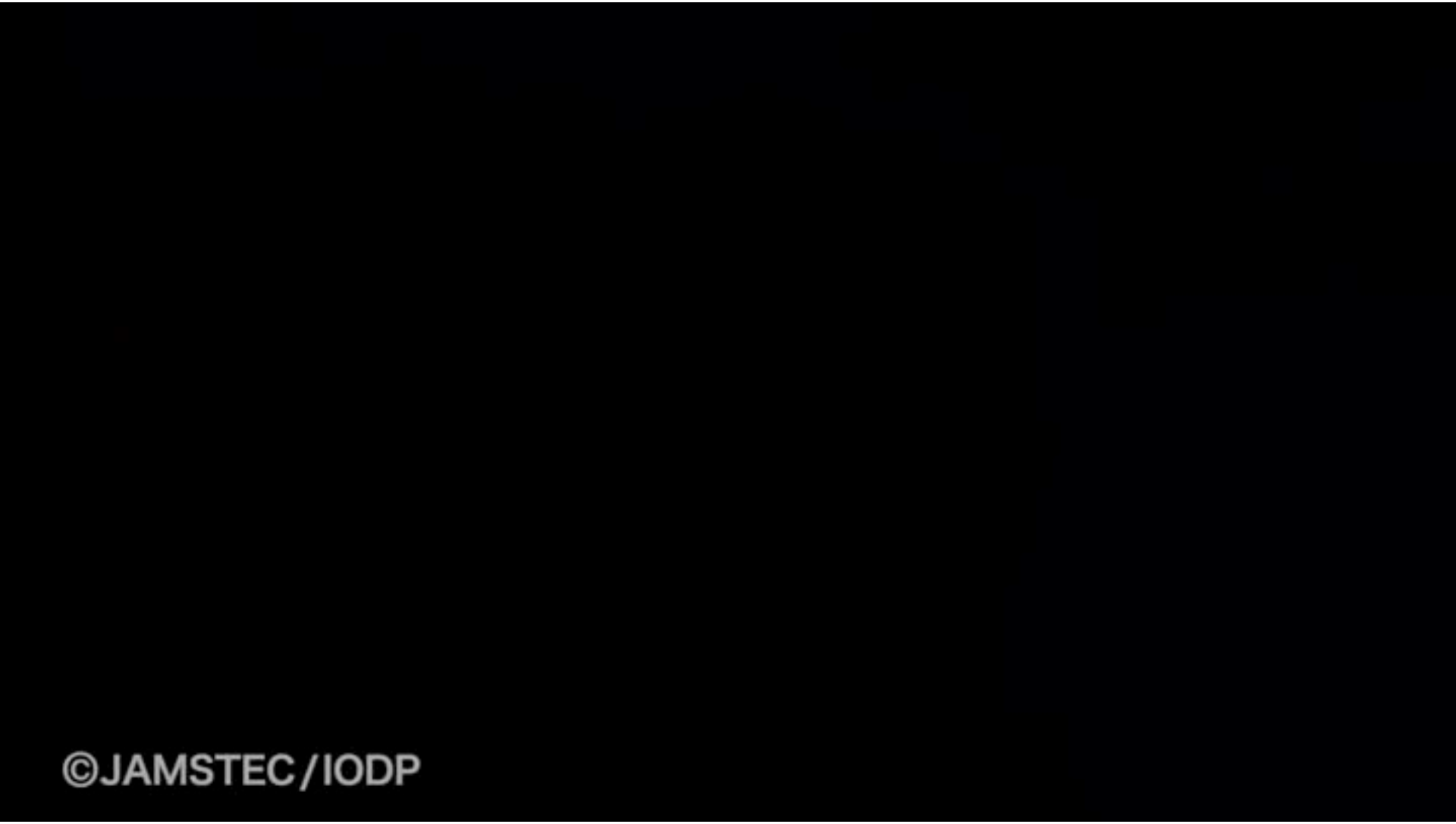
Kodaira, S. et al., *Nature Geosci.* (2012)
Chester, FM et al., *Initial Rep. IODP*, (2012)



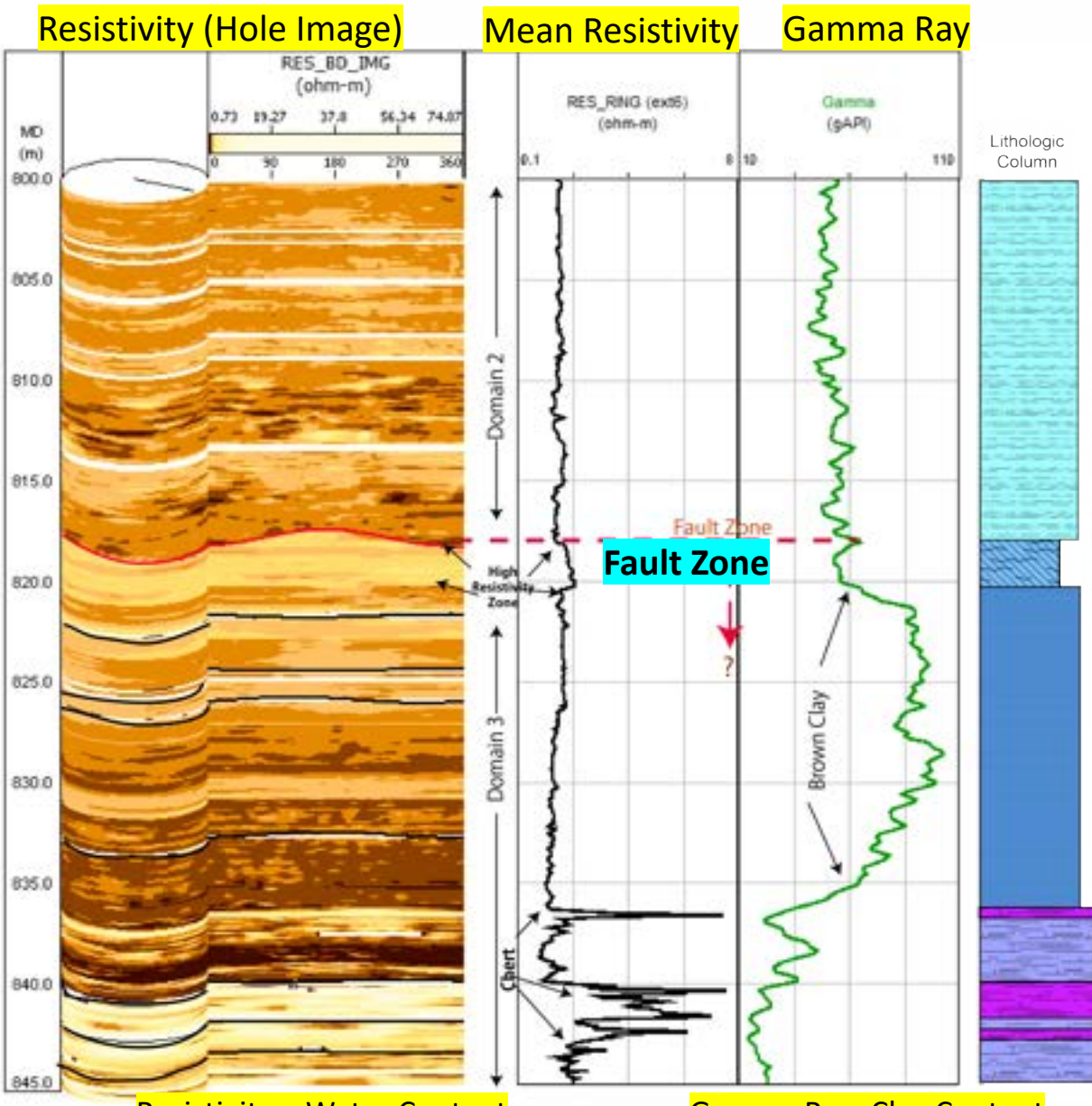
Exp. 343: Fault Zone Core from 817mbsf

For the first time in the history of Scientific Ocean Drilling, M9-earthquake fault zone was drilled, logged and sampled.

Installation and Recovery of Thermistor String, Exp. 343T

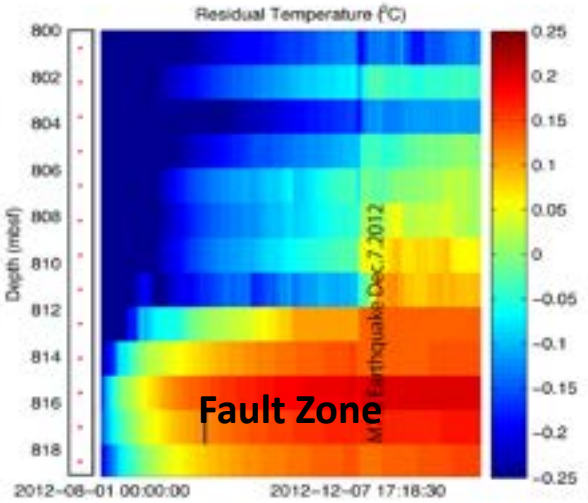


Fault at 817mbsf and Thermal Anomaly

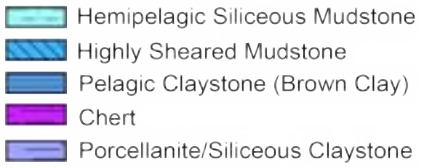


Fulton et al., *Science* (2013)
Mori et al.,*Oceanography* (2014)
Kirkpatrick et al., *Tectonics* (2015)

Residual Temperature



Friction Coefficient less than 0.1



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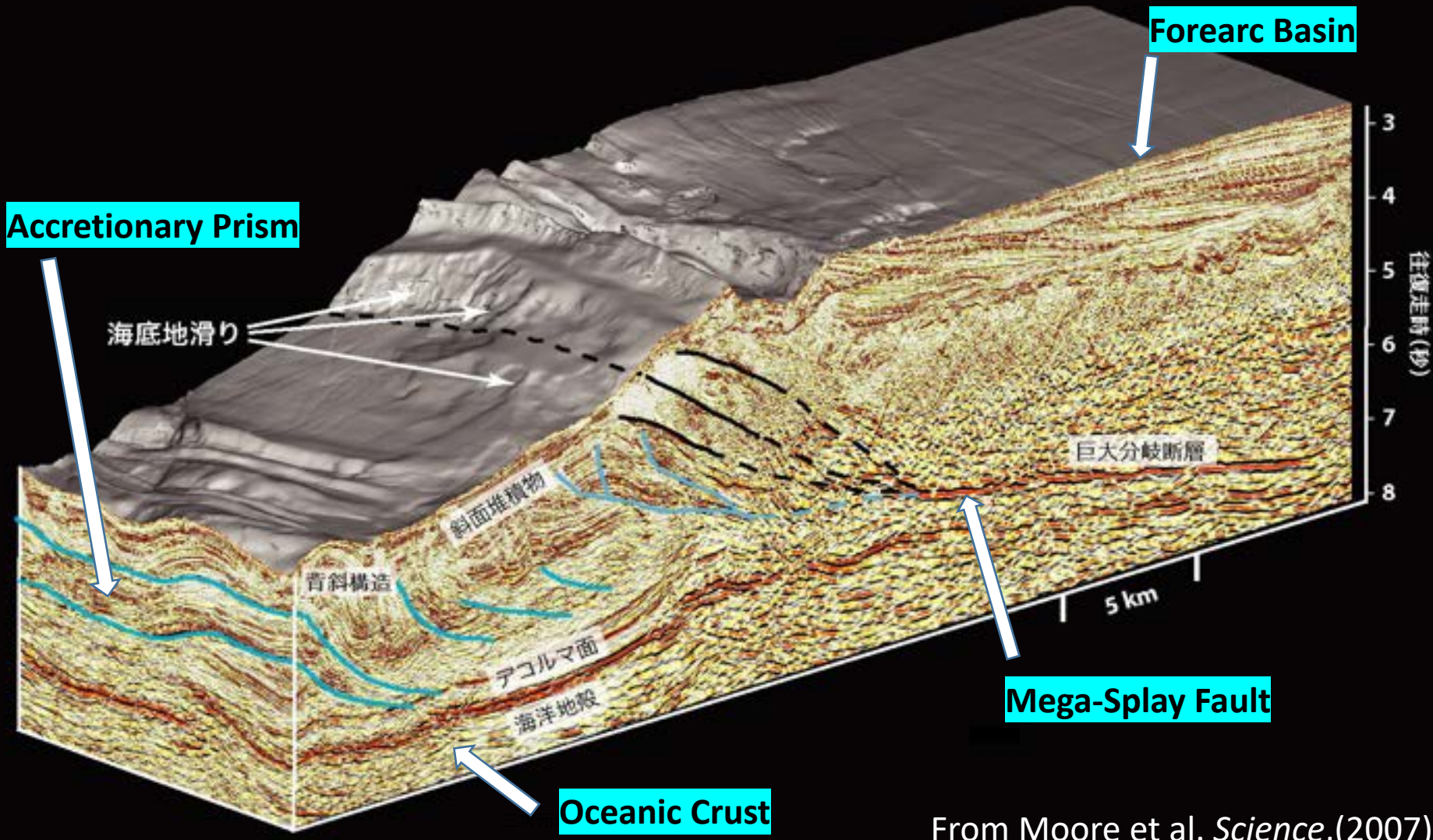
IODP
Nankai Trough Seismogenic Zone Experiments (NantroSEIZE)

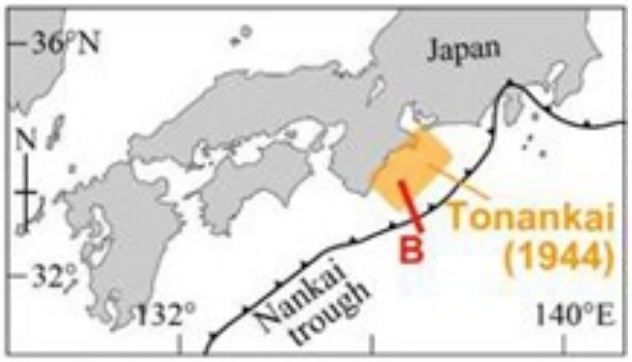
Multiple Expeditions
2007-2018

3D Seismic Profile of the Nankai Trough
Accretionary Prism & Forearc Basin
(JAMSTEC - Univ. Hawaii Collaboration)



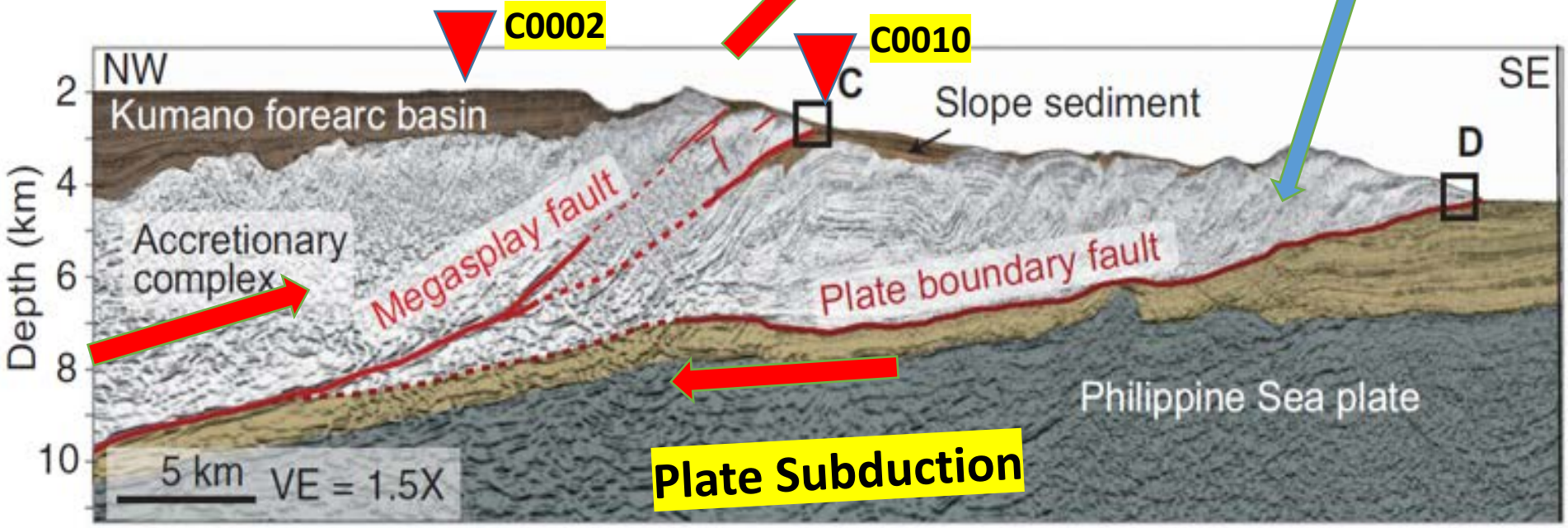
From Moore et al. *Science*,(2007)

A Model of Tsunami Generation by Mega-Splay Fault
- 2007 Version -



Surface Propagation of Seismic Rupture through Mega-splay Fault: The Cause of Tsunami

Weak Newly Formed Accretionary Prism: Non-Seismogenic

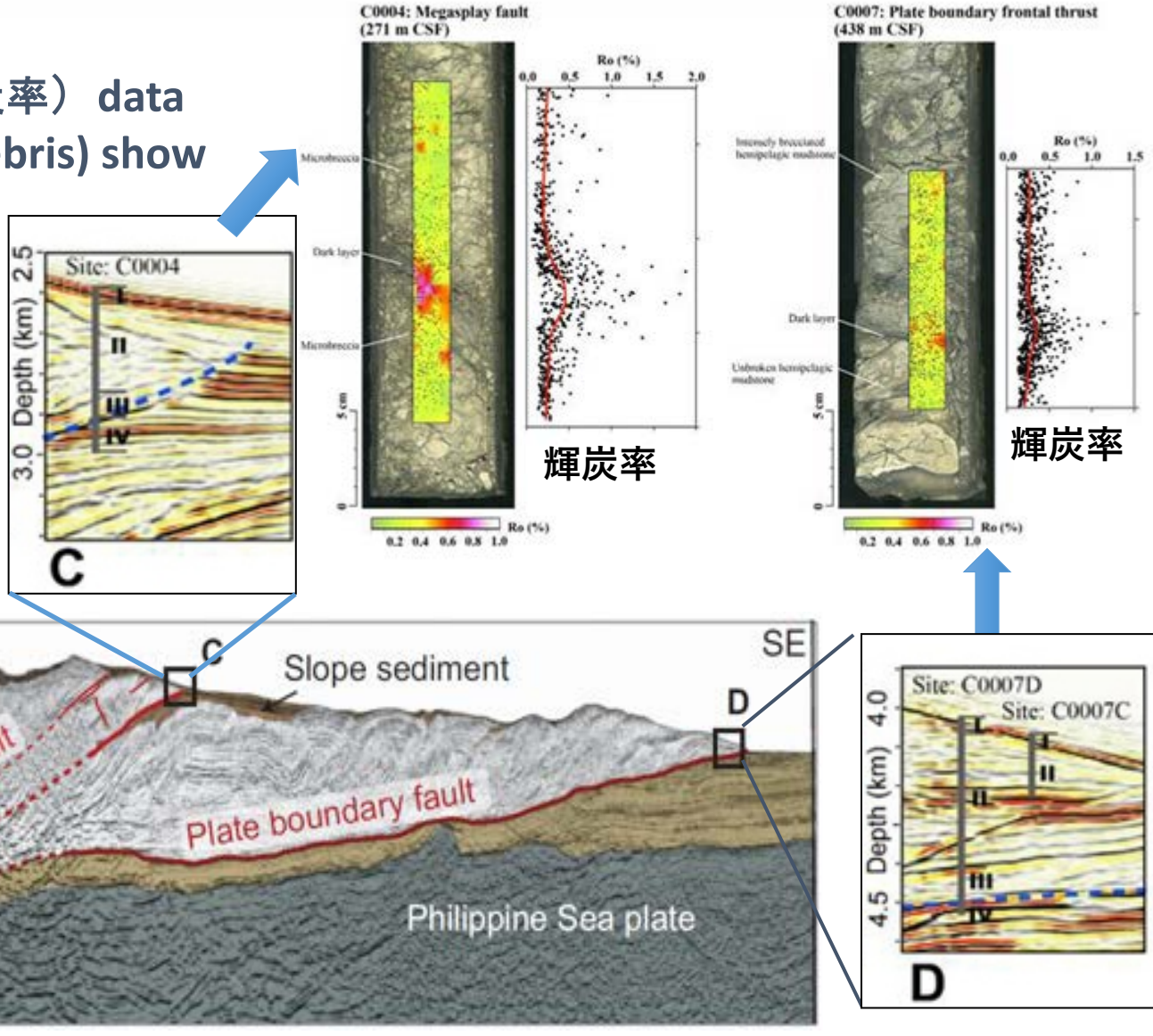


Observatory Site

Seismic Profile from Moore at al., *Proc. IODP,* (2009)

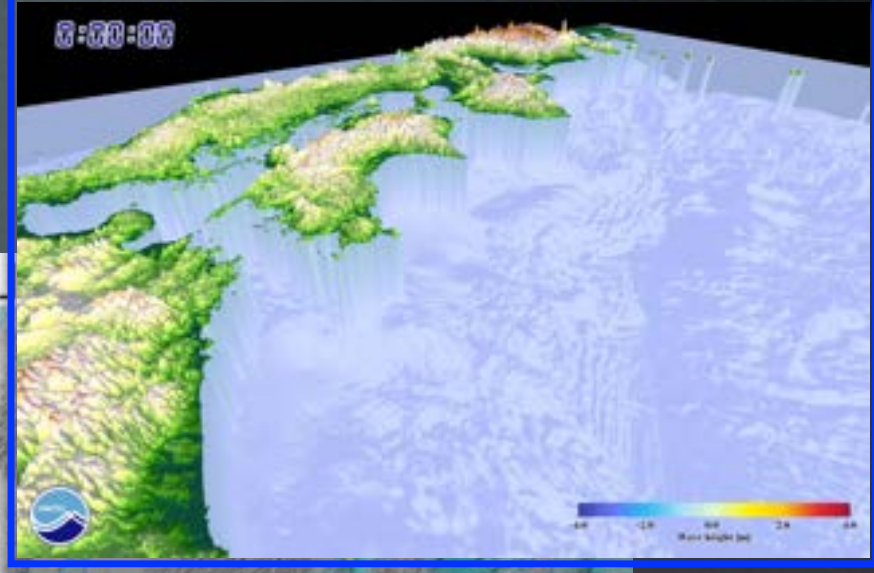
Evidence for Trench Seismic Slip at the Nankai Trough
A New Model for Tsunami Generation

Vitrinite reflectance (輝炭率） data (Coalification of Plant Debris) show frictional heating at the mega-splay fault and the forefront of the plate boundary.



Sakaguchi et al. *Geology* (2011)

Revised Model of the Nankai Trough Mega-earthquake & Tsunami Generation



By JAMSTEC

図４「最大クラスの地震・津波

Kuroshio-cho Town
1946 Nankai Earthquake T.H.=6m
Maximum Rupture and Tsunami Zone T.H.=34m
(T.H.= Tsunami Height)

Previous Zone of the Maximum Rupture
(M9.0)

南海トラフ

津波地震を検討する領域

Add-on Tsunami Generation Zone
based on the IODP data
(M9.1)

by Japan Cabinet Office (2012)
（内閣府　中央防災会議）

DONET Technology Innovation

Connector Joint

Node for Extension

Termination Device

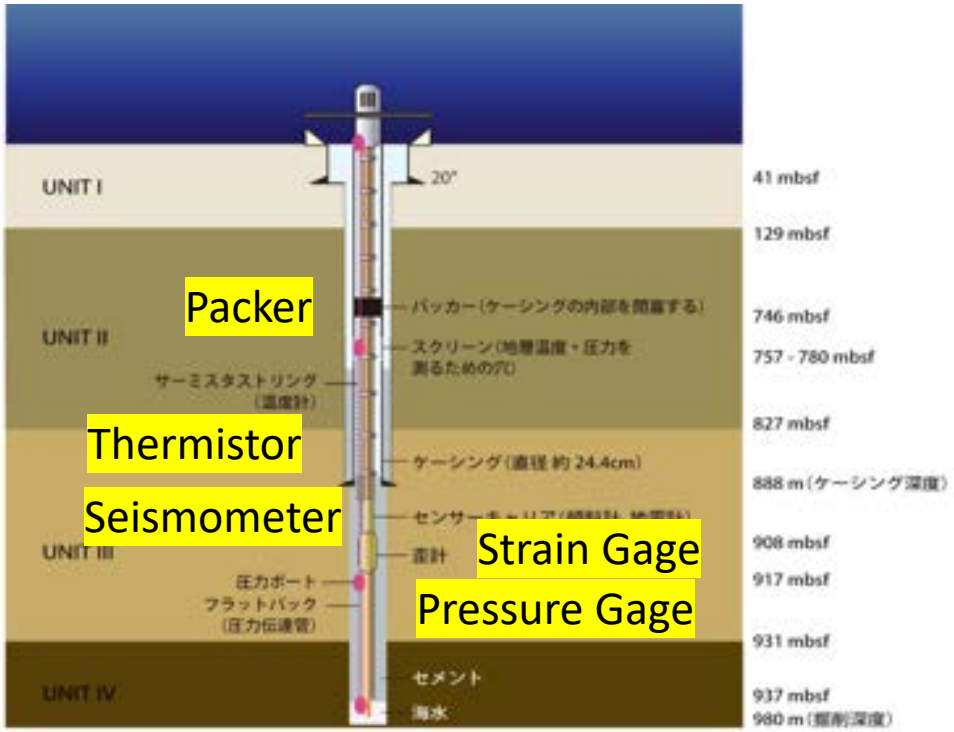
Seismometer

Pressure Gage (Tsunami Sensor)

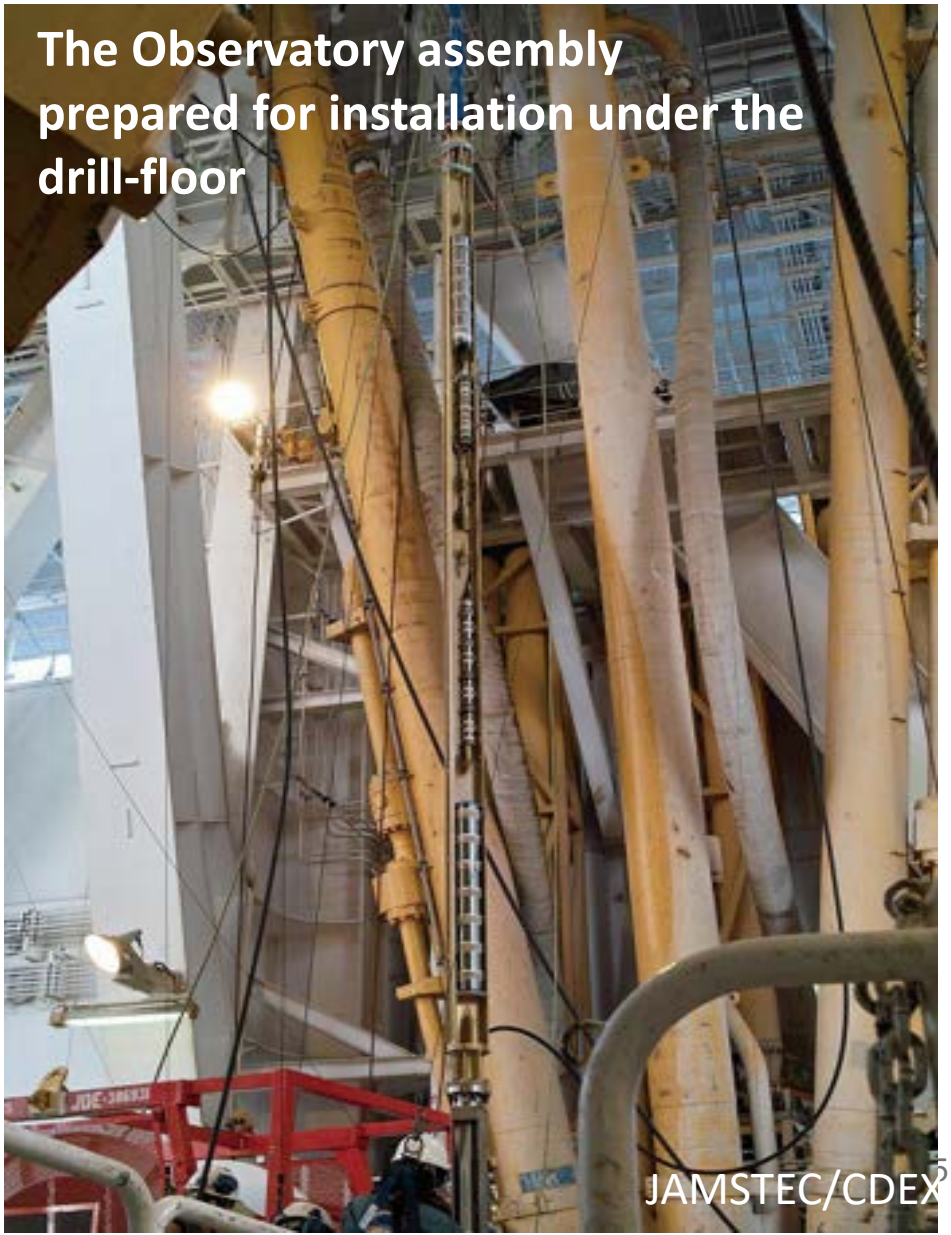
Extension Cable

By JAMSTEC

Borehole Observatory of C0002 Site Nankai Trough



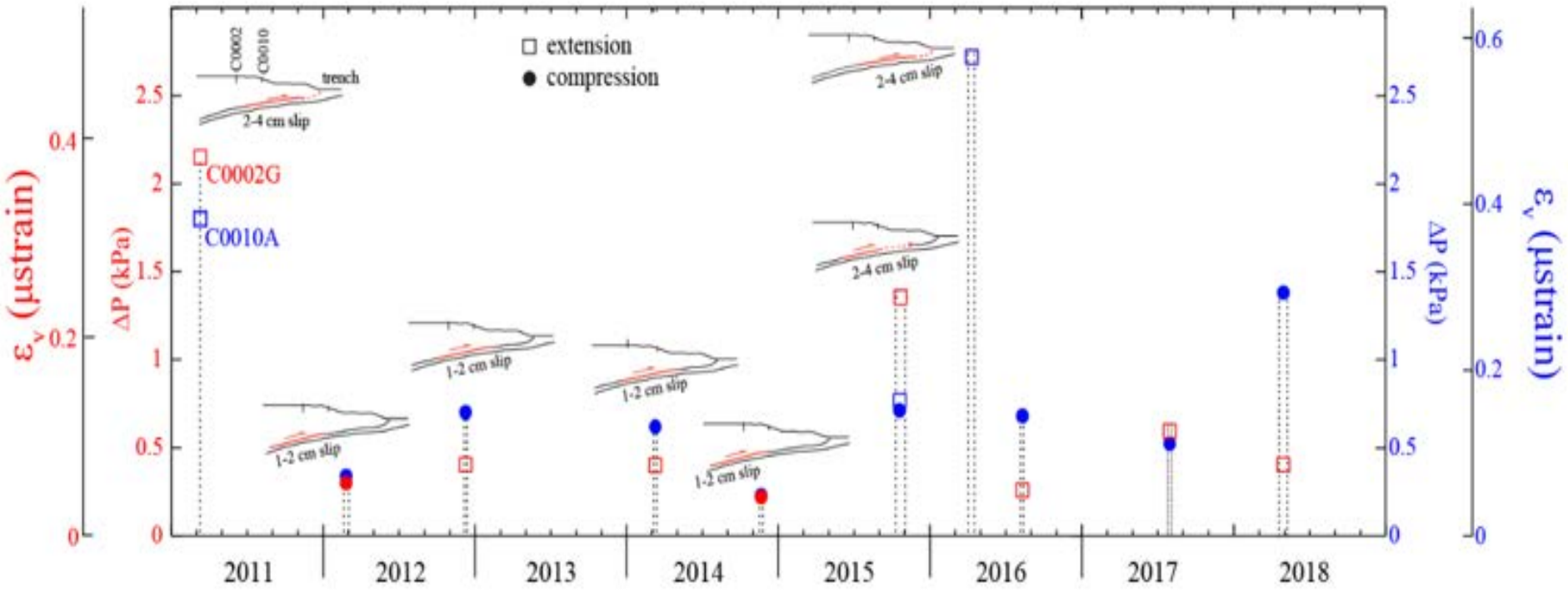
JAMSTEC/CDEXより

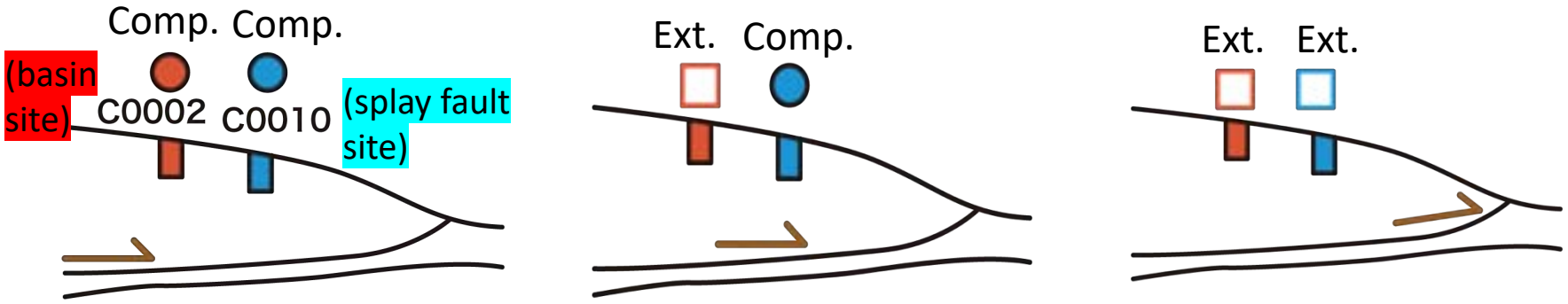


JAMSTEC/CDEX

Detection of Slow-Slip Events by Pore Pressure Measurement

From Araki et al. *Science* (2017)

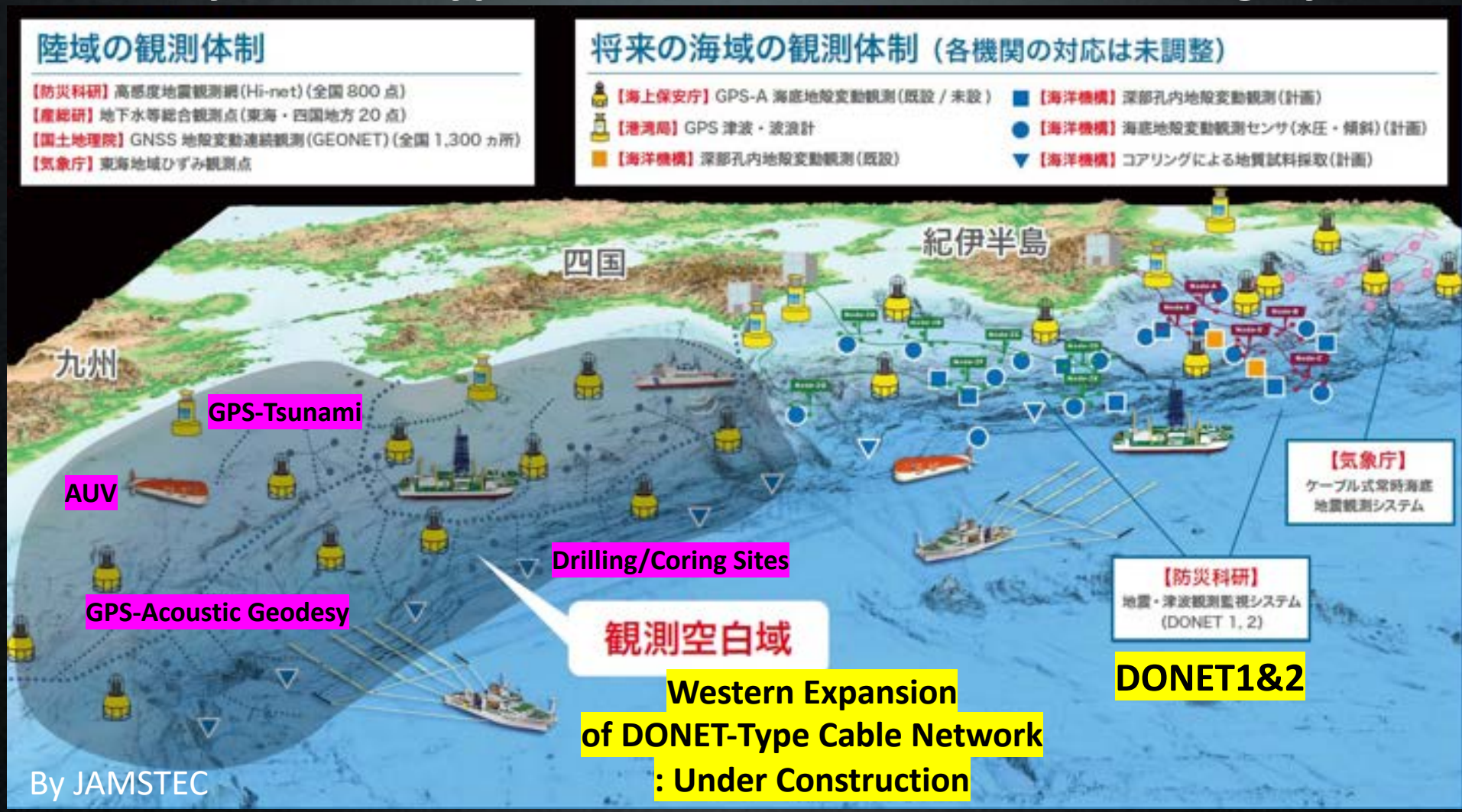




1-4cm of slip at each event

Equal with 30-50% release of subduction strain

Proposed Full Coverage of the Nankai Trough by DONET-type Network & Real-time Warning System



次の南海トラフ沈み込み帯での巨大地震は、いつ、どこで、どのように発生するかは不明である。予測、予知することも現在の科学技術力ではできない。しかし発生に至る過程や、一部で地震が発生した後の追跡は可能である。我々は即時モニタリングを最低限行うことによって、多くの生命・財産を守ることができるであろう

Japan Trench and Nankai Trough Project Summary

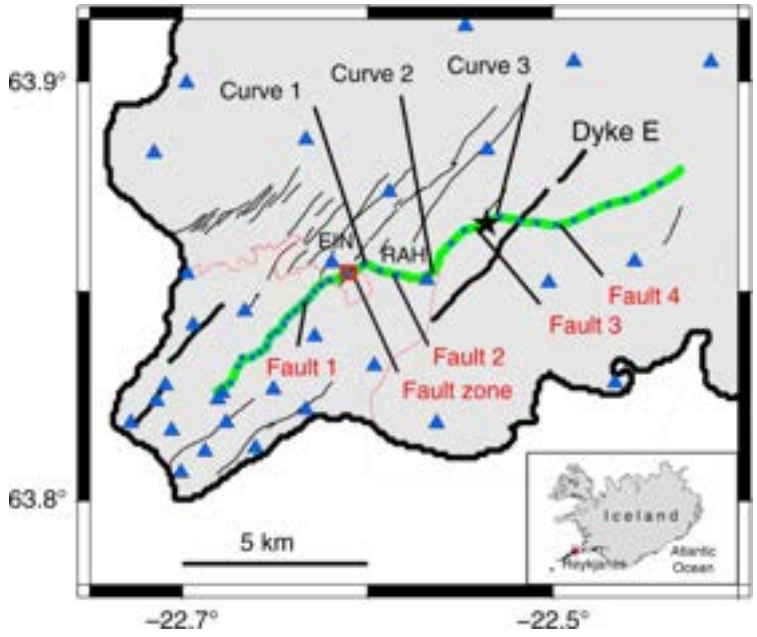
◎ Technical innovation of core-log-seismic-observatory integration has completely revised our understanding of the plate boundary mega-earthquake and tsunami genesis.

◎ Combined borehole observatory and seafloor cable network would provide real-time warning system for the reduction of casualties.
(The system is now utilized at the national and local government levels and private organizations)

Future Cutting-edge Technology
The *Chikyu* and IODP Beyond No.1

Further Development of Core-Log-Seismic-Observatory-Experiment Integration

Key Technology: Fiber Optic Cable as Seismic & Crustal Motion Sensor



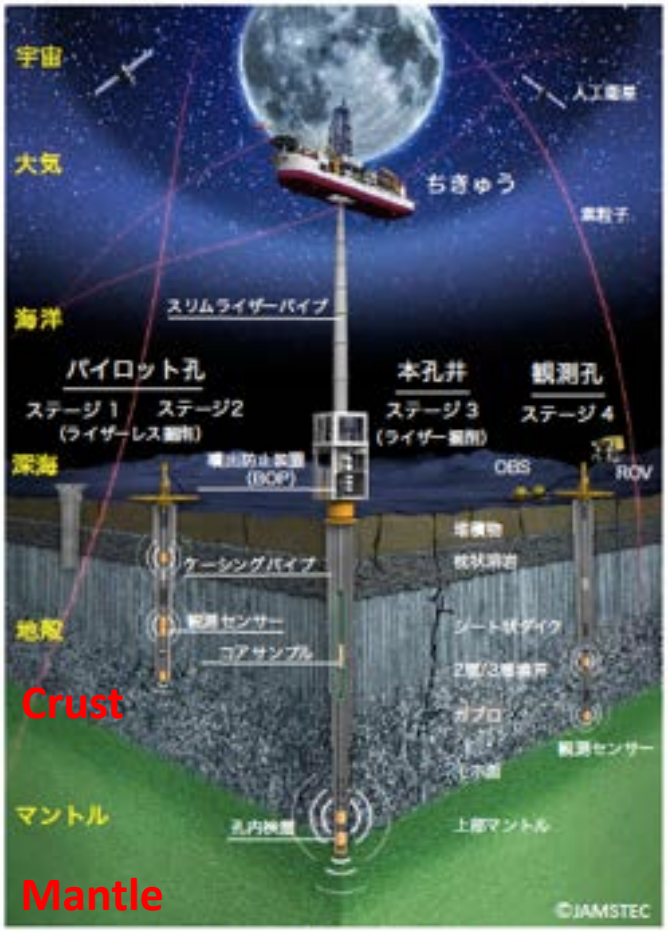
Jousset, P. et al., *Nature Comm.* (2018)

◎**Observation of High-Resolution Plate-wide Seismicity and Crustal Deformation**

◎**New Insight into Earth's Interior Dynamics and Geo-Hazard Science**

Iceland crustal deformation observed by fiber optic cable (green line)

Future Cutting-edge Technology The *Chikyu* and IODP Beyond: No.2



地殻～上部マントルに至る国際海洋科学掘削プロジェクトを段階的に実施し、2050年までに人類未到のマントル到達と惑星地球の標準データの取得を目指す概念図。

After Inagaki, Kuramoto and Taira, *Monthy Chikyu* (in Japanese), (2021)

◎ Ultra-deep Drilling from the Oceanic Crust to the Uppermost Mantle

◎ Drilling Transect of Oceanic Plates (Mantle Convection, Plate Tectonics, Earth's Material Cycle and Evolution of Life)

◎ Insights into Evolution and Habitability of Exoplanets

◎ Borehole Experiments for Deep-Biosphere (e.g. Role of Electro-magnetic Energy)

◎ Mantle Minerals as Paleo-detector for Dark Matter and Neutrino

Baum, S. et al. et al,, arXiv:2106.06559 (2021)

Baum, s, et al., Looking for Dark Matter with Olivine, Tohoku Univ. Frontier Symposium (2022)

Acknowledgements

Providing this opportunity to me by Dr. Hiroko Watanabe, Tohoku University and the organizing committee is greatly appreciated.

I would like to thank my fellow co-workers for long-time collaboration concerning the projects of Marine Geology & Geophysics, D/V *Chikyu* and IODP.

I am grateful for the information provided by Drs. Eiichiro Araki and Keisuke Ariyoshi of JAMSTEC for the preparation of my talk.