

U.S. Science Support Program – Workshop Report

**Submarine Paleoseismology: Using giant piston coring within IODP
to fill the gap in long-term records of great earthquakes**

Zürich, Switzerland July 16-18, 2015

Report by

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1. Summary

Twenty-first century great earthquakes and tsunamis demonstrated that our understanding of these events is limited by short historical and even shorter instrumental records. Such data are inadequate to fully characterize Earth's complex and multi-scale seismic behavior and its consequences for the increasingly populated regions adjacent to tectonically active plate boundaries. Examining prehistoric events preserved in the geological record is the only way to deliver observational data, constraining theoretical earthquake recurrence models and assessing extreme worst-case scenarios of future great earthquakes for better risk prevention.

Many large earthquakes affect offshore environments and their adjacent populated coastal regions. Shaking of seafloor can trigger mass-wasting and surficial sediment resuspension that evolve downslope into debris flows, turbidity currents and other gravitational density flows. In subaquatic environments, the sedimentary record is preserved providing high sensitivity and stratigraphic continuity, so extreme-event deposits are better identified and easier to date than their terrestrial counterparts. The rapidly evolving field of subaqueous paleoseismology or the study of paleoearthquakes is rapidly evolving and much progress has been accomplished within the past 15 years. These studies, which are mostly based on conventional 10-m-long cores, demonstrate the potential to advance our understanding of earthquake recurrence for better hazards assessment. However, due mostly to the lack of longer cores, these studies often focus on time periods too short to provide robust input for long-term seismicity evaluation such as the growth of structures and even longer time-frames such as the evolution of the plate boundary. With ECORD opening their mission specific platform (MSP) approach to include giant piston coring within IODP, a new horizon has opened up for designing and performing objective-driven multi-coring expeditions fully dedicated to the rapidly growing field of submarine paleoseismology. IODP is uniquely positioned to address the complex feedback mechanisms between the earthquake structural deformation, proximal and distal ground motion relative to the deformation zone and its manifestation in the marine archive. The longer record will eventually provide a more complete event stratigraphy, constrain earthquake recurrence, the growth of faults and evolution of the plate boundary far beyond the instrumental record and historical catalogues.

The workshop was held in ETH, Zürich from 16-18 July 2015 to discuss and define a strategy how and where we could best make use of giant piston coring efforts within IODP to make some major advancements in submarine paleoseismology. Fifty-nine participants including 24 students and early-career scientists from 14 countries, and representing a broad spectrum of expertise ranging from marine geology to seismology, attended the workshop. The first day was devoted to overview presentations of major scientific themes and questions. This set the ground for the following group discussion that generically addressed objectives, needs, opportunities and challenges for submarine paleoseismology within IODP. The second day featured several presentations and posters by participants about their own perspective on the state-of-the-art and future opportunities for submarine paleoseismology, followed by group discussion to identify potential study areas and scientific approaches.



Workshop participants received funding from USSSP, ECORD through the Magellan Plus Workshop Series; and there were contributions by the Swiss National Science Foundation, the Swiss Academy of Science, the Swiss Seismological Service and the International Association of Sedimentologists and ETH Zürich.

Already before the workshop, we had identified the Japan Trench as an ideal study area and submitted an IODP Pre Proposal (Proposal 866-Pre, Japan Trench Paleoseismology). Workshop discussions during the first two days revealed endorsement of the scientific community for the Japan Trench as a primary target for understanding causes, consequence and recurrence of submarine earthquakes and tsunamis. The 3rd day was dedicated to develop IODP Proposal 866 full based on input from the previous workshop days. The constructive discussions and clearly defined action plan constitute a critical step towards the development of a competitive full proposal, with submission date targeted in 2016. Furthermore, the workshop also identified high potential for the application of submarine paleoseismology within IODP to advance our understanding of long-term earthquake histories in the Mediterranean Sea, and the Hikurangi and Cascadian Margins. Workshop discussions nurtured an already existing wealth of information taking into consideration the emerging needs of these highly populated regions and the potential of better assessing seismic hazards. The 3rd day of the workshop also featured group discussions to define action plans to begin developing additional IODP submarine paleoseismology proposals.

2. List of Recommendations

The workshop was highly successful in accomplishing the following:

- Compiling and discussing objectives of submarine paleoseismology that can be addressed by giant piston coring research within IODP.

- Identifying needs and challenges in understanding the sedimentary environment and seismotectonic setting by site survey analyses and ancillary projects as key prerequisites for successful submarine paleoseismology studies
- Assembling and sharing state of knowledge from existing data and projects across various sedimentary and tectonics regimes
- Discussing strategies in selecting potential coring sites and determining the specific methodologies (in particular chronostratigraphic methods within trench depths) to meet the science objectives
- Fully involving early career researches in leading group discussion and participating in the workshop
- Starting the process of IODP proposal developments (i.e. endorsement of the Japan Trench as a primary target for understanding causes, consequence and recurrence of submarine earthquake and tsunamis (developing IODP Proposal 866 full for submission targeted in 2016), as well as also identifying high potential for the application of submarine paleoseismology within IODP to advance our understanding of long-term earthquake histories in the Mediterranean Sea, and the Hikurangi and Cascadian Margins.

Post workshop Plan

Following the workshop in July the participants are working together to

- Write a white paper highlighting needs and opportunities of submarine paleoseismology within IODP aiming at contribution to *Scientific Drilling* in 2016.
- Organize a session on Mediterranean Sea Paleoseismology during the upcoming EGU conference in April 2016
- Co-editing a thematic issue on submarine paleoseismology to be published by *Marine Geology* in 2016
- Continuing joint efforts in Japan Trench site-survey data collection and compilation to strengthen input to IODP Proposal 866 full, focusing on selection of proposed coring sites feasible for Mission Specific Platform giant piston coring action
- Focusing on the objectives of Japan Trench paleoseismology proposal and clearly outlining how hypothesis would be tested through MSP giant piston coring
- Preparing submission of IODP Proposal 866 full in 2016

3. List of Participants and Workshop Agenda

* PhD students or early career scientist, *italics supported by USSSP*, +*partly supported by ECORD, USSSP and IAS*

Name	First Name	Affiliation	Country
*Allin	Joshua	National Oceanography Centre Southampton (NOCS)	UK
*Arai	Kazuno	Japan Agency for Marine Earth Science and Technology (JAMSTEC)	Japan
Barnes	Phil	National Institute of Water and Atmospheric Research (NIWA)	New Zealand
Beck	Christian	University of Grenoble	France
*+Beeson	<i>Jeff</i>	Oregon State University	U.S.
*Bernhardt	Anne	University of Potsdam	Germany
<i>Brother</i>	<i>Daniel</i>	United States Geological Survey (USGS)	U.S.
Cattaneo	Antonio	Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER)	France
Chapron	Emanuel	Université Toulouse	France
*Clare	Mike	National Oceanography Centre Southampton (NOCS)	UK
Dalla Valle	Giacomo	Istituto ISMAR/CNR - Institute of Marine Sciences, Bologna	Italy
Eglinton	Timothy	ETH Zürich	Switzerland
Fäh	Donat	ETH Zürich	Switzerland
Goldfinger	Chris	Oregon State University	U.S.
*Grall	<i>Céline</i>	Lamont / Columbia Univ.	U.S.
Gutierrez-Pastor	Julia	ETH Zürich	Switzerland
*Guyard	Hervé	Institut de Physique du Globe de Paris	France
*Hausmann	Rachel	Orgegon State University	U.S.
Howarth	Jamie	GNS Science	New Zealand
Ikehara	Ken	Geological Survey of Japan, AIST	Japan
*Kioka	Arata	University of Tokyo	Japan
Kodaira	Shuichi	Japan Agency for Marine Earth Science and Technology (JAMSTEC)	Japan
*Kremer	Katrina	ETH Zürich	Switzerland
Kürçer	Akin	General Directorate of Mineral Research and Exploration (MTA)	Turkey
Lamarche	Geoffroy	National Institute of Water and Atmospheric Research (NIWA)	New Zealand
Leau	Helene	Institut Polaire Francais (IPEV)	France
Malgesini	Giuseppe	D'Appolonia S.p.A. - Geosciences	Italy
Marco	Shmulik	Tel Aviv University	Israel
McHugh	Cecilia	QueensCollege, Columbia Univ.	U.S.
*Meier (Coble)	<i>Katherine</i>	United States Geological Survey (USGS)	U.S.
Moernaut	Jasper	Univ. Austral da Chile	Chile

PARTICIPANTS (continued) * PhD students or early career scientist, *italics supported by USSSP*

Name	First Name	Affiliation	Country
<i>*Mondal</i>	<i>Dhiman</i>	Queens College / City University of New York	U.S.
Nakamura	Yasuyuki	Japan Agency for Marine Earth Science and Technology (JAMSTEC)	Japan
Nelson	Hans	Granda / University of Leeds	Spain
<i>*Patton</i>	<i>Jay</i>	Humboldt State University	U.S.
Polonia	Alina	Istituto ISMAR/CNR - Institute of Marine Sciences, Bologna	Italy
<i>*Pouderoux</i>	Hugo	Univ. Rennes	France
Proust	Jean Noel	Centre national de la recherche scientifique (CNRS) Renne	France
<i>*Reusch</i>	Anna	ETH Zürich	Switzerland
<i>*Rui</i>	Bao	ETH Zürich	Switzerland
<i>*San Pedro</i>	Laurine	Univ. Brest /	France
<i>*Schwestermann</i>	Tobias	ETH Zürich	Switzerland
<i>Seeber</i>	<i>Leonard</i>	Lamont / Columbia Univ.	U.S.
Smith	David	British Geological Survey (BGS) / ECORD Science Operator (ESO)	UK
Spieß	Volkard	Univ Bremen	Germany
Strasser	Michael	ETH Zürich	Switzerland.
<i>*Strupler</i>	Michael	ETH Zürich	Switzerland.
Sugisaki	Saiko	Geological Survey Japan / AIST	Japan
Sultan	Nabil	Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER)	France
<i>*Sumner</i>	Esther	National Oceanography Centre Southampton (NOCS)	UK
Szczucisnki	Witold	University of Poznan	Poland
Talling	Pete	National Oceanography Centre Southampton (NOCS)	UK
Tappin	David	British Geological Survey (BGS)	UK
<i>Torres</i>	<i>Marta</i>	Oregon State University	U.S.
<i>Underwood</i>	<i>Mike</i>	New Mexico Tech	U.S.
Usami	Kazuko	Geological Survey of Japan, AIST	Japan
Vaiani	Stefano	Bologna Univ.	Italy
Wang	Kelin	Geological Survey of Canada	Canada
Wiemer	Stefan	ETH Zürich	Switzerland

Workshop Agenda

Thursday July 16 (Day 1)			
Start		Session	Leading person
8:30	9:00	Registration and gathering	
9:00	9:15	Welcome, Introductions & Workshop Goals	Michi Strasser, Tim Egliton
9:15	9:45	MSP Giant Piston Coring within IODP, Calypso coring system on Marion Dufresne, giant piston coring on new JAMSTEC vessel	Antonio Cattaneo, Helene Leau, and Shuichi Kodaira
9:45	10:15	KEYNOTE: Can we reconcile seismicity analysis and paleoseismology?	Stefan Wiemer
10:15	10:45	Coffee Break and Posters	SV Service
10:45	11:15	KEYNOTE: dynamic loadings related to earthquake shaking and soil behavior	Nabil Sultan
11:15	11:45	KEYNOTE: Triggers and dynamics of Sediment gravity flows	Pete Talling
11:45	12:15	KEYNOTE: Seismic Sediment Gravity flows: Implications for active tectonic margin deposits & Stratigraphy	Hans Nelson
12:15	12:45	KEYNOTE: Earthquake triggered sedimentation: lessons learned and future challenges	Cecila McHugh
12:45	14:00	Lunch at venue and Posters	SV Service
14:00	15:30	BREAKOUT SESSIONS, to discuss objectives, needs, opportunities and challenges	
		<ul style="list-style-type: none"> - Group I: What do we need to learn/know about “earthquake site characterization”, site precondition, other processes affecting site location etc, from auxiliary studies accompanying giant piston coring efforts? - Group II: What type of sampling and analyses are needed to develop (earthquake) event stratigraphy. What auxiliary studies can be done on giant piston cores retrieved with paleoseismological objectives - Group III: What types of results are needed from the paleo record as robust input to earthquake statistics (randomness, cycles, clusters)? How about dealing with uncertainties, incomplete records, what is statistically relevant etc.? 	
15:30	16:00	Coffee Break and Posters	SV Service
16:00	17:30	Report and Discussion from Break out groups: 15 min summary presentation -15 min Discussion / group	Group leaders
17:30	18:00	Plenary Discussion and Wrap up Day 1	Steering Committee
19:45		Social Dinner @ Zeughauskeller http://www.zeughauskeller.ch/en/home	
Friday July 17 (Day 2)			
Start		Session	Leading person
8:30	10:15	Presentation by participants about their own perspective on state-of-the-art and future opportunities for submarine paleoseismology	
Ikehara, K.		Turbidite paleoseismology along the Japan Trench	
Polina, A.		Seismo-turbidite sedimentation in the Ionian Sea	
Sumner, E.		Turbidite Palaeoseismology and the Sumatran Margin	
Pouderoux, H.		Turbidite paleoseismology of the northern Hikurangi subduction margin of NZ	
Barnes, Ph.		Advancing Hikurangi subduction paleoseismology: Where to from here?	
Shmulik, M.		Dead Sea Fault seismites preserved in drill cores and outcrops: Achievements and open issues	
Spiess, V.		The Shelf Canyon Swath of No Ground – The role of earthquakes and other triggers for the supply mechanisms to the world’s largest sedimentary fan system	
10:15	10:45	Coffee Break and Posters	SV Service
10:45	12:30	Presentation by participants continued	
Cattaneo, A.		Holocene Paleoseismology from the Algerian Margin	
Beck, Ch.		Local estimation of paleo-magnitudes along an active fault strand using co-seismic	

Brother, D.		sedimentary events: an attempt for the Sea of Marmara's Central Basin AUV- and ROV-based paleoseismic study of the Palos Verdes Fault, offshore southern California	
Clare, M.		Building hazards catalogues for statistical analysis - How can we best acquire and analyse long-term cored sequences?	
Underwood, M.		A Holistic View of Sediment Dispersal in Subduction Zones, with Implications for Paleoseismology	
Goldfinger, C.		Location, Location, Location: An illustrated guide to site selection and sediment dynamics for subduction plate boundaries	
Seeber, L.		Earthquakes and structural growth recorded by submarine sedimentation: A bridge between their time scales	
12:30	14:00	Lunch at venue and Posters	SV Service
14:00	15:30	BREAKOUT SESSIONS, to identify potential study areas with specific objectives, needs, opportunities and challenges:	
Breakout groups may be defined either by seismotectonic setting, sedimentary/oceanographic setting, research disciplines or others depending on input from 1 st day discussion			
15:30	16:00	Coffee Break and Posters	SV Service
16:00	17:30	Report and Discussion from Break out groups: 15 min summary presentation -15 min Discussion for each group	Group leaders
17:30	18:00	Plenary Discussion and Wrap up Day 1	Steering Committee
Saturday July 18 (Day 3)			
<i>Day 3 is dedicated to develop the 866 Full Japan Trench Paleoseismology Proposal, Additionally breakout groups formed to discuss potential for proposal development in the Mediterranean Sea and along the Hikurangi Margin..</i>			
<i>Start</i>		<i>Session</i>	<i>Person who takes the lead</i>
8:30	9:30	Review of PreProposal 866-Pre and SEP evaluation in light of the previous two workshop days and Project Strategy Discussion	Mike Underwood
9:30	10:00	Update on Site survey data and future data acquisition plans & Discussion about needs and priorities	Yasu Nakamura and Shuichi Kodaira
10:00	10:30	Coffee Break and Posters	SV Service
10:30	11:00	Update from recent piston-coring and upcoming coring campaigns & Discussion about needs and priorities	Ken Ikehara,
11:00	12:00	Continued project strategy discussion, Discuss strawman proposal outline and break-groups / writing groups	Steering Committee
12:00	13:30	Lunch at venue and Posters	SV Service
13:30	15:00	BREAKOUT SESSIONS, detailed outline, figures, references and identification of action items and writing tasks	
15:00	15:30	Coffee Break and Posters	SV Service
15:30	16:30	Reports Break out groups & defining schedule and further action plan	Group Leaders
16:30		Wrap up day 3 and closing remarks	Steering Committee

Posters @display throughout the workshop		
Allin	Joshua	Different controls on canyon filling and flushing events in Central Portuguese Margin canyons
Arai	Kazuno	Possibility for the occurrence of tsunami-generated turbidity currents: Insights from the 2011 Tohoku-Oki Earthquake.

Barnes	Phil	Advancing Hikurangi subduction paleoseismology: Where to from here?
Beeson	Jeff	Mapping the Northern Segment of the San Andreas Fault: Fault Zone Characteristic & Turbidite Paleoseismology
Bernhardt	Anne	Potentially suitable sectors for turbidite paleoseismology along the Chilean continental margin
Brother	Daniel	Marine paleoseismic studies along the U.S. West Coast and Alaska: highlights from the USGS Coastal and Marine Geology Program
Chapron	Emanuel	Paleoseismological potential of fjords basin fills located at plate boundaries : a case study from Reloncavi Fjord, Northern Patagonia, Chile
Dalla Valle	Giacomo	Submarine Landslides in the South-Adriatic basin: implications for paleoseismic analysis and margin sedimentation
Goldfinger	Chris	Land-Marine Paleoseismic Integration for the Washington Cascadia Margin
Grall	Céline	Title related to submarine paleoseismology
Guyard	Hervé	Paleoseismology in the Lesser Antilles arc from offshore turbidites (expeditions GWADASEIS, IODP 340, and CASEIS)
Hausmann	Rachel	Marine and lacustrine paleoseismology: How turbidite records within a narrow latitudinal zone reveal seismic shaking levels of great historic Cascadia earthquakes
Kioka	Arata	Submarine mud volcanoes as very-long term natural paleoseismometers
Kremer	Katrina	Non-seismic forcing of submarine landslide along convergent margins
Kürçer	Akin	General Directorate of Mineral Research and Exploration (MTA) of Turkey: Active Tectonic, Paleoseismology and Marine Researches
Meier (Coble)	Katherine	Influence of depositional environment on turbidite records: Examples from high-resolution datasets offshore southern California
Moernaut	Jasper	What can we learn from Chilean lake turbidites?
Palamenghi	Luisa	The SoNG' Sand Pile: A simplified autigenic sedimentary dynamic system
Rui	Bao	Determination of Radiocarbon Age Distributions of Organic Matter in Hadal Sediments in the Japan Trench by Ramped PyrOx/AMS
San Pedro	Laurine	Possible origin and sedimentary processes of megaturbidites in the Ionian Sea (Central Mediterranean Sea)
Seeber	Leonard	Mega-turbidites in the Lomboc forearc Basin of the Sunda Arc: Markers for deformation in mega-earthquakes?
Strasser	Michael	Tracking past earthquakes in the Sediment record along the Japan Trench. The IODP Proposal 866-Pre "JTRACK-PaleoSEIS"
Sugisaki	Saiko	Optical dating for marine sediments: implications for sedimentation mechanisms
Szczucisnki	Witold	Tsunami / storm sedimentary record on outer continental shelf of Andaman Sea
Reusch	Anna	Correlative landslide and sediment expulsion deposits as paleoseismic tools
Tappin	David	Title related to submarine paleoseismology

4. Synopsis of possible drilling expeditions and strategies

We have identified the Japan Trench as an ideal study area and submitted an IODP Pre Proposal (Proposal 866-Pre, Japan Trench Paleoseismology) using a multi-coring approach by MSP giant piston coring to recover continuous upper Pleistocene-to-Holocene stratigraphic successions comprising event-deposits, for which the detailed stratigraphic fingerprint and spatial-temporal distribution can be analyzed for proxy-evidence of great earthquakes. There is a high potential of using turbidites and other sedimentary features to reconstruct a long history of great earthquakes off NE Japan. Proposal 866-Pre has the following objectives:

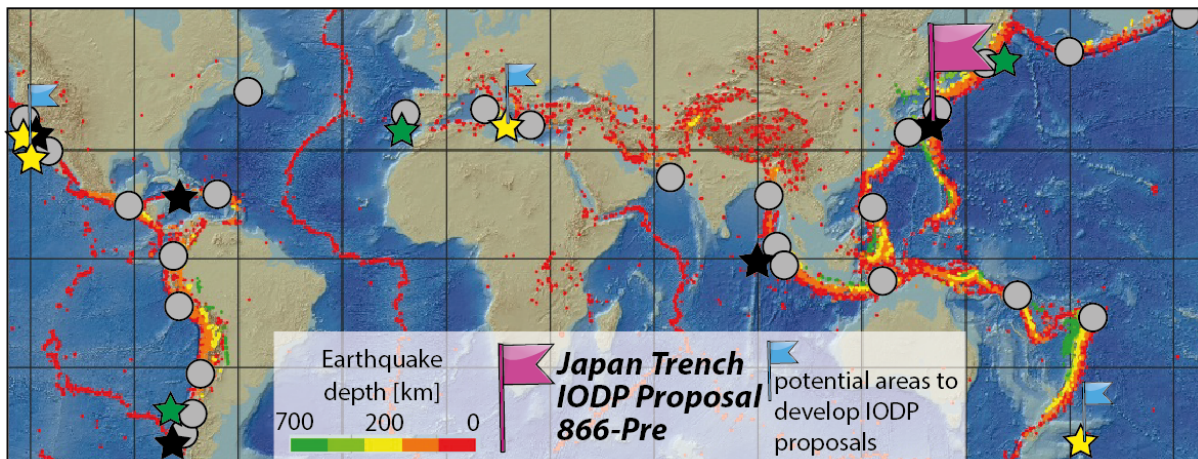
Objective 1: Identify the sedimentological, physical, chemical, and biogeochemical proxies of event deposits in the sedimentary archive that allow for confident recognition and dating of past earthquakes

Objective 2: Explore the spatial and temporal distributions of such proxies and investigate how they relate to fault characteristics and rupture areas of great earthquakes across the entire Japan Trench subduction system

Objective 3: Elucidate the long-term recurrence pattern of events similar to 2011 Tohoku earthquake

Our Proposal was positively reviewed by the Science Evaluation Panel (SEP) in January 2015: According to the Evaluation Letter, “SEP was pleased to see this new proposal and believe there is scope to provide important testing and development of a technique being increasingly used for hazard assessment” and “strongly” encouraged us to develop a Full proposal. Furthermore, SEP stated that “Although care must be taken about applying the method of turbidite paleoseismology, the panel did feel that significant progress, with global applicability, can be made in the Japan Trench in testing and developing methods that will initially build on sedimentary deposits generated from the 2011 event itself”.

With this encouragement the workshop aimed at developing the full proposal for Japan Trench Paleoseismology. The goal is to create a highly competitive proposal with strong potential for opening new avenues of research in the field of submarine paleoseismology. Therefore, the workshop objectives focussed at more general discussions among experts ranging from marine geologists to seismologists for defining the best strategy of *how* and *where* we could best make use of giant piston coring efforts within IODP. This included critically reviewing the various approaches to identify gaps, challenges and potential for further development within the field to further strengthen the Japan Trench Paleoseismology proposal. Furthermore, **participants were encouraged to design ideas for additional proposals and identified high potential areas for the application of submarine paleoseismology within IODP to advance our understanding of long-term earthquake histories in the Mediterranean Sea, and the Hikurangi and Cascadian Margins.**



Compilation of global seismicity, regionally-representative major earthquakes (grey dots), and paleoseismologic data sets, illustrating how little is known about long-term earthquake recurrence: **Green** & **yellow** stars show arguably complete archives spanning <2 and >5 kyrs, respectively. Black stars show fragmentary and debated records. Full list of references available at https://www.dropbox.com/s/pk0rncyvs0gotyq/doc77-3_Paleoseis_compilation.pdf?dl=0

In summary, the workshop aimed at featuring high-level discussion and stimulating new avenues for the rapidly growing submarine paleoseismology community. We succeeded at bringing the community together and building for the future.