Workshop of The InterRidge Working Group « Oceanic Transform Faults »
Institut Universitaire Européen de la Mer, May 22 to 24, 2018
Synthetic report

Forty-two international scientists participated in the two and a half day workshop held at the IEUM campus, Plouzané, France. The meeting began with a series of keynote talks and poster presentations covering different subjects such as global characterization of transform faults and their relation to mid-oceanic ridges and different approaches to understand, discover, and model processes active at transforms and fracture zones. The titles of the keynotes can be found at the end of this document as well as at the meeting website (http://otf.science). Poster were presented at the institute hall throughout the meeting allowing participants to display their recent work, stimulating discussions during coffee breaks. After the talk session the participants proceeded to identify and discuss the key questions to understand nature, evolution, and characteristic processes of the oceanic transform faults. Several main scientific topics were identified along with strategic approaches to answer the main questions in the next future. A text document synthetizesing the main conclusions of the workshop can be found at the end of this document and at the website ((http://otf.science).

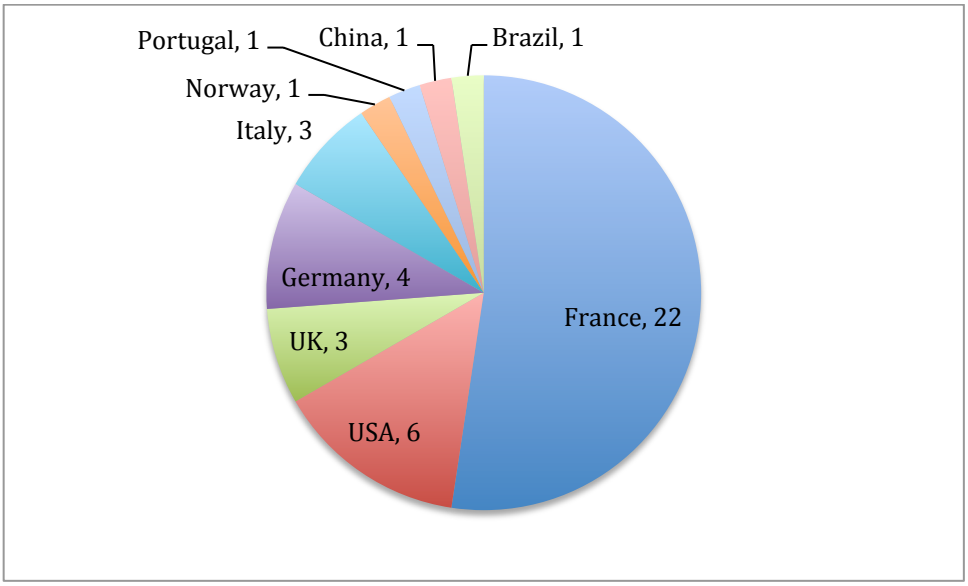
Participant profiles

There were 51 registrants, but 9 colleagues could not join the meeting due to different reasons, so we had 42 final participants.

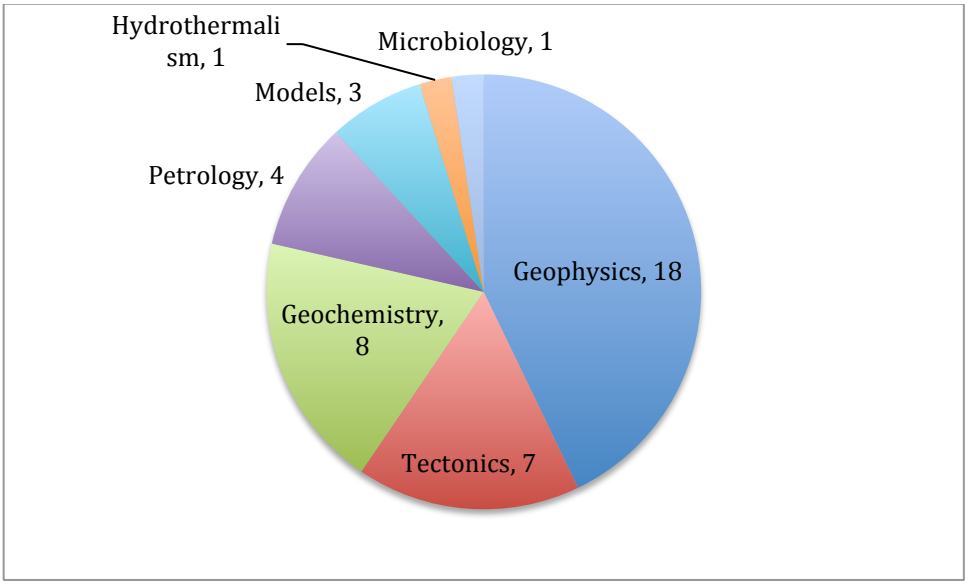
Name	First name	Institution	Country
Agranier	Arnaud	University of Brest – CNRS, Géosciences Océan, IUEM	France
Graham	David	Oregon State University	United States of America
Hamelin	Cedric	University of Bergen	Norway
Hanan	Barry	San Diego State University	United States of America
Hemond	Christophe	University of Brest – CNRS, Géosciences Océan, IUEM	France
Hensen	Christian	GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel	Germany
Meyzen	Christine	Università degli Studi di Padova - Dipartimento di Geoscienze	Italy
Revillon	Sidonie	SEDISOR	France
Aslanian	Daniel	IFREMER	France
Carton	Helene	Institut de Physique du Globe de Paris	France
de Melo	Guilherme	Federal University of Rio Grande do Norte	Brazil
Dyment	Jerome	CNRS and IPGP	France
Evain	Mikael	Ifremer	France
Funnell	Matthew	Durham University	United Kingdom
Giusti	Marion	University of Brest – CNRS, Géosciences Océan, IUEM	France
Lamarque	Gaelle	Ifremer	France
Ligi	Marco	Istituto di Scienze Marine - CNR	Italy
Maia	Marcia	CNRS - University of Brest, Géosciences Océan, IUEM	France
Marjanovic	Milena	Institut de Physique du Globe	France

		de Paris	
Morrow	Thomas	University of Idaho	United States of America
Perrot	Julie	University of Brest – CNRS, Géosciences Océan, IUEM	France
Roland	Emily	University of Washington	United States of America
Royer	Jean-Yves	CNRS - University of Brest, Géosciences Océan, IUEM	France
Schnürle	Philippe	IFREMER GM-LGS	FRANCE
Sibrant	Aurore	University of Brest – CNRS, Géosciences Océan, IUEM	France
Zhang	Fan	Southern University of Science and Technology	China
Schmidt	Christopher	GEOMAR	Germany
Szafranski	Kamil	IPGP	France
Arcay	Diane	CNRS - Geosciences Montpellier	France
Morgan	Jason	Royal Holloway, University of London	United Kingdom
Ruepke	Lars	GEOMAR	Germany
Brunelli	Daniele	Università di Modena e Reggio Emilia	Italy
Devey	Colin	GEOMAR	Germany
Dick	Henry	Woods Hole Oceanographic Institution	United States
Prigent	Cécile	University of Delaware	United States of America
Briais	Anne	CNRS - Geosciences Environnement Toulouse	France
Deverchere	Jacques	University of Brest – CNRS, Géosciences Océan, IUEM	France
Duarte	Joao	University of Lisbon	Portugal
Geoffroy	Laurent	University of Brest – CNRS, Géosciences Océan, IUEM	France
Gutscher	Marc-Andre	CNRS - University of Brest, Géosciences Océan, IUEM	France
MacLeod	Chris	Cardiff University	UK
Moulin	Maryline	IFREMER	France

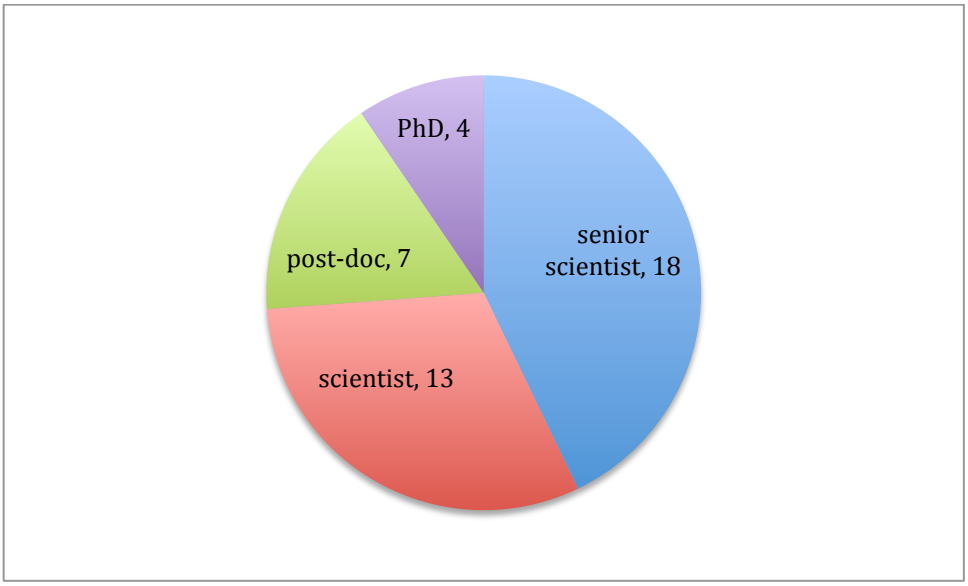
The majority of participants were French, many from Brest, one of the larger centers for Marine Sciences in France, 12 participants from other European countries, and 8 from outside Europe. There was a good equilibrium between French and foreign participants (22 to 20).



All specialities were represented, with a dominance of geophysics. We hope during the three years of the working group activity to attract more specialists of disciplines such as hydrothermalists and numerical modellers, as well as microbiologists.



Eleven young career scientists attended the meeting, InterRidge partly funded 5 (3 USA, 1 China and 1 Germany) and a large number of younger scientists were also present. This is an important point, as it shows the interest of the younger generation of scientists for the theme of the workshop. The research planned and discussed during the working group will be developed and implemented in the near future mostly by the younger scientists.



A website was created (http://otf.science) in order to disseminate information about the workshop. The website will be updated and used as a platform for exchange among the working group members, and between the working group and the scientific community throughout the duration of the project . The information on the working group activities and progress will also be divulgated through a dedicated page on InterRidge website (https://www.interridge.org/WG_Transform_Faults).

Oceanic Transform Faults

An InterRidge Working Group

InterRidge Working Group Oceanic Transform Faults
FIRST WORKSHOP – Plouzané, Brest – May 22nd-24th 2018
Program

Tuesday, May 22nd, room D at IUEM, Plouzané

9:00 – 9:15 – Welcome coffee
9:15 – 9:30 – Anne Marie Tréguier, director of OSU IUEM
9:30 – 9:50 – Jérôme DYMENT et Nadine LE BRIS – InterRidge Program
9:50 – 10:00 – Marcia MAIA (LGO, IUEM, WG coordinator) – Presentation of the WG and the workshop

10:00 – 13:00– Session 1 Tectonics and structure of transform faults (chair B. Hanan)
10:00 – 10:30 Colin DEVEY (GEOMAR) **A 100Ma history of oceanic spreading from the Vema Fracture Zone**
10:30 – 11:00 Coffee break and posters (Hall IUEM)
11:00 – 11:30 Marco LIGI (ISMAR CNR) **Megatransforms: a New Class of Oceanic Transform Plate Boundaries**
11:30 – 12:00 Marcia MAIA (IUEM) **Evolution of a multi-segmented slow-slipping transform system: the Equatorial St. Paul transform**
12:00 – 12:30 Laurent GEOFFROY (IUEM) **Oblique continental extension and the birth of transform faults: the Gulf of California as a case-example**

12:30 – 13:30 Lunch break (buffet at IUEM)

13:30 – 14:00 Diane Arkay & Serge Lallemand (CNRS) **From transform faults to subduction**
14:00 – 14:30 Jason Phipps Morgan, (Royal Holloway) **Transform topography revisited**

14:30 – 16:00 Session 2 Petrology & geochemistry (chair M. Maia)
14:30 – 15:00 Barry HANAN (SDSU) **A New Kind of Hotspot-Ridge Interaction: Evidence from the Southeast Indian Ridge**
15:00 – 15:30 Daniele Brunelli (University of Modena) **Temporal record of magmatic activity and source melting along fracture zones**
15:30 – 16:00 Henry Dick, (WHOI) **The Crust-Mantle Boundary on the Atlantis II Transform Wall, SWIR**

16:00 – 16:30 coffee break and posters (Hall IUEM)

16:30 – 19:00 Session 3 Deep structure and numerical models of transform faults (chair D. Brunelli)
16:30 – 17:00 Emily Roland (University of Washington) **Fault zone structure at the Gofar oceanic transform: physical properties constrained by seismic velocity and numerical models**
17:00 – 17:30 Louis Geli (IFREMER) **Understanding the relations between seismicity and fluid compressibility in submarine environments: learnings from two case studies, e.g. the Main Marmara Fault and the East Pacific transform faults**
17:30 – 18:00 Taras Gerya (ETHZ) **Nucleation and evolution of oceanic ridge-transform spreading patterns**

19:15 departure for Brest, free evening

Wednesday, May 23rd, room D, B-220 and A-219 at IUEM, Plouzané

9:00 – 9:15 – coffee
9:15 – 10:15 Session 3 Deep, continue, structure and numerical models of

transform faults (chair D. Brunelli)
9:15 – 9:45 Fan Zhang (Southern University of Science and Technology) **Structure of fracture zones as resulting from geophysical constraints**
9:45 – 10:15 Lars RUEPKE (GEOMAR), **Temperature, deformation, and fluid flow at oceanic transform faults in 3-D geodynamic models**

10:15 – 10:45 coffee break and posters (Hall IUEM)
10:45 – 12:30 round tables
12:30 – 13:30 lunch
13:30 – 16:00 round tables by group of interest
16:00 – 16:30 coffee break and poster (Hall IUEM)
16:30 – 19:00 first joint discussion after the round tables

19:15 Departure to pointe St. Mathieu for the WS dinner
22:30 return to Brest

Thursday May 24th, room D at IUEM, Plouzané

9:00 – 9:15 – coffee
9:15 – 10:30 continue general discussion and wrap up of the main conclusions and recommendations
10:30 – 11:00 coffee break
11:00 – 12:30 Wrap up

12:30 – 13:30 Lunch

14:30 End of WS and departure to Brest

Scientific report on the InterRidge Working Group on Oceanic Transform Faults
Institut Universitaire Européen de la Mer, Plouzané, France, May 22-24, 2018

Forty international scientists participated in the two and one-half day workshop held at the IEUM campus, Plouzané, France. The meeting began with a series of keynote talks and poster presentations covering different subjects such as global characterization of transform faults and their relation to mid-oceanic ridges and different approaches to understand, discover, and model processes active at transforms and fracture zones. The titles of the keynotes and posters can be found at the meeting website (http://otf.science/keynotes/). After the talks we proceeded to identify and discuss the important questions required to understand the nature, evolution, and different characteristic processes of these features. Finally, we identified several main lines of questions to be addressed and proposed ways to approach and answer these questions.

Extensive discussion concerning topics such as typology, morphology, and nomenclature revealed a general confusion in the basic terminology used to describe transforms and fracture zone systems, a problem also true for pre-existing features inherited from ridge evolution and basin opening. Participants suggested the adoption of terms, such as TFZs for Transform Fracture Zones and TFSs for Transform Fracture Systems, to define the whole system from the active part to its extension into the drifting plates. This consensus arose from the clear need to study the transform and fracture zone system as a whole, encompassing the simple idea of active and "inactive" parts. Several examples and model results have shown evidence for fracture zone activity in various context, ages, and their influence on the later phases of the plate's evolution. Concurrently with the need for clarifying the TFS vocabulary, the need for a uniform public database, sharing all available sample metadata as: sample descriptions, dredge information (location, dredge track, dredge composition, photographs, etc.), was recognized; a task force was created to tackle this subject.

Group discussion led to these major questions:

- What are the controlling physical parameters (temperature, fluid content and nature, alteration…) of a transform fault and how do they impact the deformation pattern, the rupture process and associated seismicity?
- What are the characteristics, in terms of strength and rheology of fracture zones (generally, hydration and lithology), and what are the causes and consequences for reactivation, origin and temporal evolution, and their influence on subduction processes including the initiation of subduction?
- How does serpentinization and weathering affect the mechanical properties in the deformation zone, and what influence does the elemental exchange between the oceanic crust and oceans have on these processes? Which are the interactions between these processes and microorganism patterns and distribution, both at the surface and at depth?
- What is the frequency and magnitude of the temporal fluctuation of the major physical properties (temperature, rock mechanics, rheology), and how is the thermal cycling stemming from the primary magmatic/tectonic accretion at the ridge segment transferred to and across the transform domain?
- What is the tectono-magmatic response time of the TFS to changes in plate motion parameters (e.g. velocity and direction), different TF lengths, FZ age, orientation and

slip rate? What are the primary controls on the tectonic style (e.g., segmentation, rotation of the TF, bounding ridge tip propagation) of response to plate motion changes?
- What do we need in order to better understand these physical properties, and how they impact the mechanical behavior and the rheology of TFS?
- What is required to improve our knowledge of the active deformation rate in transforms (seismicity, displacement)?

To answer these questions all agreed to the general need of high resolution bathymetry and imaging (photos, videos), micro and macro-seismicity, active seismic surveys (refraction and reflection), detailed rock sampling and geological mapping to understand the lithology and the deformation patterns of the rocks; studies on fluid circulation and rock interaction through sampling, including sediment and pore water sampling, as well as MT-EM measurements to investigate fluid contents and distribution in depth.

To address the question of active processes we need direct measurements of the displacement at fast rates coupled with seismological data. There is a strong need for numerical modelling advancements and better model-data fusion. This includes augmenting current 3-D models of TFS with thermo-elastic deformation and melt migration mechanisms, so that seafloor observations (e.g. bathymetry, seismic focal mechanisms, and magmatism) can be related to dynamic processes at depth. Quantifying the physical properties of tranforms and fracture zones and lithosphere rheologies that are consistent with observed TFS will allow refining current and future models. There is also need of a better knowledge of the mechanics of the deformation, both through models, experimental runs and measurements of the deformation and stress. New technological and methodological developments are needed here (e.g. elasticity parameters, boreholes, long term micro-seismicity and geodesy stations).

Based on these preliminary conclusions, we recognized the need to design an ideal integrated experiment, with the objective of acquiring co-located data on a system at different scales. This experiment will be applied to different types of systems, such as different slip rates or different offset lengths. The experiment will be carried out in a manner that pairs the active part (transform itself) and the “inactive” part (fracture zone) of the system. Finally, it is important to study whole system time scales to define both long and short-term variability.

The experiment will consist of:

- Acquiring dense surface bathymetry and geophysical data (gravity, magnetics) as well as dredges, with the aim to characterize the system.
- Acquiring high quality active seismic data, both multichannel reflection and refraction in order to have a better view of the crust structure and its variability.
- Deploying passive seismic instruments to record micro-seismicity and EM measurements as well as heat flow measurements to define the crustal thickness and the present day thermal profile.
- Acquisition of 4D high-resolution bathymetry, geophysical data and geologic imaging and sampling with underwater vehicles (deep tow, AUV, HOV, ROV…);

- Installing benchmark arrays for seafloor geodesy and conjugated long-term deployment of instruments for micro-seismicity with the use of a ROV/HOV. These benchmarks should be designed to warrant the reoccupation in future experiments. There is also an interest to develop and deploy land-type benchmarks with short core holes to couple the instrument with the rock/sediment.
- Assess the variability in the lithologic distribution on densely spaced vertical time slices in order to document and determine petrologic and geochemical characteristics. Use the time slice data to determine mechanisms responsible for short term (< 1 My) to long term (>10 My) thermal variability by comparing mantle residua and melt products to define.
- Recover oriented samples in the active and "passive" sections to determine the strain and stress orientation and its evolution in time.
- Extending the high frequency sampling of vertical time slices into the fracture zone domains.
- Generating an integrated geological survey, by combining bathymetry, structural observation and sampling, to define the evolution of tectono-magmatic processes through time.

Two important needs were recognized during the discussion:

1. The need for technological development of a new generation of instruments, that allow long range observation and/or autonomous operationality, to be applied for example, to seafloor geodesy, OBS and hydrophone recording, bathymetric acquisition, etc. New technological development is also needed for sampler that would allow recovery of a large number of oriented samples or cores.
2. The need for a constant integration with models/modellers. Models require co-located observations along the whole length of the transform and need quantified observations and physical parameters. Additionally, experiments could benefit by integrating model results to refine their plan. Generally, we must work towards improving the dialog between the modelers and the geoscientists who collect the observations and datasets.

Call for white papers

The participants converged on the important need for a call for white papers on different subjects and possible experiments on TFS. The papers will contribute to improve future work proposals and their success by sharing ideas, promoting consensus around common projects, and open the collaboration among the large ocean science community. The papers should cover different aspects, such as research themes, potential future projects, and scientific instrumentation development. The white papers are intended to develop and focus on projects that have high overall priority to the TFS community, and to develop future collaborative projects that are envisioned to include the authors of the white paper. Intrinsically, the call for white papers needs to address both the working group and the community. To support this effort there is a need to develop platforms for exchange of knowledge and experience, linking different communities and attracting other communities (seismologists, oceanographers, biologists, geologists, geochemists, modelers, funding agencies, etc.). The authors of the white papers shall be recognized and the ideas expressed in the text, properly acknowledged in a format close to that of the IODP proposals. The texts should be

available so that they can be updated and improved by other people, who would then join the list of the authors.

Timelines

The final discussions addressed the timelines of the working group and the community. There will be a second workshop in about three years to finalize the work of the working group. Meanwhile, we should encourage a yearly transform session at AGU (there is one every two years), organizing a pre-meeting event on transforms. We must also encourage transform sessions at EGU in order to increase the participation to the ones already regularly organized and also organize a splinter meeting. It is possible to hold combined or twin sessions (co-sponsored sessions between EGU and AGU), which would gain visibility. A problem observed, at least during AGU, is the conflicting schedule of sessions. A suggestion is to label sessions with InterRidge, so that these sessions would not have conflicting schedules. Cross-referencing the sessions is important, in order to attract different communities.