



ECORD/ICDP – MagellanPlus Workshop Series Program  
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**Scientific report for ECORD MagellanPlus Workshop Series Program**

**IODP drilling within the Corinth Continental Rift, Greece:  
A MagellanPlus- and UK NERC-funded Workshop**

**Athens, Greece, February 11-14, 2014**

**Report to ESSAC**

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## 1. SUMMARY

How rifting initiates and evolves to continental breakup and ocean basin formation is a major unanswered Solid Earth-Plate Tectonic question: continental rifting is the first stage of this process. Important insights have been derived from numerical models and from observations at mature, magma-poor passive margins where activity has ceased, but early syn-rift stratigraphy is often difficult to image and sample due to deep burial and tectonic overprinting. The Corinth Rift, Central Greece, presents an ideal laboratory for the study of continental rifting: it is young and highly active; has a near-complete syn-rift stratigraphic sequence; and has a unique existing geophysical dataset to resolve, at very high temporal and spatial resolution, how faults initiate and link, how strain is distributed over time, and how the landscape responds during the first few million years of rifting a continent. The entire interconnected rift system can be resolved and examined on a range of timescales and the Corinth rift lacks magmatism, reducing the number of variables contributing to rift morphology and stratigraphic fill. An international collaborative project, launched in 2011, has integrated all marine geophysical datasets to generate a high-resolution, high-precision fault network and stratigraphic framework of the modern rift axis combined with an equivalent onshore framework. The missing piece of the jigsaw for the Corinth rift tectonic framework is offshore drilling at key locations to provide a chronology for the entire offshore basin, and incidentally creating a high resolution Quaternary paleoclimatic and paleoenvironmental record.

To support preparation of a proposal to the International Ocean Discovery Program (IODP), a workshop was held on February 11-14, 2014, in Athens, Greece. The workshop was financially supported by the ECORD/ICDP MagellanPlus Workshop Series Program, the Natural Environment Research Council (UK), and the Hellenic Centre for Marine Research (Greece). 36 participants from 6 countries, including students and Early Career Researchers, attended a 2-day meeting followed by a 1-day field trip of the rift zone and 1-day of proposal preparation by a subset of participants. Presentations included keynotes on key global rift questions and modeling techniques of rift processes, and on current knowledge of Corinth rift chronostratigraphy, fault-basin evolution, sediment flux history and modeling potential, seismology, deep crustal structure, and the potential application of drilling to regional hazard assessment. The latest results of the marine data integration project were discussed, alongside regional complementary research projects. A session was devoted to discussion of ocean drilling core analysis techniques to establish a high fidelity chronological and environmental record. An ESO representative provided critical information on Mission Specific Platform methodologies and constraints for drilling in this environment. Workshop discussions generated the following primary scientific objectives and potential drill site locations framed around the temporal and spatial resolution of processes that could be generated from the Corinth Rift, probably unparalleled worldwide: Constrain the distribution of tectonic strain in time and space and growth history of a rift-scale normal fault network; Determine the evolution of a rift-controlled drainage system in time and space including the relative contributions of tectonics and climate; Establish the timescale of rift segment initiation and maintenance.

The meeting was extremely productive with strong endorsement of the Corinth Rift system as a key target to address global rift problems. As a result of the workshop, a proposal was submitted to IODP on October 1, 2014 for drilling within the Corinth Rift system.

## **2. OBJECTIVES OF THE CORINTH RIFT DRILLING WORKSHOP**

A Pre-proposal to drill within the offshore Corinth Rift was submitted during the previous IODP program (2008). The SSEP strongly recommended further integration of seismic site survey data within the rift to enable a comprehensive correlation of stratigraphy and fault geometry. In 2011, NERC-UKIODP provided funding of this data integration project and work is now ongoing involving collaborators from UK, Greece, France, USA, and Norway. These integrated data can now be used to reappraise drilling objectives and drill site locations in a new proposal. The NERC project provided funding for a small workshop to do exactly this. However, additional funding from MagellanPlus enabled us to expand the workshop, specifically by inviting additional rift and fault development researchers to significantly strengthen scientific discussion and the resulting proposal's global perspective, and to enable significant progress on the drilling proposal preparation. We also invited researchers from complementary projects in the Corinth rift: e.g., ICDP drilling of the Aigion Fault and Corinth Rift Laboratory, SISCOR (France), and Greek combined projects, and researchers in chronology and paleoenvironment techniques. Technical expertise gained from local ICDP drilling contributed to proposed ocean drilling methods. The aim of this team of combined participants was to generate a strong ECORD-Greek science team with support from international players in rift processes and ocean drilling.

Although a Pre-Proposal for Corinth rift drilling had been previously submitted, newly integrated site survey data and broader international community involvement necessitated a workshop prior to renewed IODP proposal submission. The proposed 3-day small workshop (~25-35 participants, including several Early Career Scientists) would include introduction to the workshop science context, keynote speakers describing primary science questions within early rift processes and fault development from the perspective of key global examples (e.g., Gulf of California, Red Sea, East African Rift, and Gulf of Corinth) and from numerical modeling (e.g., of rift initiation and of fault network evolution). Presentations on Corinth Rift and Aegean tectonic history, structure, sedimentation, seismicity and paleoclimate would provide the current state of play and drilling potential for this rift, and methods for determining Plio-Quaternary chronology and paleoenvironment provided guidance for the drilling strategy. 1/2-1 day was to be devoted to presentation and discussion of the data integration results (integrated syn-rift stratigraphy and fault network offshore and earlier rift data from onshore) and ongoing/future projects building on the resulting dataset. Subsequent breakout discussion groups would focus on A) primary science objectives for proposed drilling with a global perspective and B) drilling strategy and methodologies and borehole site location, including guidance from IODP, e.g., the MSP (Mission Specific Platform) operator, BGS (British Geological Survey). At the end of the workshop, an additional 1 day of preliminary proposal writing involving a subset of the participants was included with the aim of proposal submission in 2014. A 1 day field trip to key Corinth sites was included.

The primary goal of the workshop was to provide the scientific and technical framework required to generate a new IODP proposal targeting the Corinth continental rift, addressing both global tectonic science questions and societally-relevant problems of geohazards and petroleum resources (at both regional and global scale). One goal of the workshop was to enable a more effective proposal writing process with improved drilling strategy as a result. The workshop was also intended to provide a forum for discussion of the first fully integrated seismic reflection network within the Corinth rift, and an unprecedented resolution of rift evolution within any rift system worldwide, leading to new collaborations and new proposed projects of relevance to rift evolution, normal fault networks, fault slip history, and landscape evolution.

### 3. PARTICIPANTS

Name		Institution	
Bailey	Ian	University of Exeter, UK	
Beck	Christian	ISTERRE, France	
Beckers	Arnaud	ISTERRE, France	
Behn	Mark	WHOI, USA	
Bell	Rebecca	Imperial College, UK	Early Career Researcher
Bernard	Pascal	IPGP, France	
Bull	Jon	University of Southampton, UK	
Charalampakis	Marinos	NOA, Greece	Early Career Researcher
Christodoulou	Dimitris	University of Patras, Greece	
Collier	Richard	University of Leeds, UK	
Cornet	Francois	IPGP, France	
Ebinger	Cindy	University of Rochester, USA	
Ferentinos	George	University of Patras, Greece	
Ford	Mary	University of Nancy, France	
Gawthorpe	Rob	University of Bergen, Norway	
Goodliffe	Andy	University of Alabama, USA	
Hemelsdaël	Romain	University of Nancy, France	Student
Henstock	Tim	University of Southampton, UK	
Kouli	Katerina	University of Athens, Greece	
Kranis	Haris	University of Athens, Greece	
Lykousis	Vasilis	HCMR, Greece	
McInroy	David	British Geological Survey, UK (ESO Science Manager)	
McNeill	Lisa	University of Southampton, UK	
Nixon	Casey	University of Southampton, UK	Early Career Researcher
Papatheodorou	George	University of Patras, Greece	
Sachpazi	Maria	NOA, Greece	
Sakellariou	Dimitris	HCMR, Greece	
Skolidis	Antonis	University of Athens, Greece	Student
Skourtos	Manolis	University of Athens, Greece	
Smithells	Rosie	University of Bergen, Norway	Early Career Researcher
Spicak	Ales	Institute of Geophysics, Prague (ECORD-Magellan workshops)	
Taylor	Brian	University of Hawaii, USA	
Tsambouraki-Kraounaki	Konstantina	HCMR, Greece	Student
Umhoefer	Paul	University of North Arizona, USA	
Vogia	Stella	University of Athens, Greece	Student
Zoura	Despina	University of Patras, Greece	Student

## 4. WORKSHOP AGENDA

### DAY 1 (February 11<sup>th</sup>)

08:50 Welcome, logistics, introduction

09:00-10:15

#### Global Rift-related Science

**Chairs: Jon Bull, Dimitris Sakellariou**

09:00-09:25 *The role of fault rotation on fault lifespan and rift evolution:* Mark Behn

09:25-09:50 *Time and length scales of continental rifting: Magma-rich and magma-poor examples from East Africa:* Cindy Ebinger

09:50-10:15 *The Roles of Oblique Rifting and Sediment in Formation of the Gulf of California:* Paul Umhoefer

10:15-10:35 COFFEE BREAK

10:35-11:15

#### Global Rift-related Science (continued) and Introduction to Corinth-Aegean Region

10:35-10:45 *Landscape response to normal fault and rift development:* Rob Gawthorpe on behalf of Patience Cowie

10:45-11:10 *Sedimentation in rift environments:* Rob Gawthorpe

11:10-11:30 *Corinth Gulf - Aegean Region: Rifting within a transtensional setting:* Dimitris Sakellariou, Vasilis Lykousis

11:30-12:00 Discussion (discussion continues in breakout session)

12:00-13:00 LUNCH

13:00-15:00

#### Breakout Session 1 and Reporting: "Global Rift Science Problems"

15:00-15:20 COFFEE BREAK

15:20-17:35

#### Corinth Rift Tectonics Summary

**Chairs: Cindy Ebinger, Richard Collier**

15:20-15:45 *Basin structure and evolution of the offshore Gulf of Corinth rift: data integration results:* Casey Nixon, Rebecca Bell, & Dimitris Christodoulou

15:45-16:05 *Large scale crustal structure: The Gulf of Corinth from 100 m basin infill, to 100 km lithospheric scales:* Maria Sachpazi

16:05-16:20 *Pre-existing structural impact on rift development: "Ou Pantos Plein Es Korinthon", or why the Gulf of Corinth is an intriguing Rift:* Haris Kranis, Manolis Skourtsos

16:20-16:40 *Seismicity and mechanics of the Corinth rift:* Pascal Bernard

16:40-17:00 *Onshore tectono-sedimentary evolution of the (western) Corinth Rift:* Mary Ford

17:00-17:30 Discussion (continues on Day 2 morning)

17:30-19:00

**Poster session, Discussion, Refreshments**

### DAY 2 (February 12<sup>th</sup>)

08:30-10:00

#### Recent Corinth Programs

**Chairs: Haris Kranis, Lisa McNeill**

- 08:30-08:50 *What has been learned from drilling through the Active Aigion Fault?:* Francois-H Cornet
- 08:50-09:10 *Late Pleistocene-Holocene sedimentation and faulting in the western Gulf of Corinth: overview from a high resolution seismic survey (SISCOR project):* Christian Beck
- 09:10-09:30 *The tectono-sedimentary evolution of the Lechaion Gulf, the south eastern branch of the Corinth Graben, Greece:* Marinos Charalampakis
- 09:30-10:00 Discussion (continuing from Day 1 and continues in breakout session)
- 10:00-10:20 COFFEE BREAK

10:20-12:20

### **Methodologies**

#### **Chairs: Tim Henstock, Christian Beck**

- 10:20-10:40 *Ocean Drilling: Mission Specific Platforms:* David McInroy
- 10:40-11:05 *Techniques suitable for dating and studying the climate history encoded in Gulf of Corinth syn-rift sediments:* Ian Bailey
- 11:05-11:25 *Quaternary paleoenvironment techniques, palynology in the Eastern Mediterranean:* Katerina Kouli
- 11:25-11:45 *Techniques from Corinth coring projects:* Richard Collier
- 11:45-12:15 Discussion (discussion continues in breakout session)
- 12:30-13:30 LUNCH

13:30-15:30

#### **Breakout Session 2 and Reporting "How global rift problems can be addressed within the Corinth Rift" (three themed groups).**

15:30-16:00 COFFEE BREAK

16:00-17:30

#### **GeoHazard Regional Impact, Final Discussion and Wrap up**

- 16:00-16:20 *Overview of Greek hazard assessment and risk mitigation process:* **Greek Earthquake Planning and Protection Organization (EPPO) Representatives**
- 16:20-17:30 Discussion and wrap up

### **CONFERENCE DINNER**

### **DAY 3 (February 13<sup>th</sup>)**

#### **Field Trip**

- To visit key sites along the active Corinth rift, including the Corinth canal sequence, active fault planes, footwall uplifted Quaternary terraces, and syn-rift sedimentary sequences

### **DAY 4 (February 14<sup>th</sup>)**

#### **Proposal Writing**

- A subset of participants (12 people) worked on IODP Proposal preparation based on the workshop results.

## **5. OUTCOMES OF THE WORKSHOP**

The workshop was highly successful in accomplishing the following:

- Discussing and compiling objectives that could be tackled successfully within the Corinth Rift through ocean drilling, to advance our understanding of early rift development from a global perspective;



- Assembling and sharing state of knowledge from existing data and projects on Corinth rift stratigraphy, fault networks and rift evolution;
- Assessing the integrity of the newly integrated seismic dataset and resulting syn-rift stratigraphic and fault network correlation – it was agreed that this dataset (>5000 km of seismic profiles) provided the potential for unprecedented spatial and temporal resolution of a whole rift system;
- Selecting potential drill sites to maximize the temporal penetration of the syn-rift sequence whilst keeping with the constraints of a Mission Specific Platform drilling expedition;
- Bringing in external continental rift expertise and increasing future research collaborations in this rift and others;
- Determining the specific methodologies (in particular chronostratigraphic methods) to be applied to borehole data (cores and logs) to meet the science objectives;
- Fully involving early career researchers in organizing, directing and participating in the workshop programme;
- Starting the process of IODP proposal development for submission to SEP.

On the concluding day of the workshop, the following primary science objectives were selected as the focus for ocean drilling. These objectives are framed around the temporal and spatial resolution of processes that could be generated from the Corinth Rift, probably unparalleled worldwide:

Objectives:

- Constrain the distribution of tectonic strain in time and space and growth history of a rift-scale normal fault network;
- Determine the evolution of a rift-controlled drainage system in time and space including the relative contributions of tectonics and climate;
- Establish the timescale of rift segment initiation and maintenance.

## **6. POST-WORKSHOP ACTIONS AND PROGRESS RELATED TO DRILLING THE CORINTH RIFT**

Following the workshop in February, the workshop group worked together to prepare the drilling proposal, focusing on finalization of proposed drilling sites feasible as a Mission Specific Platform (with more limited depth penetration and slower rates of penetration), focusing the objectives, demonstrating why the Corinth rift has so much to offer as a location for establishing generic early rift evolutionary processes, and clearly outlining how hypotheses would be tested through drilling.

The proposal was finally submitted to IODP on October 1, 2014 with many of the workshop participants as proponents. The proposal was reviewed in January, 2015 by SEP, was received very well by the panel and has been sent out to external review – this is an unusual success for a “new” proposal.

## **7. SPENDING OF THE MAGELLAN PLUS GRANT**

The MagellanPlus workshop funds were 14,980 Euros, with additional funding from a separate UK NERC grant. These combined funds enabled participation of scientists regardless of their country of origin, a wider range of scientific expertise, more participation from early career scientists (including PhD students) and significant progress on preparation of the



drilling proposal during the workshop itself. The table below provides details of expenditure in GBP and the approximate total expenditure in Euros is 14,950.

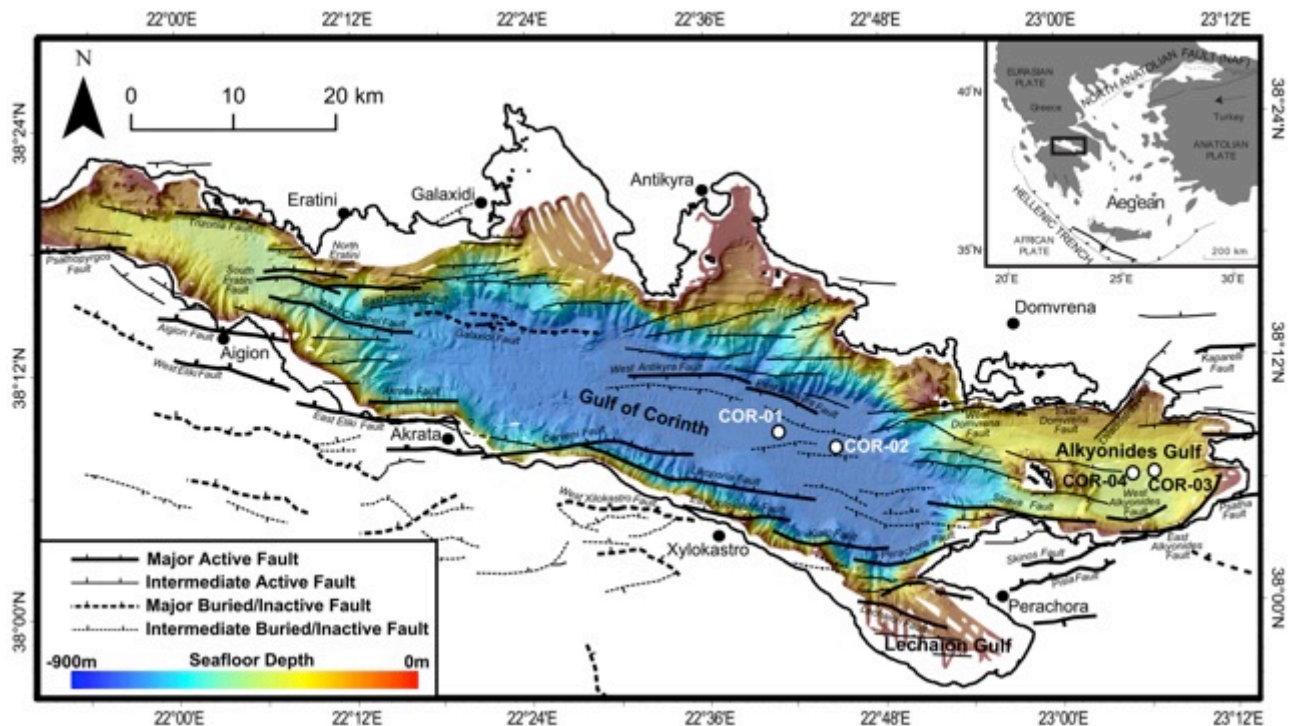
Travel	7,439.21
Accommodation, subsistence	5,248.90
Total	12,688.11



Meeting participants enjoying the conference dinner.



Haris Kranis (University of Athens) describing the geological setting of the Corinth Rift from the Panagia Korfiotissa nunnery, Mt Koutsas viewpoint on the uplifted rift flank at ~700 m elevation, during the 1 day field trip.



Fault map of the Corinth rift (Nixon et al., in prep; Bell et al., 2009; Taylor et al., 2011), bathymetry of the offshore active rift zone, and locations of the proposed drill sites penetrating the syn-rift succession expected to represent the last ~1.5-2 Myr of rift history.

## References

- Bell, R.E., McNeill, L.C., Bull, J.M., Henstock, T.J., Collier, R.E.L., Leeder, M.R., 2009. Fault architecture, basin structure and evolution of the Gulf of Corinth Rift, central Greece. *Basin Research*, 21, 824-855.
- Nixon, C., McNeill, L., Bull, J., Bell, R., Henstock, T., Christodoulou, D., Gawthorpe, R., Ford, M., Sakellariou, D., Ferentinos, G., Papatheodorou, G., Taylor, B., Goodliffe, A., Leeder, M., Collier, R., Sachpazi, M., in prep, History of high resolution basin development within the offshore Corinth rift, central Greece. To be submitted to *Geophys. J. Int.*
- Taylor, B., Weiss, J.R., Goodliffe, A.M., Sachpazi, M., Laigle, M., and Hirn, A. 2011. The structures, stratigraphy and evolution of the Gulf of Corinth rift, Greece. *Geophysical Journal International*, doi: 10.1111/j.1365-246X.2011.05014.x