CRL School 2018

Corinth Rift Observatory




Patras-Nafpaktos, Greece
21-25 September 2018

Welcome!!!

Dear Participants, welcome to the 2018 edition of the CRL-School!

As you know, the general objective of the School is to unite Master and PhD students from various Greek and foreign universities collaborating in the Corinth Rift Observatory (http://crlab.eu), together with high school European teachers to introduce them to different geophysical and geological observations and methods and first-hand scientific knowledge. At the School, methods such as seismology, GPS, SAR interferometry, the methods underlying the ESA-SENTINEL mission, the Geohazards Exploitation Platform (GEP) and paleomagnetism, will be examined from a theoretical point of view and from the point of view of their applications and results in the specific area of the Corinth Rift. This rift is one of the most seismically active regions of Europe. It is used by scientists as a natural laboratory where seismic, geodetic and geological data and products are collected and analyzed to enhance the understanding of the area from plate tectonic to local scales. The knowledge acquired there is applicable to other seismically active regions worldwide and, thus, has a general signification.

We foresee that the participants will gain understanding of all these methods and their results and be engaged in discussions about the interpretation of the results and how they can be used in teaching and learning in general Earth Sciences, Chemistry, Physics, Biology and Geology.

The school will mix topical presentations, field excursions and hands-on activities. It will take place partly in Nafpaktos and partly in Rio-Patras. In Nafpaktos, we will be hosted in a municipality building located at the old harbour, which has been generously offered to us by the Mayor and the Council of the city. In Rio-Patras we will be hosted in several departments of the University.

Highlights will be, among others, the all-day long excursion on the "*Milady Mylord"*, the oceanographic vessel of the University of Patras, the educational activities for High School, the dissemination to the general public, the presentation of the seismobox, the hand-on ESA software, the field training sessions and the presentation of cores from the sea bottom. There will be also a presentation of the structural monitoring and geometric control of the Rio-Antirrio Bridge.

The session showing posters by the students and teachers will be another of the highlights of CRL-School 2018!

The Scientific Committee has been one of the actors in preparing this School, and other persons and Institutions have also contributed to it. We would like to continue to offer students and teachers the opportunity to the CRL School in future years. Of course, this depends upon us being able to show our sponsors that the

School has been useful to students and teachers in their studies and in their daily teaching, or as inspiration for teaching geoscience in new ways in their schools.

After the School we will ask you:
- To complete the evaluation forms (for students and for teachers) as soon as possible and email it back to us,
- To make a presentation of your experiences at the CRL School to a group of your colleagues after your return from Nafpaktos and
- Teachers we invite you to send us reports and photographs about how you have used the CRL School information in your classrooms. We also encourage you to write reports on the School in publications specifically intended for geosciences, science and geography teachers.

For now, please enjoy your CRL-School 2018 in Nafpaktos and Rio-Patras! If you do not fully enjoy your time with us, please tell us, this will help us to do better next time. If, as we hope, you do enjoy attending this School, please tell your colleagues at school, fellow students and friends about it and encourage them to come to future editions of the School!

The Scientific Committee
CRL-School

Acknowledgments

The CRL School 2018 has been organized by the Scientific Committee, and has also benefitted from the generous help of:

The Centre National de la Recherche Scientifique (CNRS) and the European Geosciences Union (EGU) for financial support,

The University of Patras for logistical support,

Prof. George Papatheodorou and Maria Garaga for organising the cruise on board the "*Milady Mylord",*

The municipality of Nafpaktos for logistical support for the lectures given in municipality building,

Annita Panteleli for her invaluable help in the organization of the School,

And we thank all the speakers who have contributed to the School and their institutions.

Scientific Committee

CHAIR

Pierre Briole
École Normale Supérieure
CNRS / PSL Research University
Département des Géosciences
Paris, France
briole@ens.fr

MEMBERS

Vassilis Anastassopoulos
University of Patras
Department of Physics
Patras, Greece
vassilis@upatras.gr

Antonio Avallone
Istituto Nazionale di Geofisica e Vulcanologia
Rome, Italy
antonio.avallone@ingv.it

Anne Deschamps
Université Côte d'Azur / CNRS
GeoAzur & EduMed,
Nice, France
deschamps@geoazur.unice.fr

Panagiotis Elias
National Observatory,
Athens, Greece
pelias@noa.gr

Athanassios Ganas
National Observatory
Athens, Greece
aganas@noa.gr

Maya Ilieva
Institute of Geology and Geoinformatics
Worclaw University Poland &
Dept. of Geodesy and Geography
Bulgarian Academy of Sciences
Sofia, Bulgaria
m_b_ilieva@abv.bg

Carlo Laj
Committee on Education, EGU
École Normale Supérieure
PSL Research University
Département des Géosciences
Paris, France
carlo.laj@ens.fr

Francesco Sarti
European Space Agency
ESRIN
Frascati, Italy
francesco.sarti@esa.int

Vassilis Anastassopoulos

Antonio Avallone

Pierre Briole

Anne Deschamps

Panagiotis Elias

Thanassis Ganas

Maya Ilieva

Carlo Laj

Francesco Sarti

Corinth Rift Laboratory School – 2018

(Patras-Nafpaktos September 21-25, 2018)

Program

Friday September 21, 2018

Department of Physics, University of Patras

Chairperson: Anna Serpetsidaki

13:30 – 13:45 **Welcome to the CRL School 2018**
Vassilis Anastassopoulos, University of Patras, Greece

13:45 – 14:30 **Seismic network of Corinth Rift Laboratory and micro-seismicity in the last 20 years**
Anne Deschamps, Université Côte d'Azur, GeoAzur & EduMed, Nice, France

14:30 – 15:15 **Monitoring the deformation with GPS**
Pierre Briole, CNRS / Ecole Normale Supérieure / PSL Research University, Paris, France

15:15 – 15:45 **Break**

Chairperson: Georgia Koukiou

15:45 – 16:30 **Monitoring the deformations with InSAR**
Panagiotis Elias, National Observatory of Athens, Greece

16:30 – 18:00 **Hands-on InSAR (ESA software and on-line tools)**
Terradue - TBD
Panagiotis Elias, National Observatory of Athens, Greece
Isaak Parcharidis, Harokopio University of Athens, Greece

18:00 **Departure to Nafpaktos (Akti Hotel)**

Saturday September 22, 2018

Nafpaktos municipality room at the old harbour

This event is open to the public

08:30 **Departure from Akti Hotel**

Chairperson: Christian Beck

09:00 – 09:30 **Tectonics, structural setting and tectono-sedimentary processes in the Corinth Rift**
Haralambos Kranis, National and Kapodistrian University, Athens, Greece

09:30 – 10:00 **How to build a half-graben**
Jean-Arthur Olive, CNRS / Ecole Normale Supérieure / PSL Research University, Paris, France

10:00 – 11:30 **Paleomagnetic studies of rotational deformations in western Greece at large and small geographic scale**
Catherine Kissel, Laboratoire des Sciences du Climat et de l'Environnement, CEA-CNRS, Gif-sur-Yvette, France
Massimo Mattei, Università Roma Tre, Italy
Carlo Laj, Ecole Normale Supérieure, Paris, France

11:30 – 12:00 **Break**

Chairperson: Efthimios Sokos

12:00 – 12:45 **Corinth Rift Seismicity and Applications**
George Kaviris, National and Kapodistrian University, Athens, Greece

12:45 – 13:30 **Deterministic seismic risk assessment with the use of stochastic simulation of strong ground motion taking into account site-effects and empirical vulnerability. Case study the city of Aigion.**
Ioannis Kassaras, National and Kapodistrian University of Athens, Greece

13:30 – 15:00 **Lunch break**

15:00 – 16:30 **Hands-on GPS and seismic instruments** (two different stands in the meeting room)

16:30 – 17:00 **Break**

Chairperson: Pierre Briole

17:00 – 17:30 **Introductory presentation of the cruise on board of the research vessel**
Maria Geraga, University of Patras, Greece

17:30 – 19:30 **White scientific session with any of the attendees invited to present a 3mn pitch followed by questions and discussions**

Sunday September 23, 2018

08:30 **Departure from Akti Hotel**

Two groups:

1st group

Chairperson: Panagiotis Elias

Field trip to Psaromita and visit of several seismic and GPS stations in the field. Performing GPS Measurements, with Panagiotis Elias, National Observatory of Athens, Greece

Sedimentary chronometers: a short overview of a few rich outcrops near Nafpaktos with Christian Beck, Université de Savoie, France

2nd group

Chairperson: Catherine Kissel

Paleomagnetic sampling at sites near Aegion
Massimo Mattei, Catherine Kissel, Francesca Cifelli and Carlo Laj

14:00 **Back at Nafpaktos (Akti Hotel)**

Afternoon: Nafpaktos municipality building at the old harbour

Chairperson: Ioannis Kassaras

15:00 – 16:30 **Earthquakes in the classroom: the seismo-box educational kit**
Francesca Cifelli, Università Roma Tre, Roma Italy

Chairperson: Francesca Cifelli

16:30 – 18:00 **Presentation of the students' posters** (at the same time coffee break)

Chairperson: Athanassios Ganas

18:00 – 19:30 **Open session:** questions by the students, the school teachers and the public to the scientific team

Monday September 24, 2018

08:30 **Departure from Akti Hotel**

Two groups

1st group

Chairpersons: Maria Geraga, George Papatheodorou

09:00 – 16:00 **Cruise on board the science vessel of the University of Patras**
[Weather permitting the vessel will come to Nafpaktos to pick the School there, otherwise the participants will have to go by car to the harbour of Patras]

16:30 **Back at Nafpaktos (Akti Hotel)**

2nd group

Chairperson: Massimo Mattei

09:00 – 12:00 **Presentation of the Seismobox at the Lyceum in Nafpaktos in front of the high-school students and their teachers**
Francesca Cifelli, Università di Roma Tre, Roma Italy

12:00 – 13:00 **Lunch Break**

13:00 – 16:00 **Brainstorming on the didactic component to be implemented at CRL for the local and European schools**

Nafpaktos municipality building at the old harbour

Chairperson: Anne Deschamps

17:30 – 19:30 **Debriefing of the matters learned during the cruise.** This session will be under the entire responsibility (including the animation) of the students and school teachers who will have to set up a 2-hours session with a rich scientific and technical content and a clear didactic structure.

20:30 **Dinner**

Tuesday September 25, 2018

08:15 **Departure from Akti Hotel**

Laboratory of Seismology, University of Patras

Chairperson: George Kaviris

09:00 – 09:30 **Presentation of the Seismology Laboratory, University of Patras**
Anna Serpetsidaki, University of Patras, Greece

09:30 – 10:00 **Structural Monitoring and Geometric control of the Rio-Antirrio bridge**
Akis Panagis, GEFYRA, Greece

10:00 – 10:30 **Earthquake induced coastal submarine landslides. The case of the disappearance of ancient Helike**
George Papatheodorou, University of Patras, Greece

10:30 – 11:00 **Marine Sediments from the Corinth Gulf focused on turbidites and initial results of IODP 381**
Spyros Sergiou, University of Patras, Greece

11:00 – 11:30 ***Move from Seismology Laboratory to Department of Geology***

Department of Geology, University of Patras

Chairperson: Haralambos Kranis

11:30 – 12:30 **Presentation of marine core in the Geology Laboratory of UPAT**
Maria Geraga, Spyros Sergiou, University of Patras, Greece

12:30 – 12:45 **Introduction to the afternoon field trip at the Helike Fault**
Athanassios Ganas, National Observatory of Athens, Greece

12:45 – 13:30 **Lunch at the cafeteria near the department of Physics**

13:30 – 14:15 ***Drive to the Helike Fault***

14:15 – 16:30 **Field trip to the Helike fault**
Athanassios Ganas, National Observatory of Athens, Greece

16:30 – 17:00 General remarks by everyone, an open air session in the Diakofto village

End of the CRL 2018 School

Departures from Aigion to Athens or back to Nafpaktos

Speakers

Vassilis Anastassopoulos

Professor
Physics Dept., University of Patras, Greece
vassilis@upatras.gr

Education

Born in Patras, Greece, in 1958. He received a B.Sc. degree in Physics in 1980 (8.41) and a PhD in Electronics in 1986, both from the University of Patras, Greece. His PhD is on Digital Signal Processing and Delta Modulation Systems.

Career

From 1980 to 1985 he has been a Research Assistant in the Electronics Laboratory, University of Patras. Since 1987 he has been a faculty member in Electronics Laboratory, University of Patras, where in 2005 he became a full professor. He worked for two years in Canadian Universities (Toronto 1989-1990, and Quebec City 1994-1995) on non-linear filters, pattern recognition, classification techniques and signal detection in noise.

Research interests

His research interests are within the scope of digital signal and image processing, radar signal detection, pattern recognition and remote Sensing. He has given emphasis on processing multi-spectral, SAR and infrared imagery, in handwritten analysis and biometrics, in information fusion including image fusion, decision fusion and sensor fusion architectures. He has also carried out work on Super-Resolution and Inverse Problems. Lately, he was involved in image processing techniques for astro-particle physics. His publication record contains over 110 journal and conference papers with over 1800 citations

Selected Publications

1. A book on Sigma-Delta Modulators published by Imperial College Press (Singapore, 2003).
2. V. Tsagaris and V. Anastassopoulos: 'Multispectral image fusion for improved RGB representation based on perceptual attributes', *International Journal on Remote Sensing,* Vol. 26, No. 15, 10 August 2005, pp. 3241- 3254.
3. V. Anastassopoulos, 'Fusion and Super-Resolution in Multispectral Data using Neural Networks for Improved RGB Representation', *The Imaging Science Journal*, Vol. 53, No. 2, June 2005.

Welcome to the CRL School 2018

Vassilis Anastassopoulos
Department of Physics, University of Patras, Greece

This CRL School 2018 is the third edition of the CRL School. This School was created in 2016 as an educational component of the Corinth Rift Observatory (http://crlab.eu). This first edition in 2016 allowed us to test and validate the concept of the School, which duration was 5 days already. During the second edition of 2017 five school teachers (from Italy, Portugal, France and Greece) were invited and a strong link established with the GIFT programme of the EGU, the CRL School offering a sort of GIFT in the field with hands-on many sensors and techniques in a real situation.

The main objective of the CRL School is however to gather master and early PhD students from the various universities collaborating in the Corinth Rift Observatory. This Observatory, the most advanced Near Fault Observatory in Europe, is a superb and very important place to observe, measure and model the evolution of hazardous seismic faults and therefore gain theoretical and practical knowledge about the genesis of earthquakes. The city of Patras and its surroundings is exposed to large earthquakes and related hazards (e.g. tsunami and landslides) and the CRL School is an important event for both the scientific community and the inhabitants of the area.

Anne Deschamps

Emeritus Research Director
Université Côte d'Azur
Géoazur, EduMed

deschamps@geoazur.unice.fr

Education

Studies in France. University studies at ENS. Agregation of Physical Sciences, PhD in Seismology at the University of Paris.

Career

After three years as Assistant Professor at ENS, I joined the CNRS (Centre National pour la Recherche Scientifique) as research scientist in seismology. From 1979 to 1992, I was affected at IPGP (Institut de Physique du Globe de Paris). In 1992, I moved to Géoazur (CNRS/University of Nice Sophia Antipolis) were I was in charge of the regional seismic network in Provence Alpes Côte D'Azur region and developed the broad band seismological observation on land and more recently on sea floor in the frame of ESONET and EMSO programs.

Research interests

Working on seismic sources studies, I have participated to the characterisation of the Mediterranean large seismic events (in Algeria, Italy and Greece). I contributed to seismological studies in different countries (Colombia, Mongolia, Tanzania, Haiti, Ecuador…) to understand of relation between faults, large earthquakes and seismic crisis. Since late 1980's I am strongly involved in different projects in Greece on large earthquake, seismicity, seismogenesis and tectonics and since 2000 I contribute to the development of the Corinth Rift Laboratory recently integrated in EPOS as an European Near Fault Observatory.
More recently, I turned also my interest towards effects of strong ground motions produced by earthquakes: characterisation, site effects, site/structure interaction.
Since 15 years I am following "Sismo à l'Ecole", an initiative to bring seismology at schools and more recently EduMed (http://edumed.unice.fr/fr), a program to provide to teachers and undergraduate students with easy access to controlled data sets on meteorology, hydrology, oceanography and seismology across Mediterranean area for teaching applications.

Scientific production

I have published over 180 articles in international scientific journals.
I supervised 10 PhD students in seismology and different Masters of Science, mostly at the Université Côte d'Azur

Seismic network of Corinth Rift Laboratory and micro-seismicity in the last 20 years

Anne Deschamps,
Géoazur, Université Côte d'azur, CNRS

The Western part of Corinth Gulf which can be considered as the Western end of the North Anatolian fault, presents a high level of micro-seismicity which varies in time. The CRL seismological network starts in 2000/2001, with installation of a local network around Aigio to follow the seismicity on Aigio fault. Due to the important seismicity and a better understanding of the fault system, the network increase progressively towards West, including a participation of different institutions. The present state of the network was reached in 2013 and allows to addressing some scientific questions on the deformation of the crust in the area and the potential for large earthquakes:

- Distribution of main faults, migration of the deformation towards off shore faults.
- Near fault damaging in the upper crust.
- Clustering of micro earthquakes: what are the dimensions of the related fault segments? How they are connected with the faults on which have been observed the last main events?
- How explain de deformation budget? What is the part controlled by the seismicity?
- Role of fluids in the micro-seismicity, are these upper crust faults connected and large earthquakes.
- Can we observe creeping on low dipping normal fault…

To address these questions, CRL has developed a multidisciplinary set of observations. GNSS and deformation instruments have been very soon added, but also works on fault mapping, satellite images processing …
I will present the present state of the network, with some examples of the instrumentation and a discussion on the interest and the limitations of some specific points.

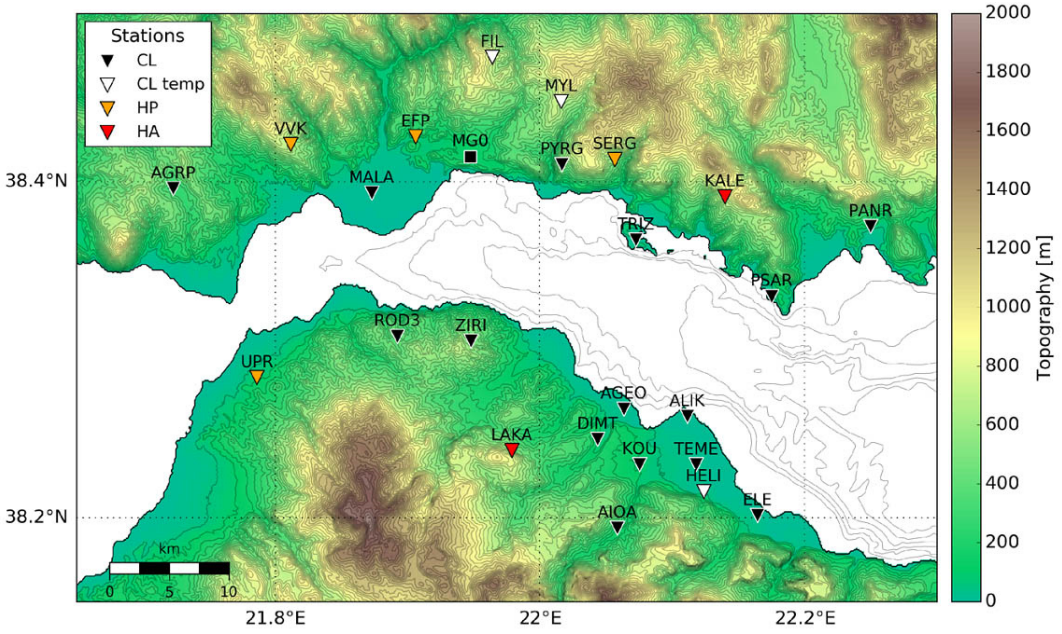


Figure 1: The main CRL seismic network (present state). Some stations on the border are also includes in CRL.

In the second part, I will present the knowledge on the background micro-seismicity from 2001 to 2015 and discuss the importance to develop methods to increase the resolution of the individual location of epicentres.
I will present in some details the relocation procedure (theory and data processing) with some examples on available data.
Obtained images for 15 years of seismicity (maps and cross sections) will be analysed in relation with known faults (faults mapped at the surface, and fault plane of 1995 event at depth).
Then, I will present the knowledge on the background micro-seismicity from 2001 to 2015 and discuss the importance to develop methods to increase the resolution of the individual location of epicentres. The relocation procedure [theory and data processing the obtained images (maps and cross sections)] will be analysed in relation with known faults (faults mapped at the surface, and fault plane of 1995 event at depth).

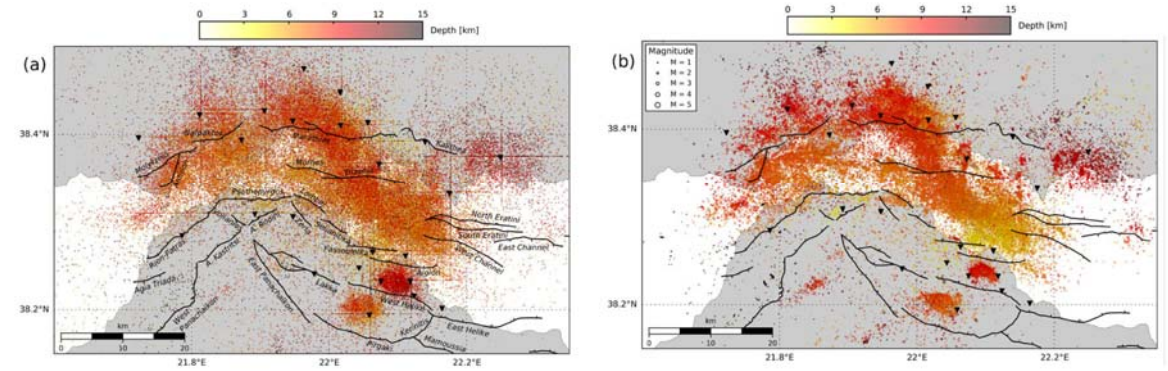


Figure 2: 15 years of micro-seismicity a) P and S automatic picking (205 000 events), b) after relocation procedure (95 000 events).

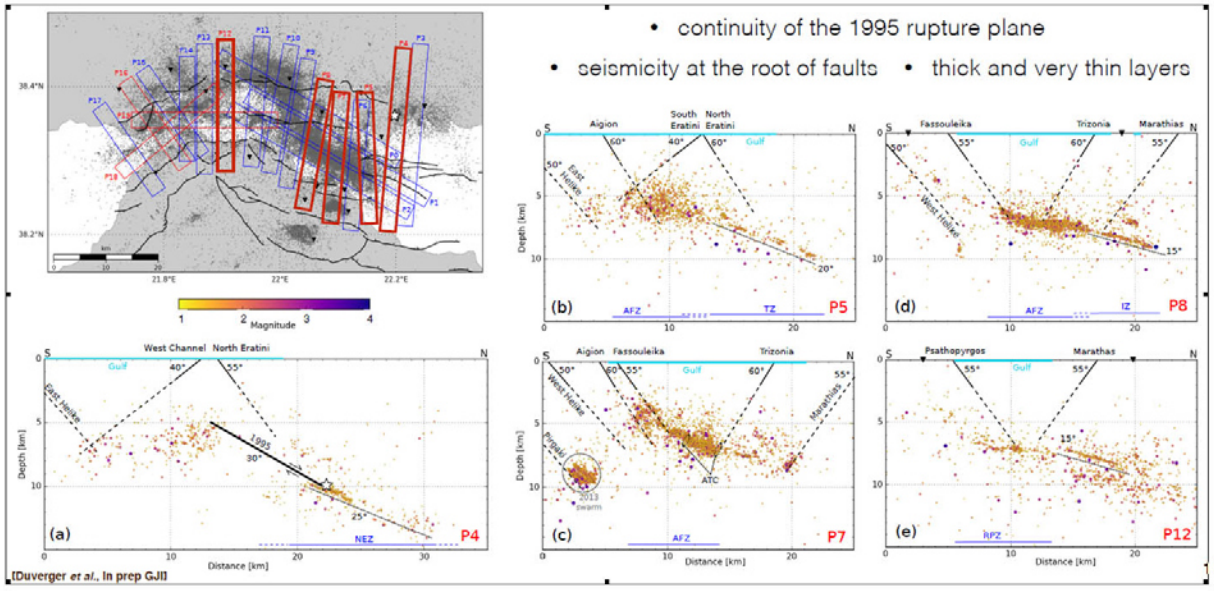


Figure 3: Selected cross sections on the micro-seismicity to discuss the relation with faults observed on the surface.

The last part of my presentation will be dedicated to the study of some swarms which have been studied in detail and I will show how fluids can be invoked to explain the time/spatial history of an almost permanent swarm in the middle of the Gulf, when such behaviour is not seen in the 2013 swarm South of Aigion.

Main bibliography:

1. Duverger, C., Godano, M., Bernard, P., Lyon-Caen, H., & Lambotte, S., 2015. The 2003/2004 seismic swarm in the western Corinth Rift: Evidence for a multiscale pore pressure diffusion process along a permeable fault system, *Geophysical Research Letters*, 42(18), 7374–7382.
2. Duverger C., S. Lambotte, P. Bernard, H. Lyon-Caen, A. Deschamps, A. Nercessian, 2018. Dynamics of microseismicity and its relationship with the active structures in the western Corinth rift (Greece), accepted to *Geophysical Journal International*, 2018
3. Godano, M., Deschamps, A., Lambotte, S., Lyon-Caen, H., Bernard, P., & Pacchiani, F., 2014. Focal mechanisms of earthquake multiplets in the western part of the Corinth Rift (Greece): influence of the velocity model and constraints on the geometry of the active faults, *Geophysical Journal International*, 197(3), 1660–1680.
4. Kapetanidis, V., Deschamps, A., Papadimitriou, P., Matrullo, E., Karakonstantis, A., Bozionelos, G., Kaviris, G., Serpetsidaki, A., Lyon-Caen, H., Voulgaris, N., et al., 2015. The 2013 earthquake swarm in Helike, Greece: seismic activity at the root of old normal faults, *Geophysical Journal International*, 202(3), 2044–2073.
5. Lambotte, S., Lyon-Caen, H., Bernard, P., Deschamps, A., Patau, G., Nercessian, A., Pacchiani, F., Bourouis,S., Drilleau, M., & Adamova, P., 2014. Reassessment of the rifting process in the western Corinth Rift from relocated seismicity, *Geophysical Journal International*, 197(3), 1822–1844.

Pierre Briole

Research Director
Ecole Normale Supérieure,
Paris Sciences et Lettres Research University,
Département des Géosciences

briole@ens.fr

Education

Ecole Normale Supérieure de Cachan in applied physics. Agrégation 1983.PhD, University Paris VI, Paris 1990

Career

2007-today	Research Director CNRS Ecole Normale Supérieure/Paris Sciences et Lettres Research University - Département des Géosciences - Laboratoire de Géologie 09/2008-2009: Directeur des études, 2010-2013: Head of the Department
2004-2007	Research Director CNRS Institut de Physique du Globe de Paris 2005-2006 Director of the laboratory of Geodesy
1990-2004	Chargé de Recherche CNRS Institut de Physique du Globe de Paris - Département de Sismologie
1989-1990	Researcher Institut Géographique National – Laboratoire d'Opto-Electronique et de Micro-informatique

Research interests

Study of the deformation or volcanoes (Etna, Campi Flegrei, Vulcano (Italy), Piton de la Fournaise (France), Nisyros (Greece), Sakurajima (Japan)) and seismic zones (Asal Rift (Djibouti), Gulf of Corinth (Greece), Northern Chile, Umbria (Italy), Algeria, Bulgaria) using various methods, including GPS, radar interferometry, high resolution imaging and local methods (tiltmeter, micro-gravity, ...).
Modelling of ground deformations and interpretation combining tectonic, geodetic, and seismological data. Development of new technologies (Projects of satellites, ground based radars, robots).

Publications and services

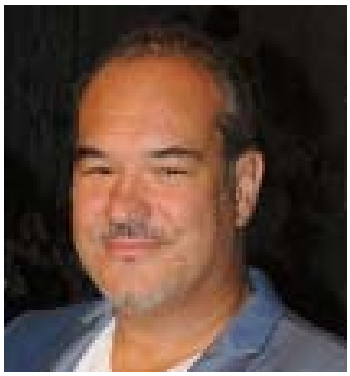
73 articles in journals with peer review, 2951 citations
194 communications in international meetings
3 articles in outreach journals, participation to 4 educational &/or educative movies, several interviews in French radios, several lectures in schools

Coordinator of the "Insegnaci Etna" project http://ietna.eu

Monitoring the deformation with GPS

Pierre Briole
CNRS / Ecole Normale Supérieure / PSL Research University

Since 1990 the deformation of the western rift of Corinth is monitored using the Global Positioning System (GPS) technique. In the first decade the observations were made during campaigns and since 2001 a permanent network has been gradually installed in the area. This network is nowadays composed of ~30 stations. The campaign network was also gradually developed and it gathers now more than 200 points. The western rift of Corinth is the fastest extending area in Europe and one of the fastest in the world. In my presentation, I will show the main results obtained in the last three decades and I will explain the basics of the GPS observation technique. This lecture will also prepare the hand-on GPS instruments presented on Saturday and the GPS observations in the field presented on Sunday.



Panagiotis Elias

Scientific staff
National Observatory of Athens
Institute for Astronomy, Astrophysics, Space
Applications and Remote Sensing (IAASARS)

pelias@noa.gr

Education

2013 PhD in the framework of co-tutelle agreement between the École Normale Supérieure (Département des Géosciences, France) and the University of Patras (Department of Physics, Greece), with title "Ground deformation observed in the western Corinth rift (Greece) by means of SAR interferometry".
2007 MSc in Signal Processing for Telecommunications and Multimedia of the department of Informatics and Telecommunications of the University of Athens, Greece.
2003 Degree of Electronics Engineering of the Technological Educational Institute of Piraeus.

Career

2005-today Scientific staff of IAASARS/NOA.
1998-2005 Research assistant of Institute for Space Applications and Remote Sensing (later IAASARS) of NOA.

Research interests

I have participated in more than 40 research projects in the field of satellite geodesy and image/signal processing exploiting the synergy of active and passive earth observations satellites as well as GNSS and other in-situ measurements such as inclinometers, levelling and seismological data. My research interest is focused in the detection and measurement of ground deformation and infrastructure instability due to geophysical processes of manmade activities. Moreover I am contributing to the development of methodologies and to the modelling of the deformation sources considering the particular underlying geodynamic and geophysical background. I am author of 17 peer refereed publications in international journals, 5 peer refereed proceedings of SPIE and 58 presentations in international conferences.

Selected publications and services

1. Elias P. and Briole P., 2018. Ground deformations in the Corinth rift, Greece, investigated through the means of SAR multi-temporal interferometry. Geochemistry, Geophysics, Geosystems, in press.
2. Ganas A., Elias P., Bozionelos G., Papathanassiou G., Avallone A.., Papastergios A., Valkaniotis S., Parcharidis I and Briole P, 2016. Coseismic deformation, geo-environmental effects and seismic fault of the 17 November 2015 M=6.5, Lefkada Island, Greece earthquake. Tectonophysics, Vol. 687, 26 September 2016, pp 210–222.

Co-responsible for the operation of 22 GNSS stations of the CRL observatory

Awards and honors

Member of the ESA Living Planet Symposium Scientific Committee for the years 2010 and 2013.
Member of the executive secretary of the Remote Sensing and Space Applications Committee of the Geological Society of Greece.

Monitoring the deformations with InSAR

Panagiotis Elias
National Observatory, Athens, Greece

How can we measure a seismic fault buried many kilometres under the ground from 600km away? How can we map a displacement of a few mm or cm from such distances? The technological advancements of the recent decades in the remote sensing permitted the sensing and measuring of the deformation of the earth crust due to earthquakes, aseismic tectonic processes, volcanoes and landslides but also to manmade activities. How can we link the deformation of the surface to the fault in depth through modelling? The basics of the satellite Synthetic Aperture Radar (SAR) characteristics and properties of its provided data as well as the basics for differential and multi-temporal interferometry methodologies will be presented. Links with the presentation of GNSS will be shown. We will focus on the case of the Corinth Rift Observatory area and present our findings so far.

The Corinth Rift is one of the narrowest and fastest extending continental regions worldwide and has one of the highest seismicity rates in the Euro-Mediterranean region. At its western termination, several active faults are located beneath the city of Patras and the surrounding area, a region of major socio-economic importance to Greece.

Apart from moderate earthquakes striking often, additional non sudden geological phenomena, such as slow and continuous ground displacements, are occurring. Both are being provoked by the movement of the tectonic plates. In many cases slow displacements are part of the seismic cycle occurring before an earthquake.

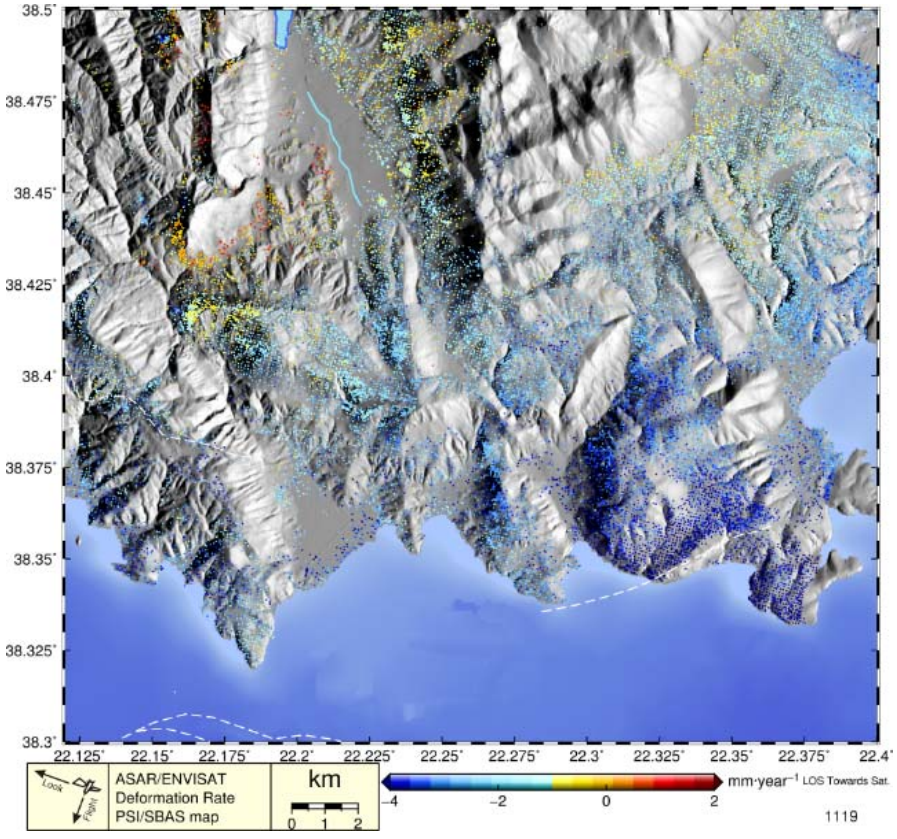
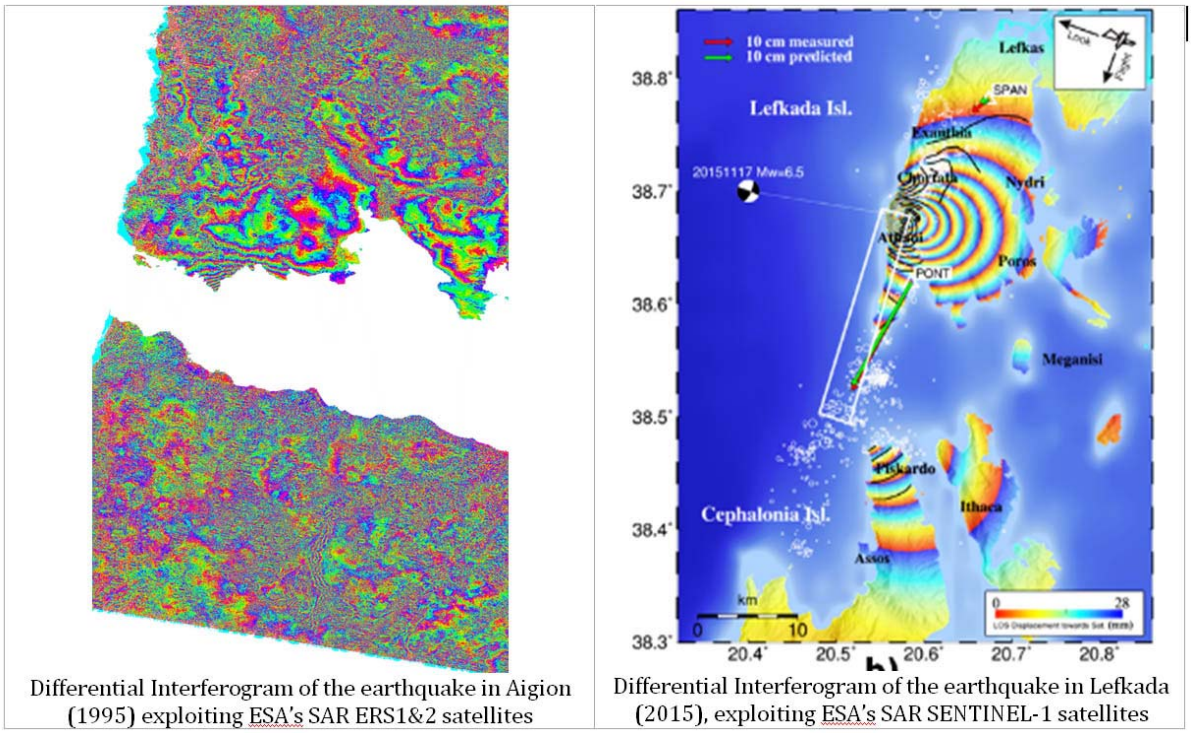


Figure 1: Velocity map produced from ASAR/ENVISAST Multitemporal interferograms of Psaromita and Galaxidi area in the North Gulf of Corinth. The coast of Central Greece is moving away from the coast of North Peloponnesus with a maximum velocity of about 1.5 cm per year.

Displacement rates for the period of 2002-2010 obtained from ascending and descending ASAR/ENVISAT multi-temporal interferometry are combined with Global Positioning System measurements from permanent and campaign stations to produce a map of vertical and east-west ground velocities.

In the city of Patras and through the gulf of Patras, the northern continuation of the 2008 Movri earthquake fault is connected to the oblique, creeping aseismically, transform zone of Rio. Further east, our observations suggest that the Aigion fault is creeping at shallow depths. To the west the Aitoliko-Stamna-Katouna fault zone

is creeping in strike direction. The contribution of the SAR interferometry to the study of the recent earthquakes of Aigion (1995), Movri (2008), Efpalio (2010), Lefkada (2003 and 2015) and Cephalonia (2014) will be demonstrated.



Differential Interferogram of the earthquake in Aigion (1995) exploiting ESA's SAR ERS1&2 satellites

Differential Interferogram of the earthquake in Lefkada (2015), exploiting ESA's SAR SENTINEL-1 satellites

Figure 2: Example of interferograms

Additionally, in Mornos Delta, Patras and all the Deltas, subsidences of no tectonic origin were detected. All these slow phenomena constitute natural hazard affecting the socio-economic activity of the region and in some cases threatening the public safety.

Issaak Parcharidis

Professor
Harokopio University of Athens
Department of Geography

parchar@hua.gr

Education

Doctor of Science: Tectonic Analysis of central and northern Greece using Remote Sensing data (1994)
BSc in Geology: Applied Geology (1983)

Career

2004-Today	Prof at Harokopio University/Dep. of Geography
2000-2003	Associate Researcher at National University of Athens
2000-2002	Scientific advisor in General Secretariat of Civil Protection of Greece
1996-1999	Special Scientist at Earthquake Planning and Protection Organization of Greece

Research interests

Earth Observation applications
SAR Interferometry

Selected publications

1. Perrou T., Garioud A., **Parcharidis I**., (2018). Use of Sentinel-1 imagery for flood management in a reservoir-regulated river basin. Frontiers of Earth Sciences, DOI:10.1007/s11707-018-0711-2
2. Chen F, Wu Y., Zhang Y., **Parcharidis I.**, Ma P., Xiao R., Xu J., Zhou W., Tang P., Foumelis M., (2017). Surface Motion and Structural Instability Monitoring of Ming Dynasty City Walls by Two-Step Tomo-PSInSAR Approach in Nanjing City, China. *Remote Sensing*; 9(4):371.
3. Neokosmidis, S., Elias, P., **Parcharidis, I**., & Briole, P., (2016). Deformation estimation of an earth dam and its relation with local earthquakes, by exploiting multi-temporal synthetic aperture radar interferometry: Mornos dam case (central Greece). *Journal of Applied Remote Sensing*, 10(2) doi:10.1117/1.JRS.10.026010

Hands-on InSAR (ESA software and on-line tools)

Terradue, Panagiotis Elias, Isaak Parcharidis

We will present basic information on the SNAP software of ESA and the GEP-TEP on-line InSAR tool. Step by step hands on process on a real case will be held in a computer room with 2 or 3 students per computer.

Haralambos Kranis

Assistant Professor
National and Kapodistrian University of Athens
Department of Geology and Geoenvironment

hkranis@geol.uoa.gr

Education

Degree in Geology (NKUA), Post-graduate Diploma, in Seismology, (International Institute for Seismology and Earthquake Engineering), Ph.D. in Geological Sciences, (NKUA)

Career

My scientific career mainly involves working for the Department of Geology and Geoenvironment, at the Sector of Dynamic, Tectonic and Applied Geology, while I have also served as Tectonics and Structural Geology expert for the General Secretariat for Civil Protection, collaborated with the Earthquake Research and Planning Organization (EPPO), and the Hellenic Centre for Marine Research (HCMR); and as a consultant for major infrastructure projects, such as gas and oil pipelines, and management of natural hazards.

Research interests

My main research interests include, but are not limited to, Tectonics and Structural Geology (especially brittle deformation), Neotectonics, Active Tectonics and Earthquake Geology, Tectonic Geomorphology and Palaeoseismology. In the last decade, I am involved in research on the tectonic control on sedimentation and basin formation in actively evolving continental rifts and their inactive analogues. Extending my scope in field geology and geological mapping, I have adopted methods and techniques that involve spatial analysis of geological structures through Structure from Motion (SfM), 3D outcrop modelling of outcrops, digital field mapping and modelling of tectonically-controlled landscapes.

Publications and services

I have published over 40 articles in peer-reviewed scientific journals, several field guides and special reports, as well as geological and neotectonic maps at various scales.

Awards and honors

Secretary General, Geological Society of Greece
Scholarship from the Government of Japan (Japan International Cooperation Agency)
Goldschmidt Lecturer, Geological Survey of Norway

Tectonics, structural setting and tectono-sedimentary processes in the Corinth rift

Haralambos Kranis
Department Geology and Geoenvironment, National and Kapodistrian University of Athens, Greece

The Gulf of Corinth (GoC) Rift, is one of the most active continental rifts worldwide, which develops within the broader plate convergence context of the Hellenic Arc. Extension and strain localization within the overriding Aegean Plate has led to the formation of this rapidly extending domain. The available data so far point to its inception at ca (?)5 Ma most probably linked to two interrelated processes, namely (i) the onset of the pronounced curvature of the Hellenic Arc; (ii) the propagation of the North Anatolian Fault into the Aegean domain.

The GoC rift has developed in two phases, namely the Rift 1 phase, from 5.0-3.6 to 2.2-1.8 Ma and Rift 2, from 2.2-1.8 Ma to present. Rift 1 is recorded in a >3 km thick syn-rift succession, (Lake Corinth) which shows upward deepening from fluviatile to lake-margin conditions and finally to sub-lacustrine, deposited in a 30 km-wide zone of distributed normal faulting. Rift 2 marks a 39 km northward shift in the locus of rifting, accompanied by footwall and regional uplift, which destroyed Lake Corinth in the central and eastern parts of the rift, while giant Gilbert deltas in the west built into a deepening lake depocenter in the hanging-wall of the newly developing border fault system. Self-organization and strain localization along co-linear border faults are considered to be responsible for the growth, linkage and death of normal faults during these two rifting phases. The major Patras dextral strike-slip fault controls the interaction between the GoC and the Patras rifts; this led to the opening of the Rio Straits at c. 400-600 ka.

The overall landscape and stratigraphic evolution of the rift was strongly influenced by factors related to structure of the Hellenide fold and thrust basement, which controlled regional palaeotopographic variations and local antecedent drainage, the latter especially visible at the southern shoulder of the rift. Along-strike, regional topography north and south of the rift is relatively high in the west, compared to the east; this exerted a first-order control on the depositional environments during rifting. The majority of sediment to the CoC rift has been supplied by north-flowing antecedent catchments on the southern flank. However, the contribution of S-flowing catchments appears to be increasing over time.

On a crustal scale, the extensional thinning of the Hellenide nappe stack, which is observed in the Peloponnesus, is overprinted by the high-angle normal faulting that controls the GoC rift inception and evolution. The interplay between these two processes is another major factor and geochronological and structural data are sought to further constrain rift evolution.

Dr. Jean Arthur Olive

Research Scientist
CNRS / Ecole Normale Supérieure
PSL Research University

olive@geologie.ens.fr

Education

B.S. Earth Science, Ecole Normale Supérieure (2007).
M.Sc**.** Geophysics, Ecole Normale Supérieure / Institut de Physique du Globe de Paris (2009).
PhD. Marine Geophysics, Massachusetts Institute of Technology / Woods Hole Oceanographic Institution Joint Program in Oceanography (2015).

Career

Research Assistant: Massachusetts Institute of Technology / Woods Hole Oceanographic Institution (2009–2014).
Postdoctoral Scientist: Lamont-Doherty Earth Observatory / Columbia University (2015–2017).
Research Scientist: CNRS / Ecole Normale Supérieure (Since 2018).

Research interests

Geodynamics of the lithosphere. Thermo-mechanical modelling of plate boundary evolution. Feedbacks between deformation and fluid Earth processes. Mechanics of extensional faults.
Ongoing projects:
• Feedbacks between extensional tectonics and surface processes.
• Detachment fault evolution at slow and ultraslow-spreading mid-ocean ridges.
• Mechanisms of distributed brittle deformation in the upper crust.

Publications and services

~20 publications in international journals.
Software development and distribution: SiStER (Simple Stokes solver with Exotic Rheologies), a 2-D code for long-term tectonic modelling; eiSPLIT, a package for shear-wave splitting analysis.
Advisor: 3 undergraduate students, 1 master's student (co-advised).
Co-chair: InterRidge Working Group on Hydrothermal Research (IMOVE).

Awards and honors

Lamont-Doherty Earth Observatory Postdoctoral Scholarship (2015).
CSDMS Student Modeler Award (2014).
AGU Outstanding Student Presentation Award (2011, 2014).

How to build a half-graben

Jean-Arthur Olive
Ecole Normale Supérieure / CNRS

The Eastern Gulf of Corinth is a prime example of half-graben: a structure in which extensional strain is primarily taken up by a master normal fault, inducing flexure of the adjacent blocks. Footwall up-warping and hanging wall down-warping typically result in the formation of a small mountain range and sedimentary basin, respectively (Fig. 1). Half-grabens are a common motif in extensional tectonics from mid-ocean ridges to both narrow (East Africa, Lake Baikal…) and wide (Basin & Range) rift settings, yet the reasons for such ubiquity are not fully understood.

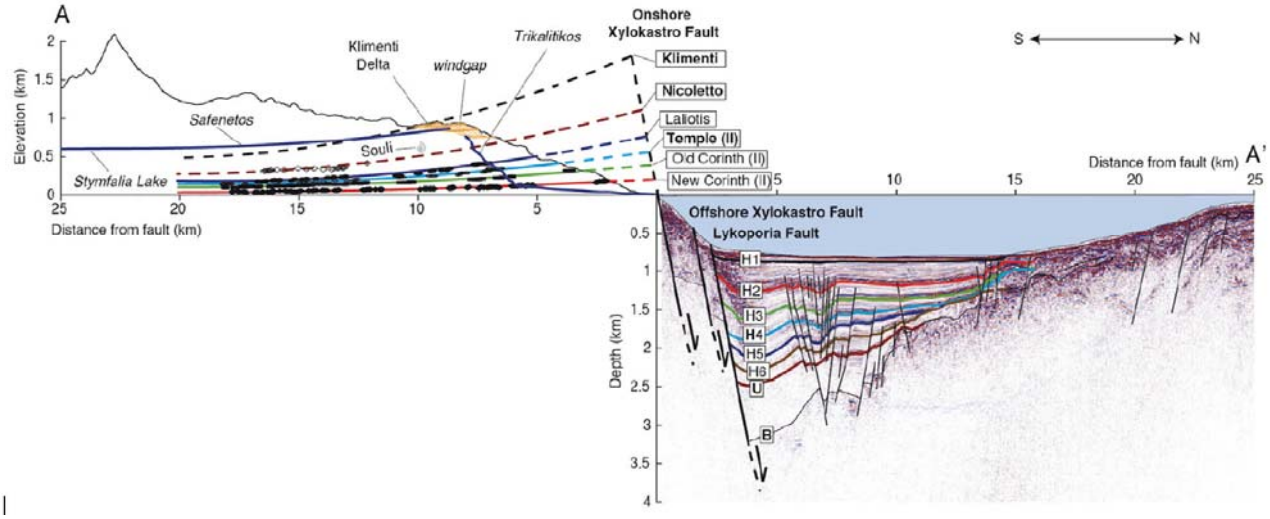


Figure 1: The Eastern Corinth half-graben [modified from *de Gelder et al.,* 2018, *EarthArXiv preprint*: doi.org/10.31223/osf.io/4sh8e], where strain is accommodated by steep north-dipping normal faults (e.g., the Xylokastro fault), and in a more diffuse fashion through distributed faults in the down-warped hanging wall (seismic profile by *Taylor et al.* [2011]). Footwall flexure is recorded by the continuous uplift and deformation of marine terraces (paleo-horizontals, dashed curves) of known age.

This presentation will focus on the mechanics of half-graben formation and evolution, beginning with the crustal deformation mechanisms that enable short-wavelength (< 20 km) flexure of the upper lithosphere in response to fault slip. The observed deflection of paleo-horizontals in the footwall (Fig. 1) is generally consistent with a low effective elastic thickness for the upper crust, suggesting that widespread brittle yielding takes place in the vicinity of the master fault. Using a combination of field observations and geodynamic modelling, I will argue that this manifests as distributed faulting in the sedimentary basin, but also as fracture growth across a range of scales in the footwall.

This first point will then bring up a key paradox in our understanding of half-graben mechanics: Given that slip on a master normal fault induces yielding of the adjacent blocks, it is unclear why new crustal-scale master faults do not rapidly initiate and turn half grabens into full-grabens or horsts. I will address this question by presenting theoretical models that predict the lifespan of a half-graben as a function of internal parameters (e.g., thermal regime, crustal rheology), as well as external forcings (e.g., surficial mass redistribution due to erosion and sedimentation, Fig. 2). I will show that the stability of half-grabens depends on a subtle balance between strain-localizing phenomena (fault weakening, active surface processes...) and delocalizing effects (a strong upper crust, a viscous lower crust…). I will conclude by discussing how the long-term processes documented in half-graben structures might manifest on seismic cycle time scales.

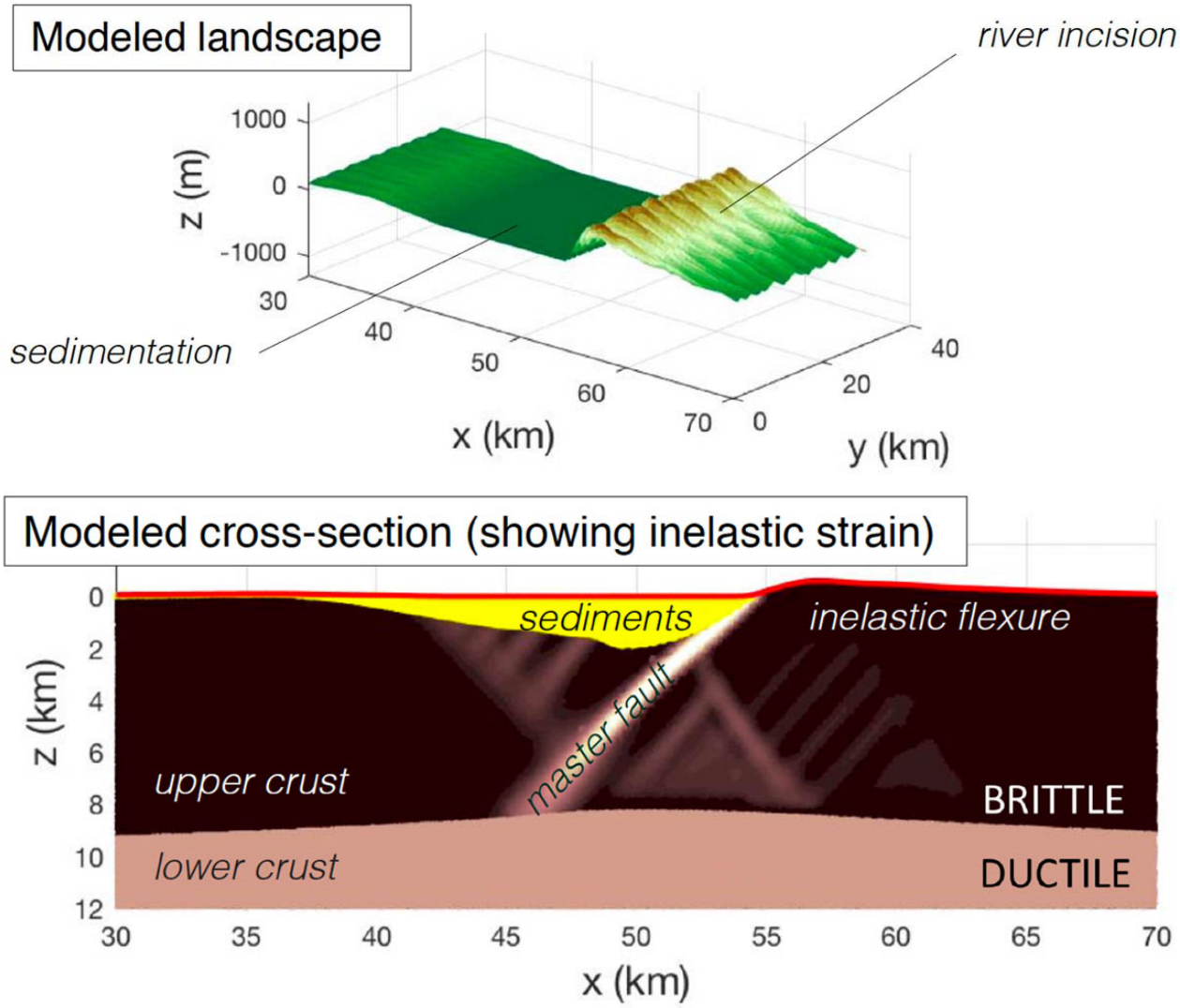


Figure 2: Numerical model of half-graben formation subjected to surface processes. This simulation predicts both the finite deformation of the footwall and hanging wall (2-D cross-section), and the resulting landscape (2-D map view) which integrates the effect of river incision and sediment deposition. These types of simulations can be used to assess the sensitivity of half-graben stability to the intensity of surface processes.

Carlo Laj

Emeritus Researcher
Ecole Normale Supérieure
Département de Géologie
&
Committee on Education
European Geosciences Union

carlo.laj@ens.fr

Education

Secondary school in Italy and the USA (American Field Service Exchange Student). University studies at the University of Paris, PhD in Solid State Physics.

Career

I have done all my scientific career as an employee of the French Atomic Energy Commission, first as a researcher in the Physics Department then in the field of geophysics.
In 1985, I was appointed as Deputy Director of the Centre des Faibles Radioactivités and Head of the Department of Earth Sciences. I created and was first director of the Laboratoire de Modélisation du Climat et de l'Environnement, which was later united with the Centre des Faibles Radioactivités to form the present Laboratoire des Sciences du Climat et de l'Environnement (LSCE). After 3 terms as Head of Department (12 years) I stepped down to a researcher position again, until I retired. I have been an "emeritus" researcher since then, and gradually reoriented my activities towards education.

Research interests

After my PhD I spent a few years working with critical phenomena (scattering of laser light by critical fluids) then moved into the field of geophysics.
My main interests in this new field has always been linked to the magnetic properties of sediments and igneous rocks (paleomagnetism), used with several objectives: geodynamical reconstructions (particularly in the Eastern Mediterranean and the Andean Cordillera), reconstruction of the history of the Earth's magnetic field (including the morphology of field reversals) and more recently reconstructions of environmental and climatic changes on a global scale.
I have published over 200 articles in international scientific journals and a few general popular articles in different journals.
Supervisor of 12 PhD students, and 8 Masters of Science

Educational activities and honors

Founder and Chairman, Education Committee of the European Geosciences Union
Participant to different National and International Education Committees
Union Service Award for creating the Committee on Education of EGU
Excellence in Geophysical Education Award of the American Geophysical Union
Fellow of the American Geophysical Union (AGU).
F. Holweck prize of the French Academy of Science
Holmes Medalist of the European Geosciences Union

Catherine Kissel

Research scientist
Laboratoire des Sciences du Climat et de
l'Environnement (LSCE), Gif-sur-Yvette, France

Catherine.kissel@lsce.ipsl.fr

Education

Dec. 1986	PhD (Paleomagnetism applied to Geodynamical studies in the Mediterranean)
May 1984	MSc (Paleomagnetism)

Career

1987-	Research Scientist, French Atomic Energy Commission
	2007: Promotion E7 - position Eq. to Directeur de Recherche 1
	2012: Honorary position of Directeur de Recherche CEA
2015-	Head of the CliMag team at LSCE
2011-2015	Deputy responsible for the Theme « Climate archives » of LSCE
2008-2011	Head of the ChronoMag team (Environmental Magnetism and Chronology) at LSCE
1997-2007	Head of the Evironmental Magnetism team at LSCE
1987-1997	Head of the Paleomagnetic team of the Centre des Faibles Radioactivités.

Research interests

Paleomagnetism, Earth magnetic field, Environmental Magnetism, Rock Magnetism, Paleoceanography

Selected publications

About 170 publications among which:

1. Kissel, C. and Laj, C., The Tertiary geodynamical evolution of the Aegean Arc: a paleomagnetic reconstruction, *Tectonophysics, 146, 183-201,* 1988.

2. Kissel, C., Van Toer, A., Laj, C., Cortijo, E., Michel, E. Variations in the Strength of the North Atlantic Bottom water during Holocene. *Earth Planet. Sci. Lett*. 369-370, 248-259, 2013.

3. Kissel, C., Sarnthein, M., Laj, C., Wang, P.X., Wandres, C., Egli, R., Magnetic fingerprints of modern sediments in the South China Sea resulting from source-to-sink processes. *Geochem. Geophys. Geosystems, accepted.*

Massimo Mattei

Professor in Geology
Department of Sciences, Roma TRE University

massimo.mattei@uniroma3.it

Education

Ph.D. Geology (1992)	University La Sapienza (Rome)
M.Sc. Geology (1986)	University La Sapienza (Rome)
Ph.D Supervisor	Prof. Renato Funiciello

Career

Jan. 2011	Full Professor, University of Roma TRE, Rome, Italy
Nov. 2011	Associate Professor, University of Roma TRE, Rome, Italy
Nov. 2008	Associate Professor, University of Basilicata, Potenza, Italy
Jul. 2004	Visiting professor at the Institute of Geophysics ETH Zurich
Dec. 1998	Visiting professor at the University of Cergy-Pointoise (France)
Nov. 1992	Ricercatore Universitario (Lecturer), University of Roma TRE, Rome, Italy
Jun. 1992	Ricercatore Universitario (Lecturer), University La Sapienza, Rome, Italy

Research interests

Field geology
Structural geology
Paleomagnetism
Tectonics
Geodynamics

Publications and services

Author or co-author of more than 100 research papers (most of them in peer-reviewed international Journals) mainly about tectonic evolution and paleomagnetism of Central Mediterranean, Iran, Anatolia Plateau, Gibraltar Arc, Greece, Andes.
Associate Editor of Geological Society American Bulletin since 2013.
Coordinator of the Italian Group of Structural Geology since Jan 2017

Suggested readings (WEB resources or scientific journal papers)

- Naomi Oreskes – “Plate Tectonics: An Insider's History Of The Modern Theory Of The Earth”
- Allan Cox – “Plate Tectonics and Geomagnetic Reversals” W H Freeman & Co. 1973.
- hhttps://www.sciencenews.org/article/remnants-earths-original-crust-preserve-time-plate-tectonics
- Brown, M., 2006. Duality of thermal regimes is the distinctive characteristic of plate tectonics since the Neoarchean. Geology 34, 961–964.

Paleomagnetic studies of rotational deformations in western Greece: at large and small geographic scale.

M. Mattei, C. Kissel and C. Laj

The geometry of the Mediterranean Alpine belt arises from the Upper Cretaceous-Cenozoic collision between the African and European plates. Large and small-scale deformations took place, among which, rotations around vertical axis. The role played by the latter in the edification of the Dinarides-Hellenides belts can only be approached by paleomagnetic studies. Indeed, most of the rocks fossilize the earth magnetic field vector at the time of their formation (cooling or sedimentary deposition). Averaged on sufficient time interval, the fossilized direction should be northward (or southward) directed. After applying adequate laboratory and field tests to check that the measured magnetization is the primary one, any deviation of the declination with respect to the north/south axis reflects a tectonic rotation of the block/structure/region (the scale depends on the geographical/ structural extent of the statistical coherency of the rotation).

The Aegean area is a seismically very active zone where we can expect large amplitude movements to occur in a short time interval. Two types of studies were conducted: one, focused on the external zones of the orogens and considering the large-scale rotations and their role in the acquisition of the curvature of the Aegean-Tauric arcs and the other one, focusing on the close surroundings of the Corinth gulf, considering the small-scale block rotations in this very tectonically active area.

On the large scale, an extensive paleomagnetic study has been conducted in the external zones of the Dinarides and Albano-Hellenides. Our approach was pioneer, starting from the most recent formations and extending back in time in order to, retrotectonically, reconstruct and quantify the eventual successive rotation phases during the Cenozoic/Quaternary period. The sampling of the external zones of the Dinarides and the Albano-Hellenic belts (175 sites) has been distributed in space in structures presenting the regional trend (120° for Dinarides and 150° for Albano-Hellenides) and in time from Eocene to Plio-Quaternary. More than 2500 cores were distributed all over the outcrops and at least two samples were fully treated in the laboratory.

The first upper Miocene to Quaternary sampled sites, are located in the Ionian islands of Kerkyra, Kefalonia and Zackinthos. The results showed that the upper Miocene formations had rotated clockwise by 25° while the Plio-Quaternary sites showed various clockwise rotation angles. The results, when reported versus age, showed that the upper Miocene was a rather stable period until the 25° clockwise rotation started at the onset of Pliocene and occurred continuously since then at rate of ~ 5°/Myr. In addition to this temporal reconstruction of the rotation, the important point is that the 25° rotation was observed in sites located both in the pre-Apulian and in the Ionian zones. It therefore could not be attributed to a shallow movement of the Ionian zone over the pre-Apulian one and the origin of this rotation was necessarily deeper. Quaternary sites from Albania were not suitable for paleomagnetic study but the 26 upper Miocene and 15 lower Pliocene marly sites showed the same pattern as the sites from the Ionian Islands indicating that the active 'Aegean' compressive front extends much farther north than hitherto believed.

Back in time, upper Eocene to upper Oligocene/lower Miocene marls were sampled in the Ionian zones in continental Greece (29 sites) and later on, in the same structures farther north in Albania (47 sites). These sites revealed quite homogeneously, a 45-50° clockwise rotation, therefore twice as that measured in upper Miocene sites. This is calculated with respect to Africa. Two phases of clockwise rotation therefore successively affected these regions. They were attributed to the middle Miocene (Langhian) and lower Pliocene tectonic phases recognized in this area on the basis of structural analyses. These results showed that the external zones of the Albano-Hellenic Belt appear to have rotated virtually as a single entity from the Peloponnesos to northern Albania over a deep decollement level probably involving the basement itself. In the meantime, the 43 Eocene to Mio-Pliocene sites sampled in the external Dinarides, did not show any significant rotation.

The pivot point of the clockwise rotation is certainly located at the vicinity of Scutari-Pec (S-P) transverse zone, immediately north of the rotating region. The strong seismic activity recorded in this region and the anomalously high positive heat flow (documented by other authors) are also evidence for the recent activity of the S-P transverse zone. Moreover, it has been shown that both the basement and the nappes are involved in the Albano-Hellenic rotation, implying that the tectonic deformation within the S-P transversal zone certainly affects the deep crust. Considering, as a first approximation that the rotation is a semi-rigid one, as suggested by the remarkable consistency of the paleomagnetic results over the Albano-Hellenic belt and the absence of large-scale strike-slip faults, a simple triangulation, around the pivot pole at the S-P zone, indicates that the observed rotations imply a horizontal displacement of about 300 km over the last 15 Ma at the latitude of the Corinth Gulf.

These data thus bring the first experimental proof that the S-P line, considered until that time as a Mesozoic tectonic boundary on the basis of geological observations, is, in fact, a very important tectonic feature during the Cenozoic and probably until the late Pleistocene time acted as a wide and deep decoupling zone between two major orogens of the central Mediterranean.
In parallel, Cretan formations did not reveal any significant rotation since Miocene while the easternmost units of the Aegean arc (23 sites from the Bey Daglari massif in southern Turkey) underwent a 25° post mid-Miocene counterclockwise rotation. This rotation did not affect the Antalya basin deposited on top of the Bey Daglari. Indeed, no post mid-Miocene rotation was observed from the 13 sites sampled in this basin.
The reconstruction of the Cenozoic evolution of the orientation of the different analyzed structures is possible on the basis of the paleomagnetic results obtained in this area. The Lower Miocene arc was almost rectilinear with an E-W trend. Its curvature has been acquired tectonically in two major phases. During the Middle Miocene a first phase of deformation is characterized by rotations occurring at the two terminations of the arc, clockwise in the west (Epirus) anticlockwise in the east (southeastern Anatolia). This phase brought the Dinarides and the Albano-Hellenides along the same axis. A second phase of rotation occurring in the last 5 Ma about a pole situated around the S-P line affected only the northwestern part. The data also indicate that the Dinarides on the western part and the Antalya basin on the easternmost part have not been involved in the geodynamical evolution of the arc.
On smaller scale, paleomagnetic data from Plio-Pleistocene sedimentary units from Corinth and Megara basins (Peloponnesus, Greece) show that Megara basin has undergone vertical axis clockwise (CW) rotation since the Pliocene, while Corinth has rotated counter-clockwise (CCW) during the same period of time. Conversely, published GPS results show that these two basins belong today to the same crustal block (Peloponnesus), which is presently rotating CCW respect to the Beotia-Locris block. The boundary between the two blocks is represented by an E-W oriented normal fault system which bounds the Corinth basin and the Megara basin to the north.
These results indicate that the overall deformation in central Greece has been achieved by complex interactions of mostly rigid, rotating, fault bounded crustal blocks. The comparison of paleomagnetic results and existing GPS data shows that the boundaries of the rigid blocks in central Greece have changed over time, sometimes changing in orientation. The Megara basin belonged to the Beotia-Locris block in the past but has now been incorporated into the Peloponnesus block, possibly because the faulting in the Gulf of Corinth has propagated both north and east (Fig. 1). Paleomagnetic and GPS data from Megara and Corinth basins have significant implications for the deformation style of the continental lithosphere. In areas of distributed deformation, the continental lithosphere behaves instantaneously like a small number of rigid blocks with well-defined boundaries.

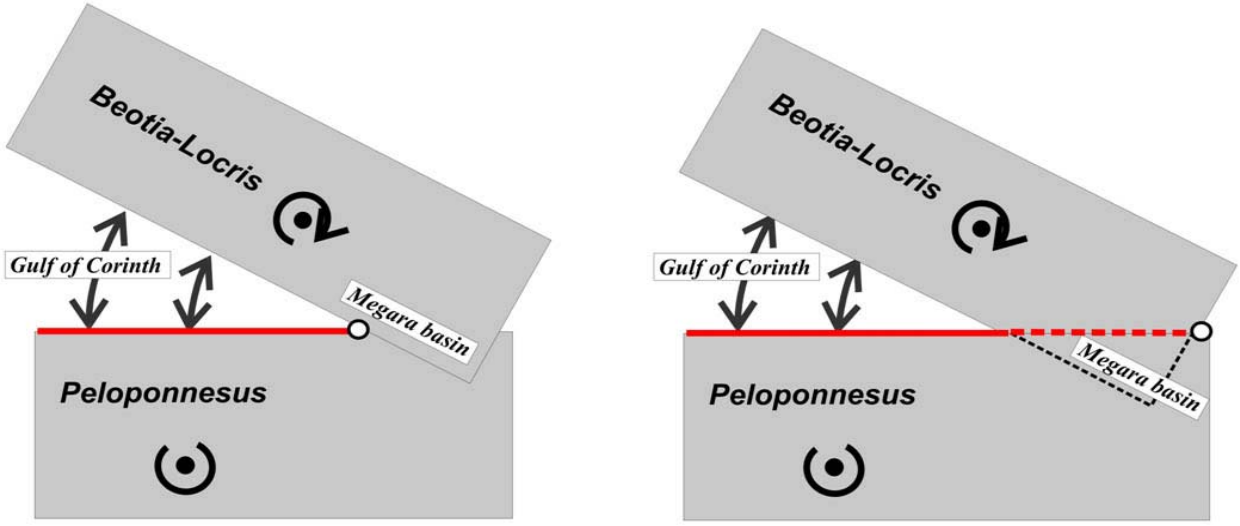


Figure 1: Schematic representation of the tectonic evolution of Central Greece. During the Plio-Pleistocene the Megara basin belonged to the CW rotating Beotia-Locris block. As a consequence of the eastward migration of the E-W oriented normal fault system the Megara basin was incorporated into the Peloponnesus block, as demonstrated by GPS data.

George Kaviris

Assistant Professor
National and Kapodistrian University of Athens
Faculty of Geology and Geoenvironment
Department of Geophysics and Geothermics

gkaviris@geol.uoa.gr

Education

1994 Graduated from the Faculty of Physics, National and Kapodistrian University of Athens (NKUA)

2003 PhD of Seismology, Department of Geophysics and Geothermics, Faculty of Geology and Geoenvironment, NKUA. Thesis subject: "Study of Seismic Source Properties of the Eastern Gulf of Corinth".

Career

2016 - today Assistant Professor of "Seismology – Seismic Anisotropy", Department of Geophysics and Geothermics, Faculty of Geology and Geoenvironment, NKUA

2013 - 2016 Lecturer of "Seismology", Department of Geophysics and Geothermics, Faculty of Geology and Geoenvironment, NKUA

2006 - 2013 Research Associate (IDAX) at the Laboratory of Seismology, Department of Geophysics and Geothermics, Faculty of Geology and Geoenvironment, NKUA.

2004 - 2007 Post-Doc Researcher in the Research Project "Pythagoras" entitled: «Identification of Anisotropic Media in Greece using body and surface waves».

Research interests

My primary research interest is Seismic Anisotropy, both of the upper crust and mantle. In addition, Seismotectonics, Seismic Hazard, Seismic Risk, Receiver Functions, Ambient Noise, Slip Distribution and Seismic Swarms.

Publications and services

Supervisor of 12 MSc and 14 BSc students.
I have more than 120 publications in international scientific journals and congress proceedings.

Publications for the Gulf of Corinth:

1. G. KAVIRIS, I. Spingos, V. Kapetanidis, P. Papadimitriou, N. Voulgaris and K. Makropoulos, 2017. Upper crust seismic anisotropy study and temporal variations of shear-wave splitting parameters in the Western Gulf of Corinth (Greece) during 2013. Phys. Earth Plan. Int., 269, 148-164, https://doi.org/10.1016/j.pepi.2017.06.006.
2. G. KAVIRIS, Ch. Millas, I. Spingos, V. Kapetanidis, I. Fountoulakis, P. Papadimitriou, N. Voulgaris and K. Makropoulos, 2018. Observations of shear-wave splitting parameters in the Western Gulf of Corinth focusing on the 2014 Mw=5.0 earthquake. Phys. Earth Plan. Int., accepted.

Awards and honors

January 2017: Highly cited Research Award for the publication "Karst collapse susceptibility mapping considering peak ground acceleration in a rapidly growing urban area" in which I was a co-author. This publication was awarded being among the five (5) most cited works of the international journal "Engineering Geology" for the period January 2014 - June 2016. The award was given in recognition for the contribution of this work to the quality of the scientific journal "Engineering Geology". A certificate has been issued by Elsevier.

Corinth Rift Seismicity and Applications

George Kaviris
Section of Geophysics and Geothermics, Department of Geology and Geoenvironment, National and Kapodistrian University of Athens

The Gulf of Corinth (GoC) can be considered a "natural laboratory" for seismology, given that it is characterized by high tectonic activity. The dominant structural feature is normal faulting. Regarding the morphology of the gulf, it is an E-W trending asymmetric graben, with the major active faults outcropping at the southern coast and dipping north, resulting in a long record of rifting in the centre of the gulf. GPS measurements in the GoC have revealed a high extension rate in a NNE-SSW direction, increasing from east to west.

Moderate to strong historical earthquakes (Fig. 1) have occurred in the western part of the Gulf (WGoC), including destructive ones, such as the 373 BC Helike earthquake, as well as during the instrumental period, with some causing severe damage to urban areas in the broader region, e.g. Eratini, M = 6.3, 1965; Antikyra, M=6.2, 1970; Galaxidi, M = 5.8, 1992; Aigion, M_s = 6.2, 1995. Regarding the eastern part of the Rift (EGoC), on February 24, 25 and March 4, 1981, a seismic sequence consisting of three major earthquakes of magnitudes M_s = 6.7, 6.4 and 6.4 occurred in Alkyonides Gulf causing significant damage to Athens. In addition, seismic swarms, such as the one that occurred in Helike in 2013, are a common phenomenon in the western part of the rift.

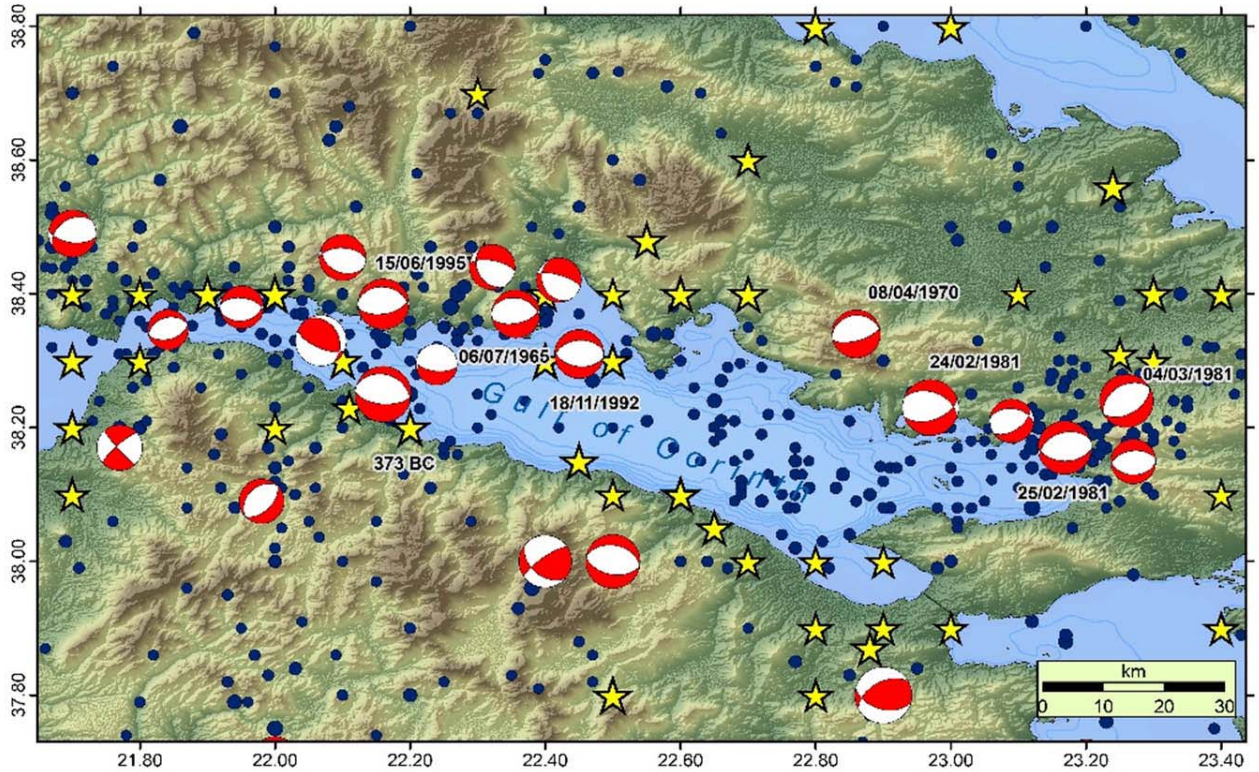


Figure 1: Seismotectonic map of the GoC. Stars represent epicentres of historical (M>6) and blue circles of instrumental (Mw>4) earthquakes. Beach balls are focal mechanisms of strong earthquakes.

The fore mentioned seismic activity has piqued the interest of several Greek and International research efforts. As a result, Hellenic Institutions have installed several seismological stations in the area, belonging to the Hellenic Unified Seismological Network (HUSN). Furthermore, the multinational initiative of the Corinth Rift Laboratory (CRL) has greatly increased the density of local station coverage and has led to the prompt provision of seismological data to the scientific community.

Waveforms recorded in the GoC have been utilized in locating earthquakes with high resolution, which permits the identification of seismogenic faults through seismological observations. The obtained data are also used in the determination of focal mechanisms, either with the method of first-motion P-wave polarities (enabled by the dense station coverage) or through moment tensor inversion (for the stronger events). Thus, we can infer the seismotectonic state of the GoC. The vast majority of the reliable fault-plane solutions indicate normal faulting

in an approximate E-W direction (Fig. 1), in accordance to the major active faults. It is worth noting that focal mechanisms in NW Peloponnesus indicate strike-slip faulting.

Reliable estimation of seismic hazard parameters, in terms of maximum expected earthquake magnitude and acceleration, velocity and displacement, is vital for earthquake resistant planning and risk mitigation, especially for earthquake prone regions as the GoC. According to the current Greek Building Code, determined using Probabilistic Seismic Hazard Assessment (PSHA), the GoC belongs to Zone II, to which Peak Ground Acceleration (PGA) equal to 0.24g is assigned for a return period of 475 years.

Conditions in the GoC have permitted detailed shear-wave splitting studies of the upper crust. The dense seismological networks, especially CRL, in combination with the intense seismicity, provide an optimal environment for such studies, where high rejection rate of data is common place. Exploring seismic anisotropy can lead to constraining fault-plane solutions and to understand the mechanisms that drive the phenomenon.

Most of the stations in the GoC showcase polarization directions of the fast shear-wave (S_{fast}) in a general WNW – ESE orientation (Fig. 2), in agreement with the direction of extension of the Gulf. The results are interpreted with the existence of microcracks, in accordance to the Extensive Dilatany Anisotropy (EDA) and the Anisotropic Poro-Elasticity (APE) models.

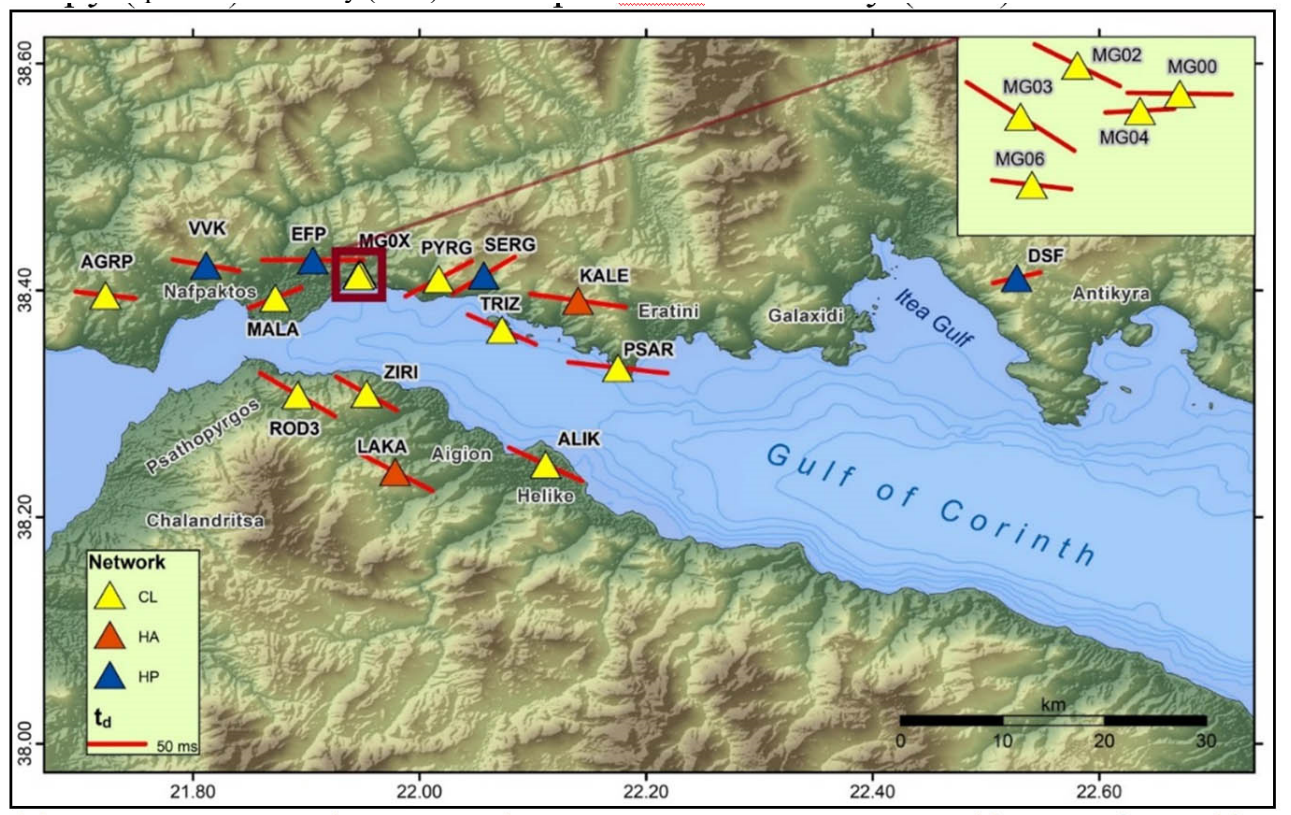


Figure 2: Map of the mean anisotropy direction in the WGoC. Stations are represented by triangles. Red lines indicate mean anisotropy directions and their length is proportional to the mean time-delay.

Ioannis Kassaras

Assistant Professor
National & Kapodistrian University of Athens
Department of Geology and Geoenvironment
Division of Geophysics-Geothermics

kassaras@geol.uoa.gr

Education

Secondary school in Athens, BSc in Geology at Dept. of Geology, National & Kapodistrian University of Athens (NKUA), PhD in Seismology at Dept. of Geology, National & Kapodistrian University of Athens

Career

July 2013 - today: Assistant Professor of Seismology, Dpt. Geophysics-Geothermics, NKUA.
January 2009 - July 2013: Lecturer of Seismology, Dpt. Geophysics-Geothermics, NKUA.
2003-2009: Laboratory Teaching Staff, Dpt. Geophysics-Geothermics, NKUA.
1995-2003: Research, Technical and Administrative Staff, Dpt. Geophysics-Geothermics, NKUA.
1993-1995: Research Fellow, Dpt. Geophysics-Geothermics, NKUA.
1991: Research Fellow at LGIT (Grenoble, France).
1989-1991: Research Fellow, Dpt. Geophysics-Geothermics, NKUA.

Research interests

Earthquake source properties
Seismotectonics and active deformation
Seismic structure of the Earth's interior, surface waves
Engineering seismology, microzonation
Seismic Risk analysis

Educational activities

Undergraduate courses
Seismology
Plate Tectonics, Seismology of Greece
Engineering Seismology
Earth structure
Postgraduate courses
Advanced Seismology
Signal processing
Data analysis
Supervision of MSc and PhD dissertations

Selected publications with educational purpose

1. Kassaras I. & Kazantzidou-Firtinidou D. 2017. "Earthquakes", Chapter in N. Dalezios (Ed), "Environmental Hazards Methodologies for Risk Assessment and Management", IWA Publishing, Water Intelligence Online, 16, doi: 10.2166/9781780407135.
2. Kassaras I. & Kapetanidis V., 2018. Resolving the tectonic stress by the inversion of earthquake focal mechanisms. Application in the region of Greece. A TUTORIAL, Chapter in: "Moment Tensor Solutions A Useful Tool for Seismotectonics", D'Amico, S. (Ed.), Springer Natural Hazards, ISBN 978-3-319-77359-9.

Deterministic seismic risk assessment with the use of stochastic simulation of strong ground motion taking into account site-effects and empirical vulnerability. A TUTORIAL. Case study the city of Aigion (W. Corinth Gulf)

Ioannis Kassaras
Department of Geophysics & Geothermics, National and Kapodistrian University of Athens

Earthquake hazards caused the most deadly natural disaster in the last two decades, resulting in over 800,000 deaths and 1.7 million injuries. The issue is particularly crucial nowadays, as manifested by extremely high losses during several recent seismic crises (i.e. Sumatra, 2004; Haiti, 2010; Christchurch, 2011; Japan, 2011; Nepal, 2015). Reason for this is in particular (a) the rapid urbanization of large parts of the population, resulting in growth of cities towards areas susceptible to earthquake hazards, (b) the economically driven reduction of the suburban construction behaviour, as largely viewed in less-developed countries, (c) the increasing exposure into technological hazards in the developed countries, i.e. nuclear power plants (as it happened in the Fukushima nuclear plant during the 2011 Japan earthquake).

Such disastrous earthquake phenomena have proven that the generic provisions of the seismic codes, underestimate the seismic hazard potential in earthquake prone areas, and so, crisis management planning is often unrealistic, thus ineffective. Remedy to this is the reconsideration of seismic codes on the basis of small-scale risk models taking into account the local seismic potential, the site's structural and societal vulnerability, and also site conditions. In other words, site-specific estimates are prerequisite towards a tailored seismic risk assessment that will guide through effective risk mitigation policies and disaster management measures.

During the last years, our working group has elaborated intense work on seismic risk assessment in several Greek cities, targeting site-specific models and allowing for tailor-made management actions in case of a crisis. We present the core and the outcome of the applied methodologies, indicating pros and cons, and highlighting future perspectives. Our approach includes: (a) Deterministic seismic hazard assessment based on the stochastic simulation of ground motion taking into account the areas' seismotectonics and site conditions. To this, new data concerning the location, geometry, and the seismic potential of faults, together with free-field ambient noise recordings have been collected through numerous field surveys; (b) Vulnerability assessment of elements at risk informed by newly created observed damage databases and in-situ observations; (c) Development of physical risk models including structural damage, and economic loss for several earthquake scenarios.

Case study

Our basic example is a scenario-based seismic risk assessment for the earthquake prone city of Aigion (W. Corinth Gulf). Within this approach, the stochastic finite-fault method is applied towards simulation of strong ground motion for three near-field earthquake scenarios, capable of occurring given the well-established seismotectonics of the area. The three scenarios are: (a) a repetition of the June 15th 1995 (M_w = 6.4) devastating earthquake, (b) a repetition of the December 26th 1861 historical earthquake of M_w = 6.7, and (c) an earthquake of M_w = 6.0 on the nearest Aigion Fault, underlying the city. The stochastic model parameterization is validated by comparisons with available recordings from permanent accelerometric stations. Site amplification is approximated by the use of ambient noise Horizontal-to-Vertical-Spectral-Ratios (HVSR) derived from in-situ free-field measurements in Aigion.

The structural exposure model of the city is developed on a building-by-building level through in-situ inspection, census data, and satellite navigation tools. The macroseismic method of RiskUE-LM1 is applied for the estimation of the structural vulnerability of 3216 inspected buildings in Aigion, based on the vulnerability classes per EMS-98 and semi-empirical indexes, accounting for the buildings' typology and structural characteristics.

Three scenarios of structural damage are presented on a building block scale, in terms of EMS-98 Damage Grades and their probability of occurrence. The obtained risk assessment indicates that the northeastern and partly the southern part of Aigion are more susceptible to damage, in accordance with the real damage distribution from the most recent devastating M6.4 1995 earthquake, the site amplification inferred from HVSR, and the macroseismic vulnerability of the constructions.

In conclusion, the current building stock of Aigion demonstrates significantly enhanced seismic behaviour compared to the pre 1995-era, due to rehabilitation after the 1995 earthquake, strengthening post-earthquake interventions to damaged buildings of 1995 and replacement of vulnerable ones with new constructions. Despite unavoidable uncertainties intrinsic to both the method and data, being open to future improvements, the inferred seismic risk assessment provided realistic and consistent results, thus allowing its exploitation towards loss evaluation and mitigation purposes for the city of Aigion.

Perspectives

Future improvements that fall in with, and/or are beyond the global state-of-the-art, include: (a) Implementation of technological capabilities of remote sensing towards buildings' inventory and vulnerability assessment; (b) Socioeconomic impact analyses towards the mitigation of risk, enhancement of preparedness and resilience of the social and economic fabric, and (c) Applications for near real-time damage assessment.

References

1. Giannaraki G. *et al*. 2018. Deterministic seismic risk assessment in the city of Aigion (W. Corinth Gulf, Greece) and juxtaposition with real damage due to the 1995 Mw6.4 earthquake, submitted to Bullet. Earth. Eng.
2. Giovinazzi S. and Lagomarsino S. 2004. A macroseismic method for the vulnerability assessment of buildings. In Proceedings of the 13th WCEE, Vancouver, Paper N° 896.
3. Grünthal G. (ed.) (1998). Cahiers du Centre Européen de Géodynamique et de Séismologie: 15, European Macroseismic Scale 1998, Europ. Center for Geodyn. & Seism., Luxembourg.
4. Kassaras I. *et al*., 2015. Seismic damage scenarios in Lefkas old town (W. Greece). Bulletin Earthquake Engineering. DOI: 10.1007/s10518-015-9789-z.
5. Kassaras I. & Kazantzidou-Firtinidou D. 2017. "Earthquakes", Chapter in N. Dalezios (Ed), "Environmental Hazards Methodologies for Risk Assessment and Management", IWA Publishing, Water Intelligence Online, 16, doi: 10.2166/9781780407135.
6. Milutinovic Z. & Trendafiloski G. 2003. An advanced approach to earthquake risk scenarios with applications to different European towns. ReportWP4: Vulnerability of Current Buildings, Risk-UE. E.C., Brussels, DOI: 10.1007/978-1-4020-3608-8_23.
7. Wyss M. & Rosset P. 2013. Mapping seismic risk: the current crisis, Nat. Hazards, DOI: 10.1007/s11069-012-0256-8.

Christian Beck

Emeritus Professor
Earth Sciences Institute (*ISTerre*), Savoie-Mont-Blanc University, and
Grenoble Universe Sciences Observatory (*OSUG*)

beck@univ-smb.fr,

Education

Master Sc. in Geology (1971, *Ecole Normale Supérieure de Saint-Cloud* and Pierre et Marie Curie University, Paris.), and *Agégation des Sciences de la Vie et de la Terre* (1972)
PhD (1975) and *Habilitation* (1985) (University of Lille)

Career

Assistant Professor (University of Lille, 1978-1987)
Professor (Savoie-Mont-Blanc University, 1988 to 2013)
Advisor in Ministry of Research and Higher Education (*M.E.S.R.-D.G.E.S.I.P.,* 2010-2013)

Research interests

C.B. focused his research on the sedimentary recording of tectonic processes at different space and time scales, for long term processes as well as for instantaneous events as earthquakes (based on field work, coring, high-resolution seismic imagery, and laboratory analyses). Since 1991, he is dedicating his work to recent paleoseismic sedimentary archives (lacustrine and marine) within integrated projects dedicated to major seismogenic active faults systems, developing sedimentological tools to characterize earthquakes and tsunamis imprints and provide long term archives for hazards estimation.
Main investigated areas are: south-eastern Caribbean Margin (Boconó-San Sebastian-El Pilar transform boundary and Lesser Antilles subduction), Sea of Marmara (North Anatolian Fault), Gulf of Corinth. C.B. participated to different International Oceanographic Surveys: Ocean Drilling Project, Leg 110 (Barbados Accretionary Complex) aboard R/V JOIDES RESOLUTION, Turkish/French MARMACORE and MARMARASCARPS projects. C.B.'s last cruise participations were dedicated to earthquakes and tsunami hazards assessment in Lesser Antilles forearc (GWADASEIS and CASEIS Cruises, 2009 and 2014). Besides, he designed and conducted lacustrine coring campaigns (Chile, French Alps, Venezuela, Albania). Within the frame of SISCOR Project (2011-2013) C.B. conducted two offshore surveys on the western Gulf of Corinth.

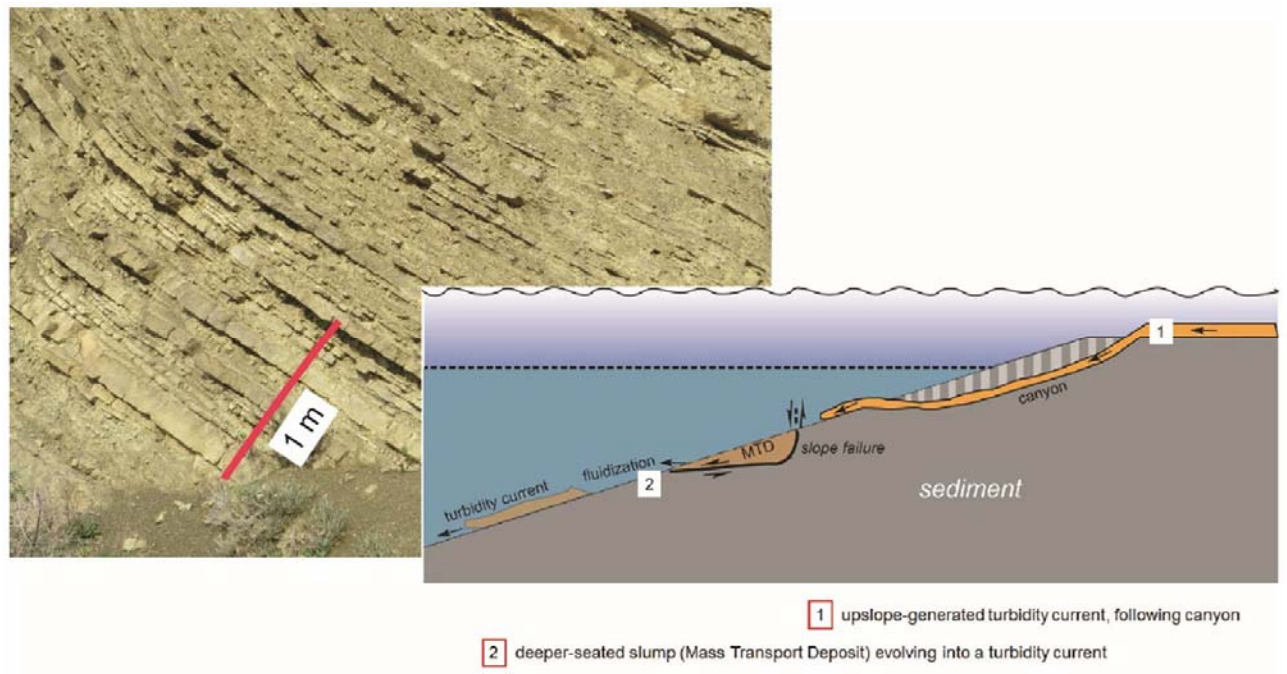
Selected publications

1. Beck, C., 2009. Late Quaternary lacustrine paleo-seismic archives in north-western Alps: Examples of earthquake-origin assessment of sedimentary disturbances. *Earth-Science Reviews*, 96:327–344.
2. Beck, C, et al., 2007. Late Quaternary co-seismic sedimentation in the Sea of Marmara's deep basins. *Sedimentary Geology*, 199:65–89.
3. Beck, C., 2012. Identification of deep subaqueous co-seismic scarps through specific coeval sedimentation in Lesser Antilles: implication for seismic hazard. *Natural Hazards and Earth System Sciences*, doi:10.5194/nhess-12-1-2012.
4. Chapron, E., Beck, C., et al., 1999. 1822 earthquake-triggered homogenite in Lake Le Bourget (NW Alps). *Terra Nova*, 11:86-92.
5. Campos, C., Beck, C., et al., 2013. Late Quaternary paleoseismic sedimentary archive from deep central Gulf of Corinth: time distribution of inferred earthquake-induced layers. *ANNALS OF GEOPHYSICS*, 56, 6, S0670:1-15; doi:10.4401/ag-6226.
6. Beckers, A., Beck, C., et al., 2016. Sedimentary impacts of recent moderate earthquakes from the shelves to the basin floor in the western Gulf of Corinth. *Marine Geology*, 384:81–102, doi.org/10.1016/j.margeo.2016.10.018

Field teaching: « Sedimentary chronometers: a short overview of a few rich outcrops near Nafpaktos" (1st group)

Christian Beck
Université de Savoie, France

Most of sedimentary accumulations (often looking monotonous!) display a rhythmicity involving two (or more) types of layers, a pattern which may correspond to an actual cyclicity. The time elapsed for the deposition of a single strata, or a repeated group of strata, may vary - for similar thicknesses - from few minutes to several hundred thousand years. The Mesozoic-Tertiary series of the Pindos Mountains (here along the northern edge of the Corinth Rift) offers outcrops illustrating two totally opposite sedimentary processes: 1) turbidity currents and 2) pure pelagic settling.



The first one will be observed and discussed in the so-called Tertiary "Pindos flysch" (close up: few meters of a 1500 m thick pile) which coarse layers represent turbidites, "instantaneous" deposits resulting from submarine landslides often triggered by seismic shocks. Detailed depositional mechanism will be discussed.
The second will be observed through Jurassic radiolarites (or radiolarian cherts) and Upper Cretaceous fine-grained thinly stratified limestones (calcareous mudstones). Both represent very low sedimentation (< 1mm/1000 yr) rate and their compositions are driven by paleoenvironmental conditions (clay supply, siliceous and calcareous plankton productions). Thus climatic cycles (orbital forcing, Milankovic cycles) and oceanic circulation changes may represent the driving factors of the stratification pattern. The time significance can be discussed following this interpretation.

Field Teaching "Paleomagnetic Sampling at sites near Aegion" (2nd group)

Massimo Mattei, Catherine Kissel, Francesca Cifelli and Carlo Laj

Among the outcrops suitable for paleomagnetic studies around the Gulf of Corinth, one will be chosen to show the participants how a paleomagnetic sampling is done for tectonic studies.
We will make a demonstration of how to drill a core of sufficient length to avoid the eventual surface weathering (i.e. risk of secondary magnetization). We'll then show how to orient a core and to measure the bedding plane in order to use these numbers to reconstruct in the geographic system the declination and inclination measured in the laboratory in the reference frame of the magnetometer. The drilling equipment will be available and after this short demonstration, each participant who volunteers will be able to drill a core, to orient it and to label it.

Figure 1: Paleomagnetic sampling and orientation

Francesca Cifelli

Associate Professor
Department of Science, Roma TRE University

francesca.cifelli@uniroma3.it

Education

1997	Master degree in Geological Sciences at La Sapienza University, Rome
1999-2003	Ph.D. in Geological Sciences at Roma TRE University, Rome
2003–2006	Post-doc at the Department of Geological Science, Roma TRE University

Carrer

2006-2015	Non-permanent researcher in Structural Geology at the Department of Geological Science, Roma TRE University
2015	Associate Professor at the Department of Geological Science, Roma TRE University

Research interests

Paleomagnetic rotations and structural evolution of curved mountain chains
Extension and dynamics of back-arc spreading in Mediterranean region
Recent tectonics in Central Iran
Seismic effects in urban areas
Science education and outreach

Teaching and educational activities

Teaching activity includes support in the first year classes and field assistance in structural geology classes
Tutor and co-tutor of Master thesis and PhD thesis
High-school teacher training activity
Italian responsible of Educational Committee of Education of the European Geosciences Union (EGU) for the organization of the GIFT (Geophysical Information for Teachers) workshops

Earthquakes in the classroom: the seismo-box educational kit

Francesca Cifelli
Roma TRE University, Department of Science

To prevent population against seismic risk, people must be aware **where** earthquakes take place, **when** earthquakes occur and **how** much is the released energy. The seismo-box (Fig. 1) has been projected with the main goal to answer these main questions.

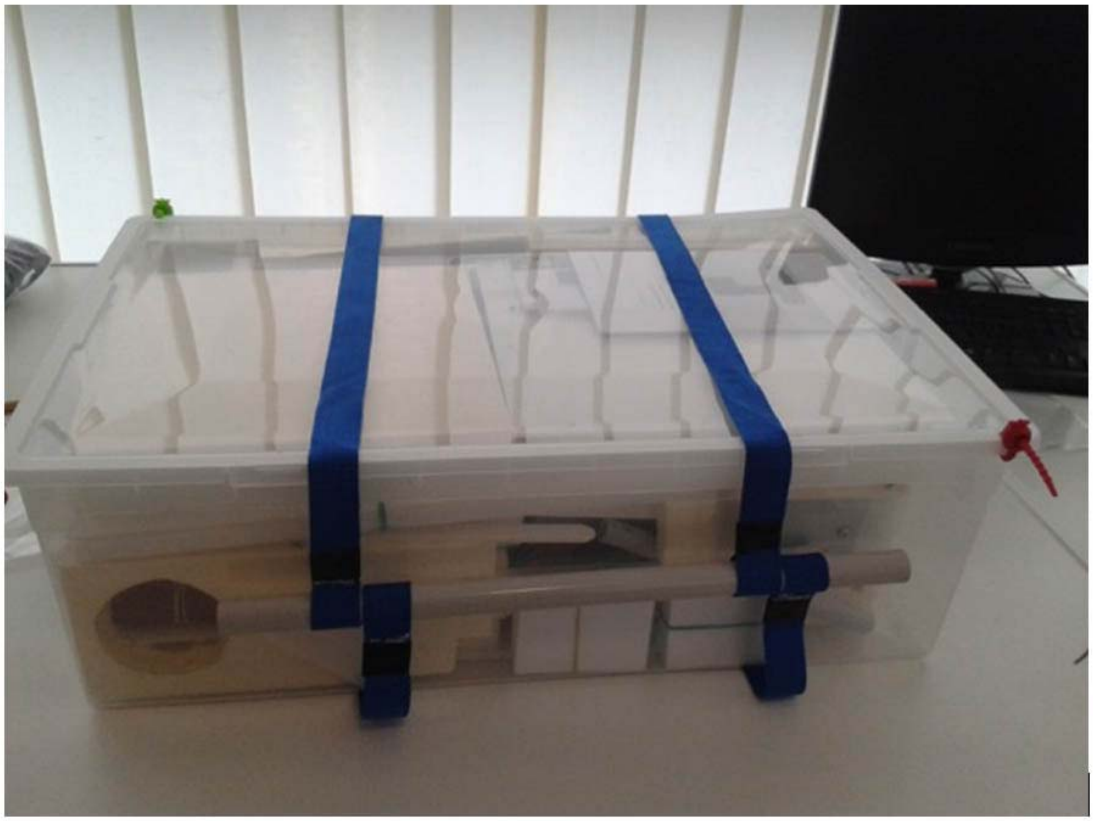


Figure 1: The educational kit seismo-box

Experiments that can be made with the seismo-box allow understanding some important aspects of earthquakes: what is the origin of an earthquake, how to record and locate it (Fig. 2), the impossibility to predict it (Fig. 3), and what its consequences on buildings are. Moreover, it is possible to better understand the difference between seismic hazard (that man cannot control) and seismic risk (that man can and must minimize).

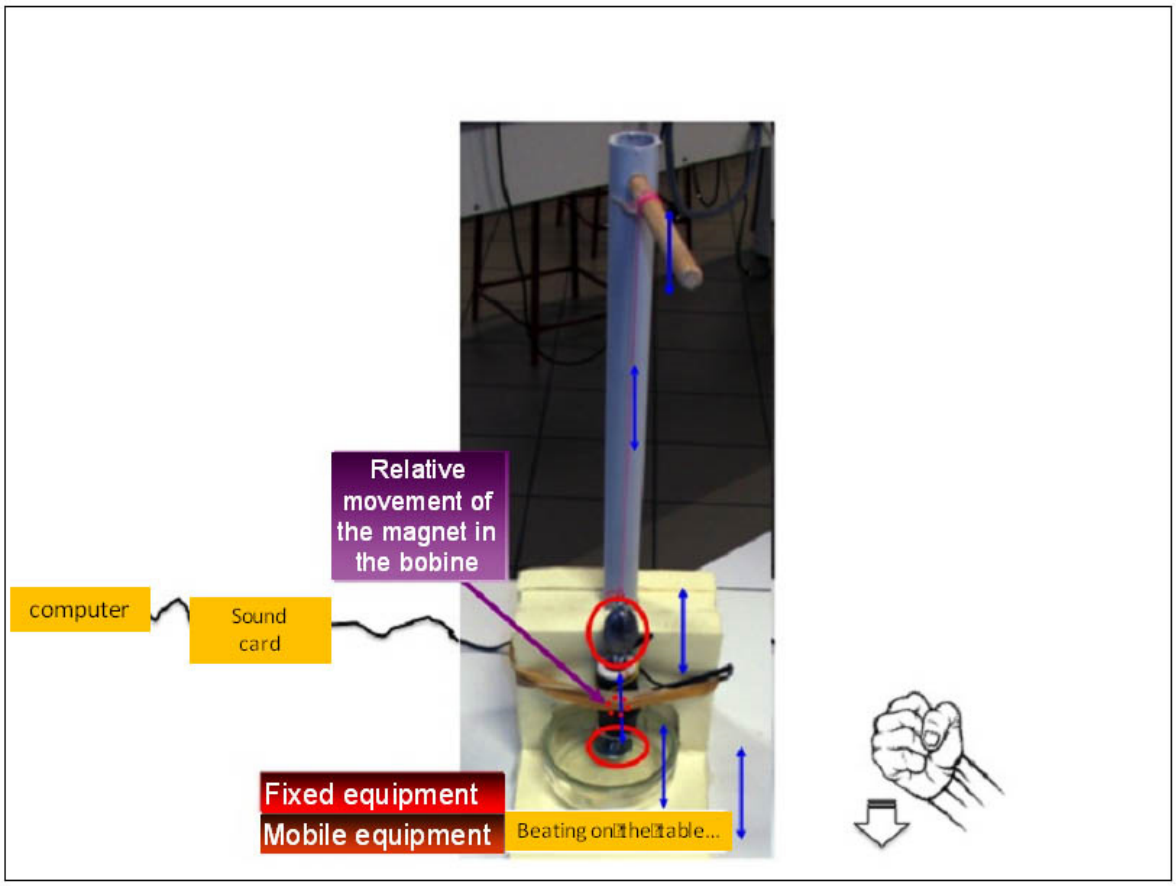


Figure 2: Recording an 'earthquake' using a hand-made seismometer.

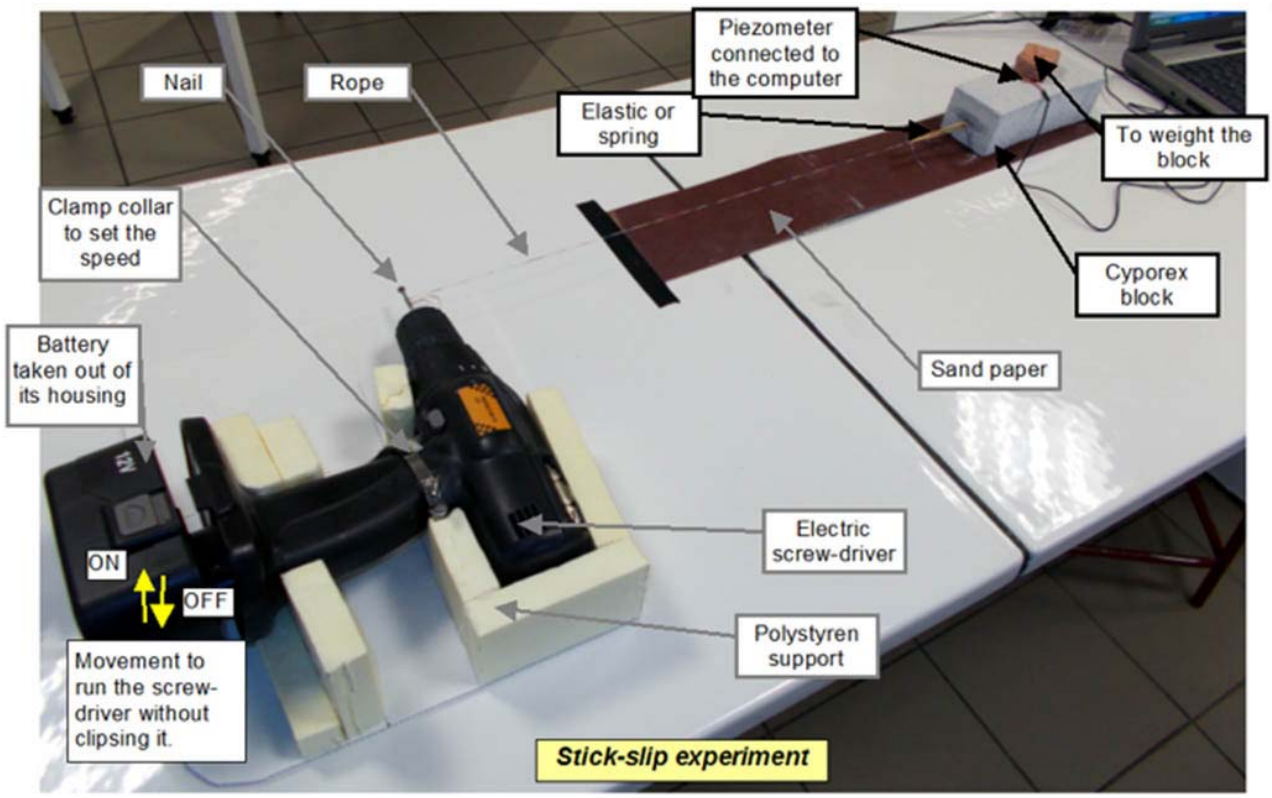


Figure 3: The stick-slip experiment to understand if it is possible to predict earthquakes.

This Seismo-box kit is made with very simple and cheap (and even recycled) materials. Among the most popular experiments possible with the seismo-box: the record of micro-earthquakes (Fig. 2), the simulation of vibrations on small buildings (Fig. 4), the liquefaction (Fig. 5) and the stick-slip experiments (Fig. 3).

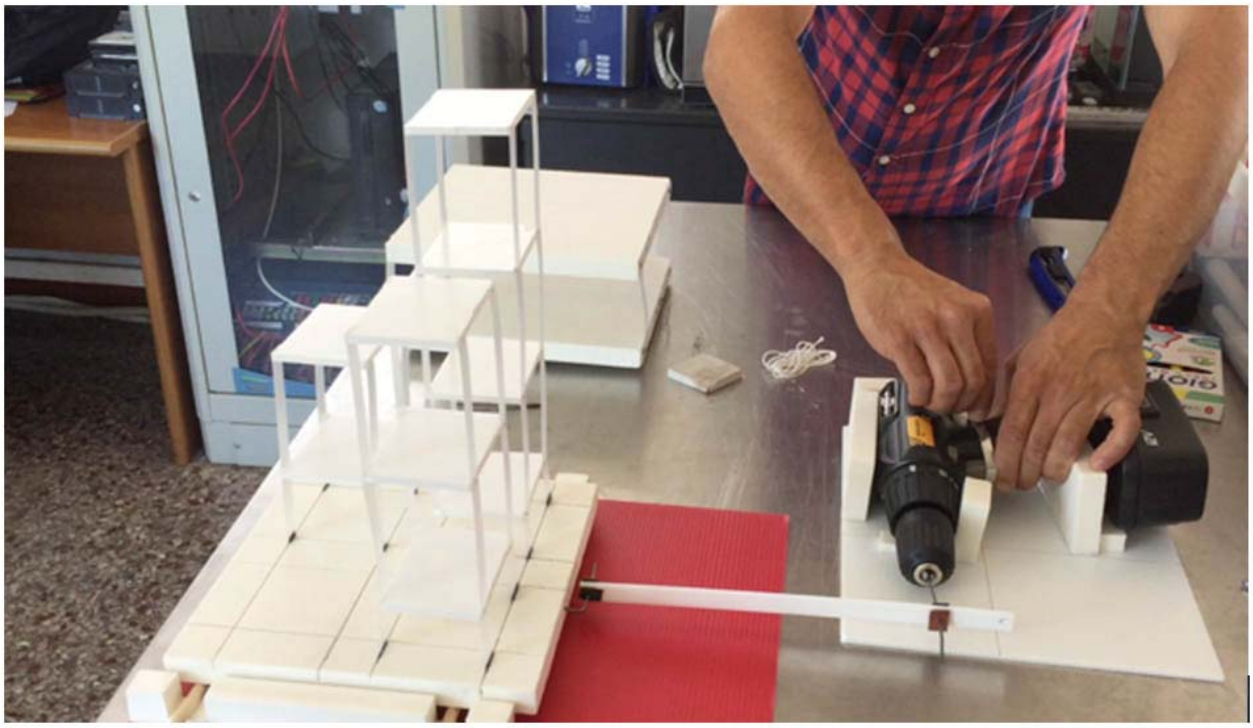


Figure 4: The resonance of buildings.

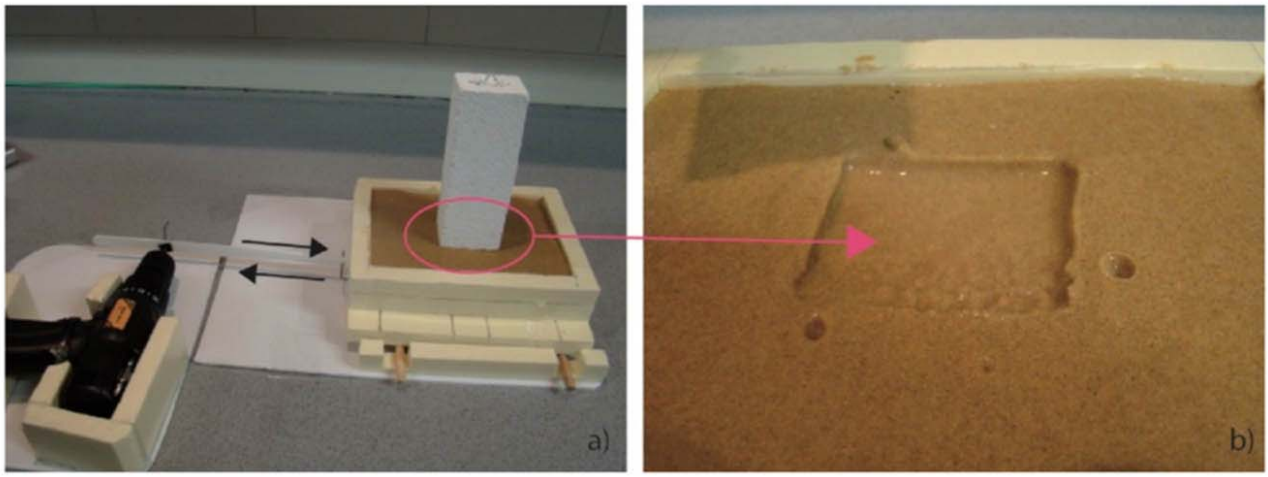


Figure 5: The ground liquefaction experiment.

Maria Geraga

Associate Professor,
Laboratory of Marine Geology and Physical Oceanography,
Department of Geology, University of Patras

mgeraga@upatras.gr

Education

2000	PhD in Oceanography, Department of Geology, University of Patras, Greece. Title of thesis: 'Evaluation of palaeoceanographic and palaeoclimatic changes during Holocene in SW Aegean Sea (Greece) and the formation of the sapropels''
1993	B. Sc. in Geology, University of Patras, Greece

Career

2015-today	Assistant Professor (permanent), Dept. of Geology, University of Patras, Greece
2012-2015	Assistant Professor (adjustment), Dept. of Geology, University of Patras, Greece.
2006-2012	Lecturer in "Archaeological Oceanography", Dept. of Geology, University of Patras, Greece
2000-2006	Under Appointed Ass. Professor in Polytechnics, in Chemical Oceanography. Higher Educational Technological Institute of Messolonghi, Greece.
1993-2006	Research Associate in the Laboratory of Marine Geology and Physical Oceanography, Dept. of Geology, University of Patras.

Research interests

Palaeoclimatology-Palaeoceanography, Marine sedimentology, Marine Geoarchaeology, Marine hazards, Marine natural and cultural heritage sites and Marine Pollution

Publications and services

36 papers in scientific journals of science citation index and peer reviewed International journals, 10 book chapters and Special Publications, over of 55 full-length papers in Proceedings of International and National Conferences and 50 abstracts. More than 800 citations with an h-index 15-18 (Scopus, Google scholar). Scientist in charge for several national and EU projects. Member of the Science Party of IODP Expedition 381 Corinth Rift. Member of the organizing committee of several national and international congresses. Supervisor of undergraduate and postgraduate dissertations and PhD dissertations.

Introductory presentation of the Cruise on board of the Research vessel

Maria Geraga
Laboratory of Marine Geology and Physical Oceanography, Geology Department, University of Patras, Greece

Acoustic is fundamental energy to the mapping of seafloor. Sophisticated equipment produces sound waves which radiate in all directions away from the source. When the sound waves moving through water hits the sea floor, some of it is reflected, some is transmitted to the seafloor, some is refracted, and some is scattered. The basic components of a sound wave are frequency, wavelength and amplitude.

Sound energy is used for the acquisition of seismic profiles and for the seafloor topography and texture. During the seismic profiling the transmitted acoustic energy is reflected from boundaries developed by changes in the acoustic impedance of the subsurface geology. Changes in acoustic impedance (density of the medium times the velocity of the sound within that medium) can generally be thought of as changes in density which indicate transitions from one stratigraphic layer to another. The sub-bottom profilers operate at different frequencies and this has an effect on the depth of acoustic penetration into the seabed and the resultant resolution. The reflected acoustic signal is received by hydrophones or by a transducer.

Sidescan sonar is an acoustic device used to provide wide-area, high-resolution 2D images (called "sonographs") of the seafloor. A towing sonar (usually called "tow-fish") emits and later receives the acoustic energy in a specific frequency range. The acoustic energy received by the sidescan-sonar (backscatter) provides information for the morphology of the seafloor and the texture of the sediments covering the seafloor.

During the field trip the students will get experience of modern seafloor surveying techniques. They will have the opportunity to collect subbottom profiling data sets by the operation of a high resolution Chirp sub bottom profiling system (Fig. 1a,c,d) and at the same time to collect side scan sonar data operating a EG&G 272 TD dual frequency (100 and 500 kHz) side scan sonar system (Fig. 1b,c,d). The field trip has been designed to survey areas from the western Gulf of Corinth covering the resent deltaic deposits of Mornos river (Fig.2). The acquired data sets will be processed by sophisticated software for interpretation.

Sources:

1. Fish, J.P. and H.A. Carr, 1991, Sound Underwater Images, A guide to the generation and interpretation of sidescan sonar data, second edition, Lower cape Publishing, Orleans, MA,
2. Trabant, P.K. Applied High-Resolution Geophysical Methods Offshore Geoengineering Hazards; D. Reidel Publishing Company: Boston, MA, USA, 1984; p. 265
3. http://www.oceanus.upatras.gr/

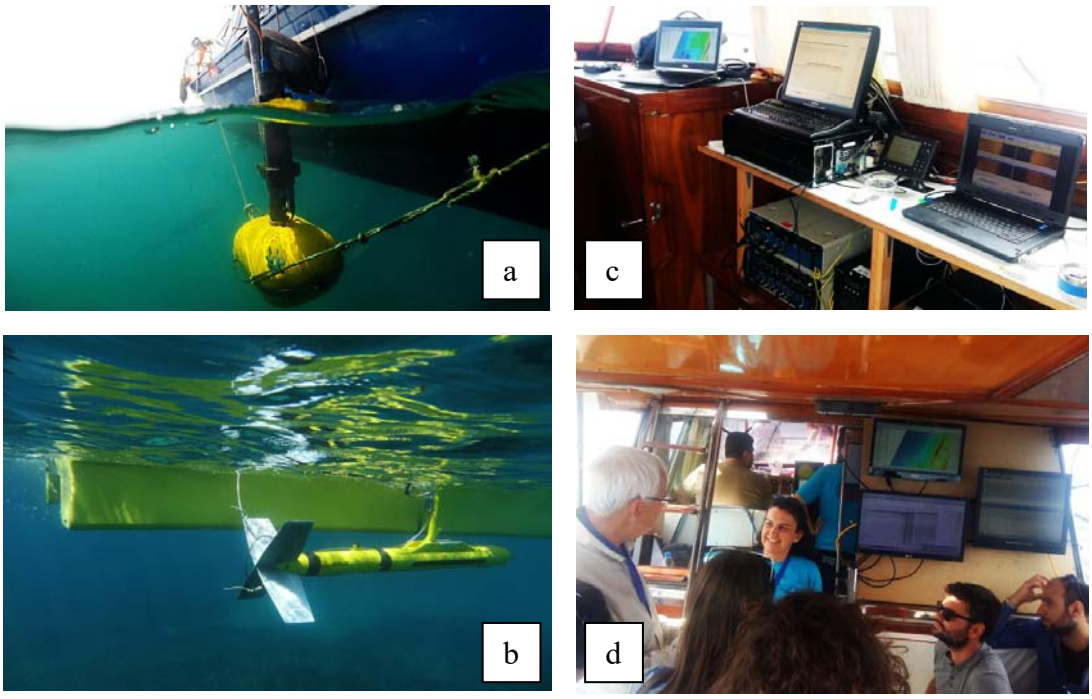


Figure 1: (a) High resolution Chirp subbottom profiling system, (b) Side scan sonar towfish, (c) and (d) data acquisition and display units.

Figure 2: Onboard during the CRL School 2017.

Anna Serpetsidaki

Teaching and Research Scientist
Seismological Laboratory, Geological Department,
University of Patras, Patras, Greece

annaserp@upatras.gr

Education

BSc Geology (1999), Geological Department, University of Patras, Greece
PhD Seismology (2004), Applied Geology and Geophysics, Geological Department, University of Patras, Greece
Postdoctoral Research (2005), Faculty of Mathematics and Physics, Department of Geophysics, Charles University of Prague, Czech Republic.

Career

2013 – today: Faculty Member of Geology Department, Patras University
2000 – 2013: Researcher, Seismological Laboratory of Patras University

Research Interests

Ground Response Analysis, Seismic Hazard, Seismic Source Properties, Moment Tensor, Microsesmic networks, Seismotectonics.

Publications and Services

1. **Serpetsidaki, A**., Sokos, E., Tselentis, G.-A. A ten year Moment Tensor database for Western Greece (2016) Physics and Chemistry of the Earth, 95, pp.2-9.
2. **Serpetsidaki, A**., Elias, P., Ilieva, M., Bernard, P., Briole, P., Deschamps, A., Lambotte, S., Lyon-Caen, H., Tselentis, G-A. & Sokos, E. (2014), New Constraints from Seismology and Geodesy on the Mw=6.4 2008 Movri (Greece) Earthquake. Evidence for a Growing Strike Slip Fault System. Geophysical Journal Intenational, 198 (3), pp. 1373-1386.
3. **Serpetsidaki, A.,** Verma, N. K., Tselentis, G. A., Martakis, N., Polychronopoulou, K., & Petrou, P. (2013). Seismotectonics of Lower Assam, Northeast India, Using the Data of a Dense Microseismic Network. Bulletin of the Seismological Society of America, 103(5), 2875-2883.

Presentation of the seismological laboratory

Anna Serpetsidaki
University of Patras – Laboratory of Seismology

The University of Patras Seismological Laboratory (UPSL), has a long history in seismicity monitoring in Western Greece, the area with the highest level of seismic activity in Europe. The Seismology Laboratory is focused in seismology research, i.e. source studies, microseismicity monitoring, seismotectonics, …The first network was installed in early 90's around the city of Patras and it was based on short period sensors with analogue telemetry. This network was monitoring the regions of Patras and western Corinth Gulf for a few years. Latter it evolved into a regional network of more than twenty stations covering the entire area of western Greece. The modern network is based on three component broad band sensors and real-time telemetry. Real time data are transmitted to central station in Patras University and then stored and processed both automatically and manually. Phase picks, locations and moment tensor solutions are stored and distributed to various centres and the EMSC. The network is part of the Hellenic Unified Seismic Network (HUSN) where real time broadband data are shared among the various seismological monitoring centres in Greece. The UPSL is a CRLNET member and has a productive cooperation with Charles University Prague and CNRS.

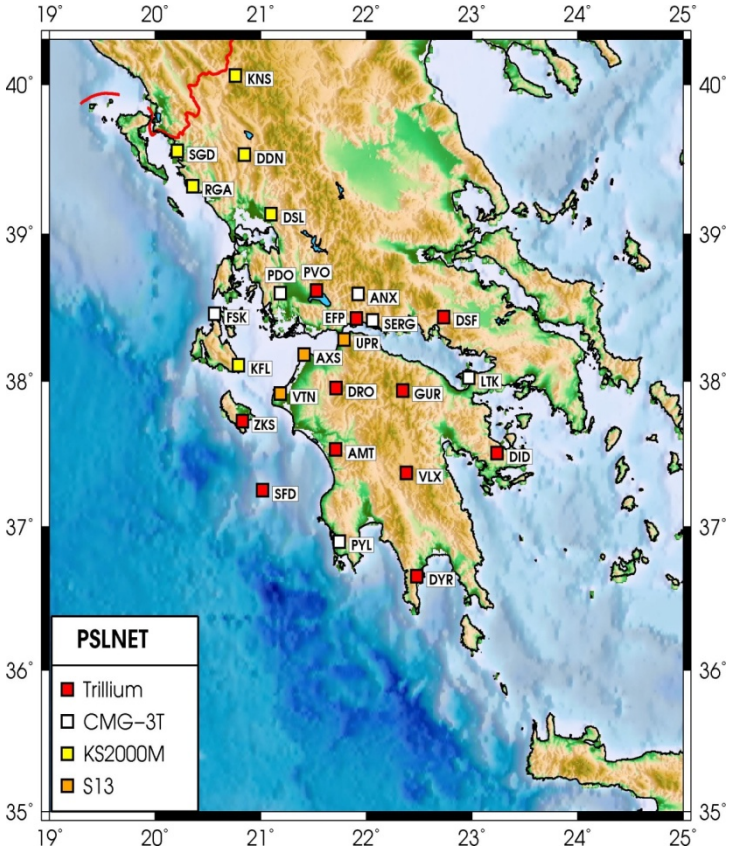


Figure: The PSLNET – Permanent Network of the Laboratory of Seismology of the University of Patras

The constant analysis of the PSLNET's data jointly with the cooperative network's data and the research of swarms and aftershock sequences provide a unique insight into the faulting characteristics of Western Greece and paves the way for detailed studies of stress tensor and stress transfer. Moreover, the study of the swarms and the calculation of weak events moment tensor can assist the comprehension of local seismotectonics and reveal the role of minor faults, which may be critical in seismic hazard.

Akis Panagis

Civil Engineer MSC University Patras
GEFYRA S.A.

akis.panagis@gefyra.gr

Education

2004 Diploma in Civil Engineering Department University of Patras
2006 Master in Seismic design of structures in Civil Engineering Department University of Patras

Career

2005-2006 Structural modelling and analysis of the lattice roof structure of the archaeological excavation in Akrotiri Santorini (In cooperation with the scientific committee appointed to investigate collapse mechanism) and evaluation of partial collapse mechanism upon dead loading.

2006-Present Structural Designer for various Industrial and residential Buildings composing of different structural system (Steel/Concrete/Timber).

2008-Present Monitoring engineer for Structural Dpt of Rion Antirrion Bridge, involved in the maintenance of Structural Health Monitoring system instrumentation, as well as with the data analysis and engineering interpretation of the records. Engaged with the structural design of Building and maintenance equipment for Rion Antirrion Bridge.

Areas of interest

Structural modelling, analysis and design of structures, Earthquake structural design, Modal Identification, Ambient structural vibration. Modal Operational Analysis. Sensor technology. Data acquisition. Data analysis Technics.

Structural Monitoring and Geometric control of the Rio-Antirrion Bridge

Akis Panagis
GEFYRA S.A.

This presentation focuses on the implementation of a complete monitoring scheme on the Rion-Antirrion Bridge that includes both permanent instrumentation, forming SHM system, and periodic Geometric control campaigns.

Initially, the main characteristics of RA Bridge are presented (multi-span cable-stayed bridge with a total deck length of 2,252m fully suspended from the pylons top) focusing on unique engineering features such as the shallow foundation of the main piers at 65m below sea level.

Consequently, the permanently installed SHM system, in terms of instrumentation & operation process is explained, as well as the regular analysis of collected data. Also, the methodology of Geometric control is discussed, as implemented during the last 14 years of operation.

Finally, two case studies regarding stay cable vibration and deck vortex shedding events are explained, demonstrating how the SHM system can be successfully integrated into the inspection and maintenance process of a significant infrastructure such as the Rion-Antirrion Bridge.

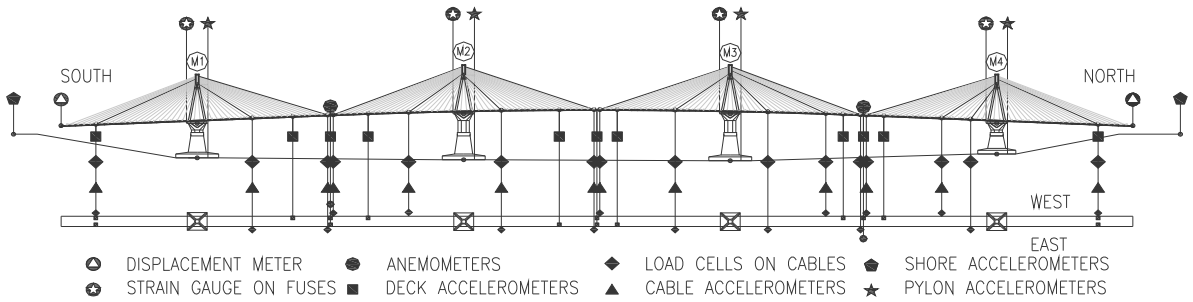


Figure 1: Rion Antirrion Bridge SHM Instrumentation

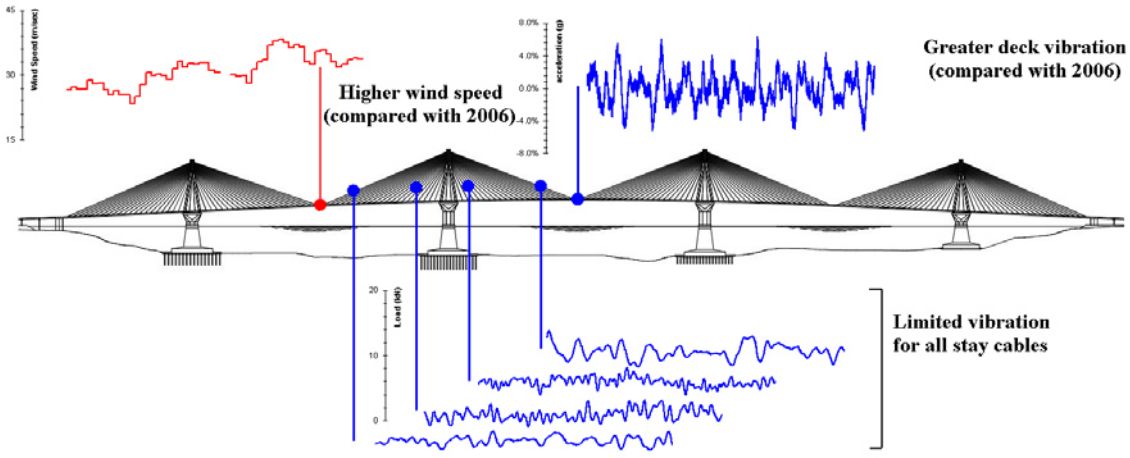


Figure 2: Structural response during MAR 2010 Storm

George Papatheodorou

Professor
Laboratory of Marine Geology and Physical Oceanography,
Department of Geology, University of Patras

gpapathe@upatras.gr

Education

1990	PhD in Oceanography, Department of Geology, University of Patras, Greece. Title of thesis: 'Recent sedimentation processes in the Gulf of Corinth'
1982	B. Sc. in Geology, University of Patras, Greece

Career

2013-today	Professor, Dept. of Geology, University of Patras, Greece
2009-2013	Assistant Professor (permanent), Dept. of Geology, University of Patras, Greece
2003-2009	Assistant Professor (adjustment), Dept. of Geology, University of Patras, Greece.
1999-2003	Lecturer in "Geological and Environmental Oceanography", Dept. of Geology, University of Patras, Greece
1995-2002	Under Appointed Lecturer in Department of Department of Ichthyology and Aquatic Environment, University of Thessaly.
1984-1999	Research Associate in the Laboratory of Marine Geology and Physical Oceanography, Dept. of Geology, University of Patras.

Research interests

Submarine gravitational mass movements, Seabed fluid flows, Marine Pollution, Marine hazards, Marine natural and cultural heritage sites

Publications and services

More than 100 articles in journals of Science Citation Index, peer reviewed scientific journals and chapters in scientific books and more than 100 publications in International Conferences in the field of Marine Sciences. More than 2000 citations with an h-index 24-30 (Scopus, Google scholar). Scientist in charge for several national and EU projects. Member of the organizing committee of several national and international congresses. Supervisor of undergraduate and postgraduate dissertations and PhD dissertations. He has served as chairman of the Geology Department (2013-2017) and he has elected Dean of the School of Natural Sciences of University of Patras (2018-2021).

Earthquake induced coastal submarine landslides. The case of the Disappearance of ancient Helike.

George Papatheodorou
Laboratory of Marine Geology and Physical Oceanography, Geology Department, University of Patras, Greece

The tectonically active Gulf of Corinth is known for the numerous submarine gravitative mass movements. Analysis and interpretation of high resolution 3.5-kHz and sparker profiles, together with side scan sonar imagery and sediment coring, revealed that the gravitational mass movements taking place are slides/slumps, debris/mud flows and turbidity flows (Fig. 1). According to the above-mentioned studies, the main mechanisms responsible for the observed mass movements include the frequent seismic activity in the region, the high sedimentation rates off the numerous river mouths, heavy rainfall and high seas, the steep slopes and the presence of gas-charged sediments. In addition, liquefaction of the alluvial fan deposits along the coastal zone (especially of the western Corinth Gulf) triggered by earthquakes is susceptible to sediment instabilities of the area. Gulf of Corinth is an ideal natural laboratory for studying submarine gravitative mass movements and a panorama of various types of movements will be presented (Fig. 2).
Moreover, the impact of a locally destructive earthquake of M= 6.2 R on 1995 at the underwater sediment failures in the western Corinth Gulf will be also presented (Fig. 3). The results of the above together with existing onshore multidisciplinary data sets will be applied to explain the disappearance of ancient Helike (373 B.C)(Fig. 4).

Sources

1. Beckers A., Hubert-Ferrari, A., Beck C., Papatheodorou G., de Batist M., Sakellariou D., Tripsanas E., and Demoulin A. (2018) Characteristics and frequency of large submarine landslides at the western tip of the Gulf of Corinth. Nat. Hazards Earth Syst. Sci., 18, 1411-1425.
2. Ferentinos G., Papatheodorou, G., Geraga M., Christodoulou D., Fakiris E., Iatrou, M., (2015): The Disappearance of Helike-Classical Greece—New Remote Sensing and Geological Evidence. Remote Sensing 7, 1263-1278; doi: 10.3390/rs70201263.
3. Papatheodorou G. and Ferentinos G. (1993): "Sedimentation processes and basin filling depositional architecture in an active assymetric graben, Strava Graben, Gulf of Corinth". Basin Research, vol. 5, pp. 235-253.
4. Papatheodorou, G., Ferentinos, G., 1997. Submarine and coastal sediment failure triggered by the 1995, Ms= 6.1R Aegion earthquake, Gulf of Corinth, Greece. Marine Geology 137, 287-304.
5. Hasiotis, T.; Papatheodorou, G.; Boukovalas, G.; Corbau, C.; Ferentinos, G. Earthquake-induced coastal sediment instabilities in the western Gulf of Corinth, Greece. Marine Geology 2002, 186, 319–355.

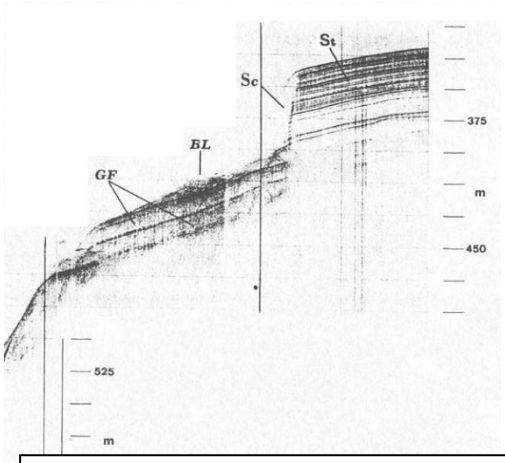


Figure 1: 3.5 kHz profile showing a slope instability feature and associated depositional pattern. St: turbidites, BL: block debris, GF: gravity flow deposits, Sc scarp (Papatheodorou and Ferentinos, 1993).

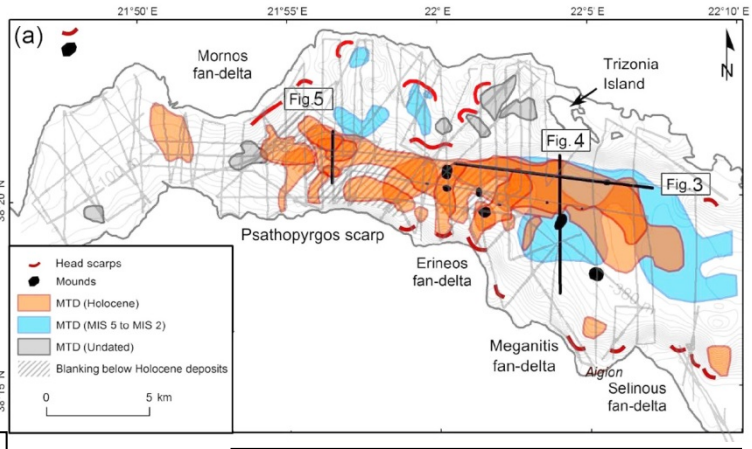
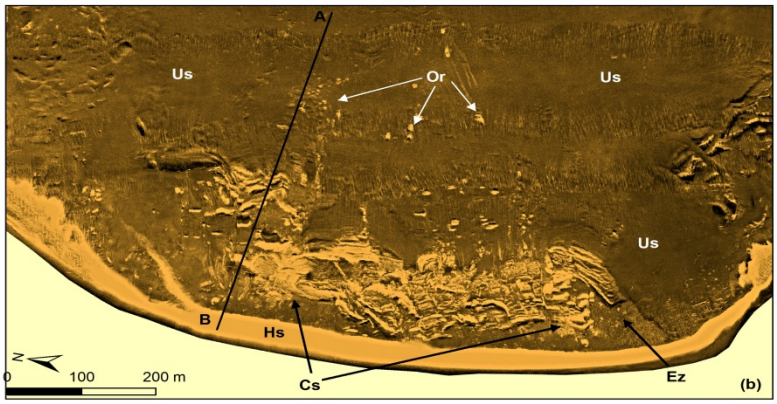


Figure 2: Inventory of gravitative mass deposits at the westernmost Gulf of Corinth for the last ca. 130 ka. (Beckers et al., 2018).



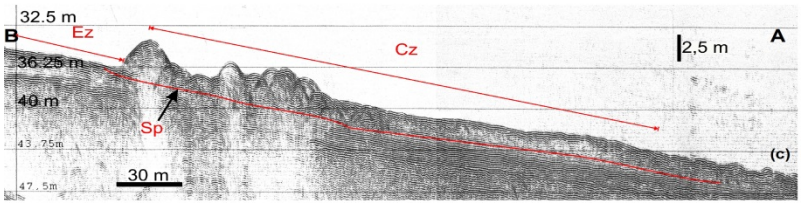


Figure 3: Side scan sonar mosaic and seismic profile showing the coastal landslide offshore Nikoleika. (Hs): Head scarp, (Ez): Evacuation zone, (Cz): compressional zone, (Or): out-runners, (Us): Undisturbed sediments, (Ez): Evacuation zone, (Cz): compressional zone, (Sp): Slip plane (Ferentinos et al., 2015).

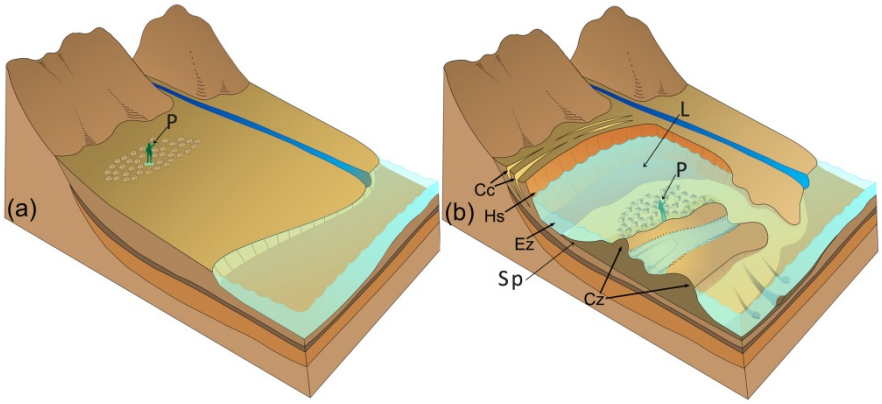
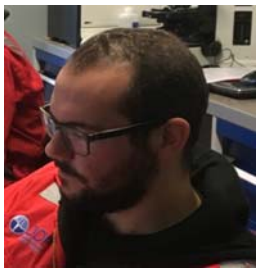


Figure 4: 3D landscape reconstruction of the delta plain where Helike was built before (a) and after (b) the translational slide which affected the surficial sediments and caused the destruction and submergence of Helike. (Cc): Crown cracks, (Hs): head of the slide, (Ez): evacuation zone, (Cz): compressional zone, (Sp): Slip plane and liquefaction horizon, (P): statue of Poseidon in upright position and (L): lagoon (Ferentinos et al., 2015).



Spyros Sergiou

PhD student
Laboratory of Marine Geology and Physical Oceanography,
Department of Geology, University of Patras

sergiou@upatras.gr

Education

2015-today PhD student. PhD thesis: ''Paleoceanographic and paleogeographic reconstruction of the southern Red Sea area during Upper-Late Quaternary''.

2015 MSc in Environmental Oceanography, Dep. of Geology, Univ. Patras. Title of MSc thesis: ''Recent sedimentary processes in the Western gulf of Corinth, Greece''. In co-operation with: University of Savoy (ISTerre - Insitut des Sciences de la Terre), France and University of Liege, Belgium.

2012 B. Sc. in Geology, University of Patras, Greece

Career

2014-today Research Associate in the Laboratory of Marine Geology and Physical Oceanography, Dept. of Geology, University of Patras

Research interests

Quaternary Sedimentology, palaeoclimatology, paleoceanography, sedimentary geochemistry-mineralogy, tectonics

Selected publications

1. Geraga M, Sergiou S, Sakellariou D, Rohing E, 2018 (in press). Results of micropalaeontological analyses on sediment core FA09 from the southern Red Sea continental shelf. In ''Geological Setting, Palaeoenvironment and Archaeology of the Red Sea'' Springer.
2. Sergiou S, Beckers A, Geraga M, Papatheodorou G, Iliopoulos I, Papaefthymiou H, 2017. ''Recent sedimentary processes in the western gulf of Corinth, Greece. Seismic and aseismic turbidites'' Bulletin of the Geological Society of Greece, 50, 383-391

Services

He is Assistant tutor for undergraduate and graduate courses, and BSc and MSc theses. He has participate in research & industrial projects. He is member in both offshore and onshore science parties of 'IODP Expedition 381- Corinth Active Rift Development'' serving as a sedimentologist.

Awards and honors

VISTA Visiting Scholar 2018. Department of Earth Science, University of Bergen, Norway.
PhD scholarship of General Secretariat for Research and Technology (GSRT) – Hellenic Foundation for Research and Innovation (HFRI).

Marine Sediments from the Corinth Gulf focused on turbidites and initial results of IODP 381

Spyros Sergiou
Laboratory of Marine Geology and Physical Oceanography, Geology Department, University of Patras, Greece

Initial results from the study of resent and old marine sedimentary deposits from the Corinth gulf will be presented. The resent sedimentary deposits will be focused on the study of two gravity cores selected from the western part of the Gulf and it will discuss the presence of the turbitic layers (Fig. 1). Turbitic layers are often deposits in the sedimentary sequences of the gulf and usually are attributed to earthquake activity. However, the comparison of their occurrence to historical palaeoseismological data suggests also an aseismic origin. The proximity of the studied coring sites to two major river fan deltas - these of Mornos and Erineos rivers- raises the enhanced river-discharging fluxes as additional origin for the turbitic events.
The old marine sedimentary deposits come from the initial results of the drilled sediments of the IODP 381 expedition (Fig. 2). The primary objectives of the expedition were to target a very recently forming active continental rift zone (the Corinth Rift, Central Greece) in order to a) obtain high spatial and temporal resolution records of the dynamics of the rifting process and its evolution, b) to study the interaction of climate and tectonics on sedimentary and surface processes in a rift zone, and c) to improve regional hazard assessments in one of the most seismically active regions of Europe. The Corinth Rift has been active < 5 Myr and has very high rates of extension, therefore it is unique in offering a chance to capture the detail of how rift faults and sedimentary basins develop. The expedition drilled, cored and logged at 3 sites along the rift. In total 1905 m of section were cored with 85% average recovery (1645 m recovered). Initial results from the offshore phase indicate that the cores hold an exciting and detailed record of how tectonics, climate and paleoenvironment have affected syn-rift basinal deposition.

Sources:

1. McNeill L., Shillington D., Carter G., Everest J., Green S., and the Expedition 381 Scientists, 2018. Preliminary results from IODP Expedition 381: Development of the active Corinth Rift, Greece. Geophysical Research Abstracts, Vol. 20, EGU2018-9231-1, 2018, EGU General Assembly 2018
2. Sergiou S., Becker A., Geraga M., Papatheodorou G., I. Iliopoulos and H. Papaefthymiou, 2016. Recent sedimentary processes in the western Gulf of Corinth, Greece: seismic and aseismic turbitides. Bulletin of the Geological Society of Greece, 50(1), 383-391. doi:http://dx.doi.org/10.12681/bgsg.11739.

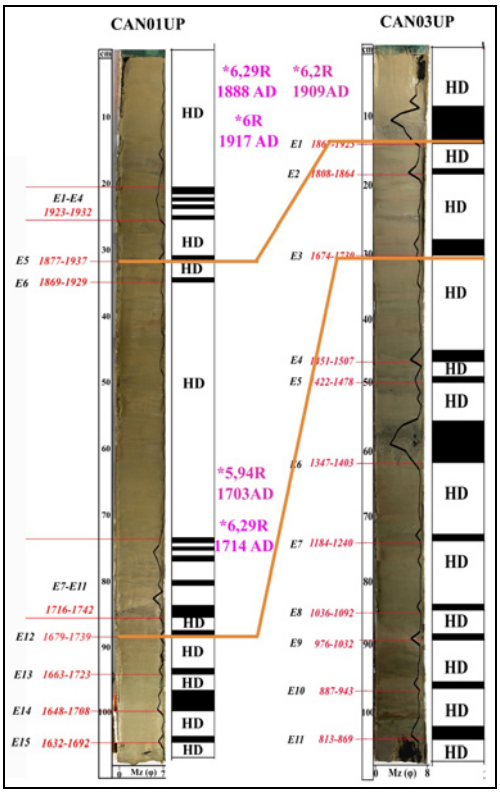


Figure 1: Age model, turbidite events (E), hemipelagic sediments (HD) and the two stratigrafically correlated turbidite horizons in two sediment cores collected from Western Gulf of Corinth (Sergiou et al., 2016).

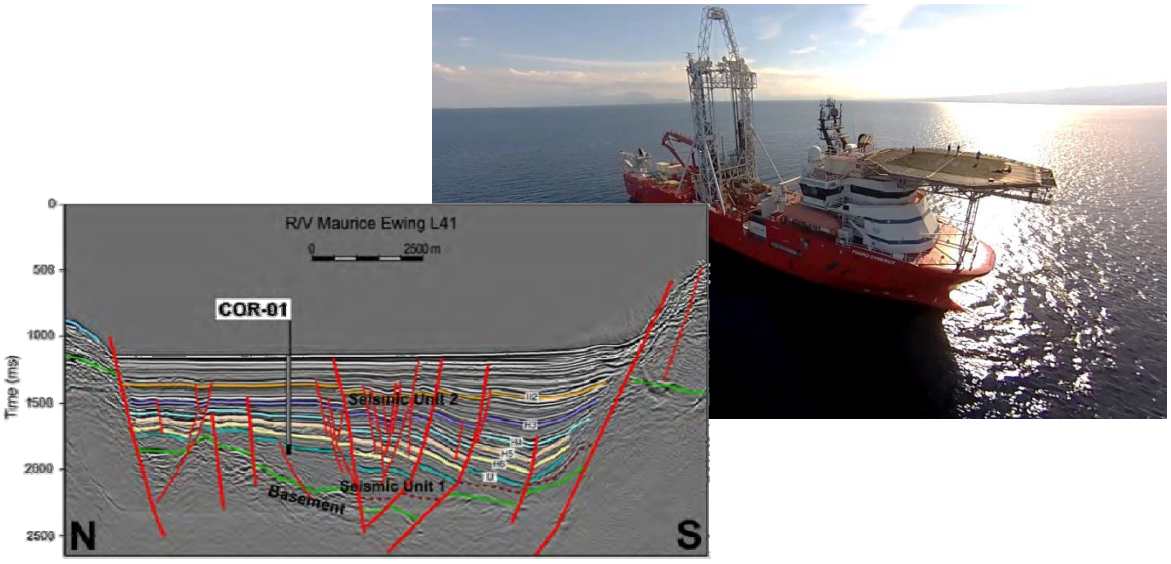


Figure 2: The IODP 381 expedition was operated as a Mission Specific Platform onboard the industry drilling vessel Fugro Synergy (up). Seismic profile from one drilled site, targeting the complete Seismic Units (down). (Source: http://www.ecord.org/expedition381/).

Athanassios Ganas

Research Director
National Observatory of Athens

aganas@noa.gr

Education

He holds a BSc degree in Geology from the National-Kapodistrian University of Athens (1986), an MSc in Structural Geology from Carleton University, Ottawa (1990) and a PhD in Geological Remote Sensing from the University of Reading, UK (1997).

Career

1997 - 2000 Image Analyst – Project Scientist, IIS SA, Athens
2000 - currently Researcher at the Institute of Geodynamics, National Observatory of Athens
In 2018 he was a Visiting Professor at the GNSS Research Centre of Wuhan University (China) and at the Department of Geosciences, École Normale Supérieure (Paris, France).
During 2007 he was a visiting scientist with USGS (Menlo Park, CA).
He has 1930 citations on the Google Scholar Index (h-index = 26).

Research interests

Active Tectonics and Remote Sensing / Geophysical Earth Observation including Fault Interaction, Tectonic Geomorphology and GNSS networks.

Publications and services

1. Ganas, A, et al, 2018. Coseismic Displacements from Moderate-Size Earthquakes Mapped by Sentinel-1 Differential Interferometry: The Case of February 2017 Gulpinar Earthquake Sequence (Biga Peninsula, Turkey). Remote Sens., 10, 1089, http://www.mdpi.com/2072-4292/10/7/1089
2. Ganas, A. et al. 2016. Coseismic deformation, field observations and seismic fault of the 17 November 2015 M = 6.5, Lefkada Island, Greece earthquake, Tectonophysics, 687, 210-222, http://dx.doi.org/10.1016/j.tecto.2016.08.012

Since May 2009 he serves as a Member of the Greek National Committee for Seismic Hazard Assessment. On March 2010 he was elected Member of the Executive Board of the Geological Society of Greece (position held until currently). He is the Editor-in-Chief of BGSG https://ejournals.epublishing.ekt.gr/index.php/geosociety . During 2010-2017 he served as regular member at the Board of Directors of the EPPO (Earthquake Planning and Protection Organisation, Greece). Since 2010 he is involved with the Geodetic Data group of the EPOS https://epos-ip.org/project

Awards and honors

In 2016 he received the best Geodesy paper of the Academy of Athens (with Kostas Chousianitis). In 1998 he received the Ktenas Prize from the Academy of Athens and in year 2002 he received the special prize of the Academy of Athens for his work on the Athens earthquake (together with S. Pavlides and G. Papadopoulos). In 2007 he won the Fulbright prize “Project Title: Earthquake recurrence and seismic hazard forecast along the Cascadian and Hellenic subduction zones”. In 2010 he was awarded the distinction «AGU Editors’ Citations for Excellence in Refereeing».

Field trip to the Helike fault

Led by Athanassios Ganas

The Helike fault is the most prominent high-angle, normal fault on the south side of the western Gulf of Corinth (Fig. 1). It is well visible in satellite images, air-photos, DEMs and it forms impressive footwall landscapes. Its seismic potential is M6.8 (Doutsos and Poulimenos, 1992) and its probabilistic rupture forecast for the next 30-yr is among the highest in this region of central Greece (Ganas et al., 2014). It is divided into two north-dipping segments with a right step near the exit of the gorge of the Kerynitis river (Koukouvelas et al 2001; Pavlides et al. 2004). The western fault segment bounds a thick sedimentary basin (a few hundred metres) and it has cut across incised streams, however the fault scarp is less pronounced. The eastern fault segment has a total length 24-26 km (20 km onshore and 4-6 km offshore). It ruptured on 26 December 1861 during the famous Helike earthquake that created surface breaks for 13 km (mapped from Julius Schmidt, then NOA Director) with a vertical displacement up to 1 m. Paleoseismological data showed that the eastern segment was activated three times during the last 2000 years, including that of the 1861 event. The event magnitude was estimated at M=6.7-6.8 and most probably they occurred sometime between 190BC-110AD the former, and around 600AD the latter. Based on the radiocarbon dating of the sediments the slip rate increased dramatically after a strong earthquake event near 1400BP. The faster slip rate evidently increased the sedimentation rate. The average slip rate on the fault over the past 2000 years is estimated at about 1.5 mm/year while the horizontal extension accommodated from this fault is about 1 mm/year. The field visit will focus on scarp morphology (Fig. 2; sketch by Koukouvelas and Papoulis), fault plane geometry and kinematics of one prominent site, to the west of Diakopto.

Figure 1: Field view of the eastern Heliki fault. Source: helikeproject.gr

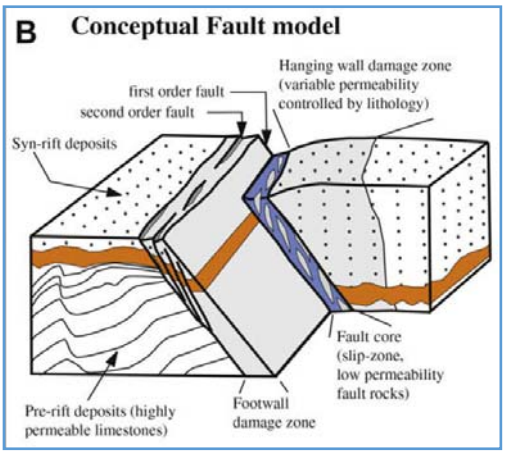


Figure 2: Fault scarp model of the Helike fault. Not to scale

References in text

1. Doutsos, T. and Poulimenos, G. 1992. Geometry and Kinematics of Active Faults and Their Seismotectonic Significance in the Western Corinth-Patras Rift (Greece). Structural Geology, 14, 689-699.
2. Ganas, A., T. Parsons, M. Segou, 2014. Fault-based Earthquake Rupture Forecasts for Western Gulf of Corinth, Greece. AGU 2014 Fall Meeting, 15-19 December 2014, San Francisco, CA, USA (abstract T13C-4666).
3. Koukouvelas, I., Stamatopoulos, L., Katsonopoulou, D. and Pavlides S. 2001. A palaeoseismological and geoarchaeological investigation of the Eliki fault, Gulf of Corinth, Greece, J. of Structural Geol. 23, 531-543.
4. Pavlides, S., Koukouvelas J., Kokkalas S., Stamatopoulos L., Keramydas D., Tsodoulos J. 2004. Late Holocene evolution of the east Eliki Fault, Gulf of Corinth, (central Greece). Quaternary Int. 115/116, 139-154.
5. https://en.wikipedia.org/wiki/Helike
6. https://en.wikipedia.org/wiki/Johann_Friedrich_Julius_Schmidt