

Proposal for the establishment of a Task Force of the International Lithosphere Program (ILP) for 2015-2020

The seismic cycle at continental transforms from seismological observation and forward simulation

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I. Introduction

During the 2010-2015 ILP funding period two independent task forces have generated substantial progress on the research foci ‘Bridging the gap from microseismicity to large earthquakes’ (Bohnhoff, ILP task force III) and ‘Numerical geomechanical modelling of processes in the lithosphere’ (Heidbach, ILP task force VII). The fact that both task forces are now coming to an end while great challenges lie ahead triggered discussion on how to best follow up the addressing the pending key questions. Here, we propose to continue both topics together and in a complementary way in the framework of a unified proposal for a new task force for the new ILP funding period 2015-2020.

Results from both, geomechanical modelling and experimental seismology towards a more profound understanding of the seismic cycle at transform faults were achieved by the proponents with a focus on the Marmara region addressing key topics related to the model of the seismic cycle. In the case of the Marmara region, a major ($M > 7$) earthquake is overdue in direct vicinity to the population center Istanbul and has to be considered as a major potential thread. Here we intent to contribute to research at the forefront within the here proposed task force.

II. Objective

Following up the recent works we here intent to contribute towards a better characterization of the kinematic setting of this key section of the North Anatolian Fault Zone (NAFZ). Given the recent activity on this topic the here proposed task force will not start from scratch but instead can build on extensive existing networks that were consolidated in the recent ILP period. In particular our networks involve key researchers from the involved disciplines such as experimental seismology, geomechanical modelling, fault-zone evolution, plate kinematics.

The following three key topics are to be addressed with the here proposed Task Force:

1. Improving and further refining existing kinematic models for the NAFZ in north-western Turkey based on world-class seismological waveform recordings from the recently implemented ICDP-GONAF downhole geophysical observatory (Prevedel et al., 2015). GONAF involves seven vertical geophone arrays surrounding the eastern Marmara seismic gap in 300 m deep borehole drilled on-land and on the Princess islands.
2. Refining simulation of stress and strain accumulation by means of forward 3D geomechanical-numerical models addressing key-questions such as a) What are the key ingredients for the next generation of numerical models that describe the complete stress tensor and its changes in space and time? b) Which is the most likely earthquake scenario for the seismic gap?, c) Is the central segment creeping or not?
3. Combine and integrate the scientific results from 1. and 2. towards a general model of the current setting of the Marmara seismic gap and its role in the current understanding of seismic cycles at transform faults worldwide. This is of particular relevance for improving our general understanding of geodynamic processes along strike-slip faults and –at least likewise important- its implications for seismic hazard assessment for nearby-located population centers.

IV. Outreach

In particular this Task Force will provide a platform and a network for young scientists to present and discuss their model concepts. Several PhD students are already involved in the previous studies leading to this proposal. The aim of the Task Force is to continue attracting young researchers as well as experienced experts that are willing to share their expertise in geomechanical modelling in order to jointly improve our knowledge of geodynamic processes.

V. Key partners within this planned task force

Within the here proposed task force we plan to closely collaborate with the following researchers and institutions all of which are already long-standing partners of the proponents: Dr. Hideo Aochi (BRGM, France), Prof. Dr. Zvi Ben-Avraham (University of Tel Aviv, Israel), Prof. Dr. Yehuda BenZion (University of Southern California, USA), Dr. Ulubay Ceken (AFAD/Disaster and Emergency Management Presidency, Ankara/Turkey), Prof. Dr. Georg Dresen (GFZ Potsdam, Germany), Dr. William L. Ellsworth (USGS Menlo Park, USA), Dr. Hisao Ito (JAMSTECT, Japan), Prof. Dr. Peter E. Malin (ASIR, USA), Dr. Dave Mencin (UNAVCO), Dr. Marcos Moreno (GFZ Potsdam, Germany), Sinan Özeren (ITU, Turkey) Prof. Dr. Mark D. Zoback

(Stanford University, USA).

VI. Recent key publications by the proponents:

- Prevedel., B., Bulut, F., Bohnhoff, M., Raub, C., Kartal, R.F., Alver, F., Malin, P.E. Downhole Geophysical Observatories: Best Installation Practices and a Case History from Turkey. *Int. J. Earth Sci (Geol Rundsch)*, doi: 10.1007/s00531-015-1147-5, 2015.
- Martinez-Garzon, P., Kwiatek, G., Sone, H., Bohnhoff, M., Dresen, G., Hartline, C. Spatio-temporal changes, faulting regimes and source parameters of induced seismicity: A case study from The Geysers geothermal field. *J. Geophys. Res.*, 10.1002/2014JB011385, 2014.
- Ickrath, M., Bohnhoff, M., Bulut, F., Dresen, G. Stress rotation and recovery in conjunction with the 1999 Izmit Mw7.4 earthquake. *Geophys. J. Int.*, doi: 10.1093/gji/ggt409, 2014.
- Martinez-Garzon, P., Bohnhoff, M., Zambrano-Narvaez, G., Chalaturnyk, R. Microseismic Monitoring of CO₂ Injection at the Penn West Pembina Cardium EOR Project, Canada. *Sensors*, 13, 11522-11538; doi:10.3390/s130911522, 2013.
- Bohnhoff, M., Bulut, F., Dresen, G., Malin, P.E., Eken, T., Aktar, M. An earthquake gap south of Istanbul. *Nature Commun.*, 4:1999, doi: 10.1038/ncomms2999, 2013.
- Hergert, T. and O. Heidbach, 2010, Slip-rate variability and distributed deformation in the Marmara Sea fault system, *Nature Geoscience* 3, 132-135, doi:10.1038/NGEO739.
- Moreno, M., C. Haberland, O. Oncken, A. Rietbrock, S. Angiboust and O. Heidbach, 2014, Locking of the Chile subduction zone controlled by fluid pressure before the 2010 earthquake, *Nature Geosciences*, doi:10.1038/ngeo2102.
- Hergert, T. and O. Heidbach, 2011, Geomechanical model of the Marmara Sea region - II. 3-D contemporary background stress field, *Geophys. J. Int.*, doi:10.1111/j.1365-246X.2011.04992.x, 1090-1102.
- Altmann, J.B., B. Müller, T. Müller, O. Heidbach, M. Tingay and A. Weißhardt, 2014, Pore pressure stress coupling in 3D and consequences for reservoir stress states and fault reactivation, *Geothermics*, 10.1016/j.geothermics.2014.01.004.
- Bedford, J., M. Moreno, J.C. Baez, D. Lange, F. Tilman, M. Rosenau, O. Heidbach, O. Oncken, I. Ryder, M. Bevis, M. Bartsch and C. Vigny, 2013, A high-resolution, time-variable afterslip model for the 2010 Maule Mw=8.8, Chile megathrust earthquake, *Earth Planet. Sci. Lett.* 383, doi: 10.1016/j.epsl.2013.09.020, 26-36.

Curriculum vitae Prof. Dr. Marco Bohnhoff

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Education and professional experience:

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|------------------|---|
| since Jun 2010 | Professor for 'Experimental and Borehole Seismology' at Freie Universität Berlin and Helmholtz-Centre GFZ Potsdam |
| Nov 2013 | Offer 'Chair of Geophysics' at Montanuniversität Leoben/AU (declined) |
| since April 2010 | Head of Helmholtz-University Young Investigators Group 'From Microseismicity to Large Earthquakes: Studies Related to Seismic Hazard Assessment, Carbon Sequestration and Sustainable Resource Management' at GFZ Potsdam and Freie Universität Berlin. |
| 2013-2015 | Spokesman of Think Tank at GFZ Potsdam (Zukunftskommission) |
| Mar-Jul 2013 | Temp. Head of GFZ-Section 3.2 'Geomechanics and Rheology' |
| 2007 - 2010 | Heisenberg-Fellowship of the German Research Foundation (DFG). |
| 2007 - 2009 | Visiting Scholar at Stanford University (host: Prof. M.D. Zoback). |
| May 2009 | Certified Manager (Malik Management Zentrum St. Gallen/CH) concluding the Helmholtz-Akademy, a two-year management training awarded by the Helmholtz-Association (www.helmholtz.de). |
| Jun 2006 | Venia Legendi (Adj. Professor) at Ruhr-Universität Bochum (RUB). |
| Feb 2006 | Habilitation (Dr. rer. nat. habil.) at RUB. |
| 2003-2007 | Research Scientist at GFZ Potsdam in Section 3.2 'Geomechanics and Rheology' (head: Prof. G. Dresen). |
| 2000-2003 | Assistent Professor (C1) at the Chair of Geophysics (Prof. H.P. Harjes) at RUB. |
| Jan 2000 | Ph.D. (Dr. rer. nat.) in Geophysics at Universität Hamburg (UH). Dissertation on 'Crustal structure of the Cretan region from wide angle seismic data' (supervisor: Prof. J. Makris). |
| 1997-2000 | Research Scientist at UH within the ICDP/KTB priority program of the German Research Foundation DFG. |
| Mar 1997 | Diploma in (M.Sc.) in Geophysics at UH. Master thesis on 'Crustal structure of the Iceland-Faeroe Ridge from wide angle seismic data'. |
| 1992-1997 | Studies of Geophysics at UH. |
| 1989-1992 | Job training (Berufsausbildung) as 'Energieanlagen-Elektroniker' with Bosch-Siemens Hausgeräte GmbH. Training shortened by 1 year. |

Curriculum vitae Adj. Prof. Dr. Oliver Heidbach

Current Positions: Senior Scientist, Helmholtz-Centre Potsdam
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Education & Training

Tertiary Education

HSC (Abitur) 1986, 1986 - 1995: Student of Geophysics and Meteorology at the Ludwig-Maximilians University of Munich, Germany and University of Reading, England.

Topic of the 'Diploma' thesis: *Modelling of crustal deformation in the Mediterranean with the finite element method*. Academic degree: Dipl.-Geophys. (Master of Geophysics)

Postgraduate education and degrees

2000 Dissertation at the Faculty of Physics of the Ludwig-Maximilians University of Munich; title of doctoral thesis: *The Mediterranean - 3D Numerical modelling of crustal deformation in comparison with results from satellite geodesy*; Academic degree: Dr. rer. nat. (Ph.D.)

2009 Habilitation at the Faculty of Physics of the University Karlsruhe, Germany; title of habilitation thesis: *Spatial and temporal variability of the contemporary crustal stress pattern of the Earth*; Academic degree: Dr. habil. (Adj. Prof.)

Previous appointments

- 1994-1995 Research assistant at the Institute of Geophysics, University Munich, Germany in the continental deep drilling project
- 1995-2000 Researcher at the German Geodetic Research Institute (DGFI) in Munich in the DFG projects *Mediterranean Geodynamics* and *Jordan Rift Dynamics*
- 2000-2003 Post-Doc at the Heidelberg Academy of Sciences and Humanities in the *World Stress Map Project*
- 2003-2008 Assistant Professor at the Geophysical Institute, Karlsruhe Universität, Germany
- since 2009 Senior Scientist at the GFZ German Research Centre for Geosciences, Germany
- since 2009 Adj. Professor at the University Karlsruhe, Germany (Priv.-Doz., Dr. habil.)
- since 2011 Head of the Research Group *Analysis and Modelling of Crustal Stress*

Responsibilities

Since 2009 head of the World Stress Map Project

2005-2014 chair of the International Lithosphere Program Task Force VII *Temporal and Spatial Changes of Stress and Strain*

2003-2008 Head of the *Tectonic Stress Group*, Geophysical Institute, Karlsruhe University,

2003-2008 Associate head of the World Stress Map Project

2003-2008 Coordinator of the sub-project *Geodynamics and Tectonic Stress A6* of the Collaborative Research Center 461 *Strong Earthquakes - A Challenge for Geosciences and Civil Engineering* at Karlsruhe University;

2004-2008 Leader of the project *Numerical stress field modelling of the Istanbul Region* of the CEDIM Megacities Project Istanbul