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Understanding the Co-evolution of Mountain Building and Seismic Hazard in Regions of Continental Convergence (Ref IAP-17-35)

Department of Earth Sciences, Durham University
In partnership with School of Engineering, Newcastle University

Supervisory Team	• **Dr Richard Walters, Durham University** • **Professor Mark Allen, Durham University** • **Professor Zhenhong Li, Newcastle University**

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Overview

The field of tectonic deformation between the Arabian and Eurasian plates is spatially complex, with seismicity localised in mountain belts surrounding several low strain-rate regions (Figure 1). Despite this complexity, recent work suggests that a simple dynamic model can explain 95% of the deformation field and also largely explains the distribution and style of earthquakes across the region (Walters et al., 2017). This model treats the lithosphere as a homogenous viscous fluid that deforms under the influence of external boundary forces and internal variation of gravitational potential energy.

However, this model is based on a relatively sparse set of GPS measurements of interseismic velocity, and the velocities of large areas are unconstrained by data. A denser and more precise field of velocity is required to test the limits of this model and resolve whether more complex configurations of rheology are required. A high-resolution velocity field could also be used to better assess the seismic hazard in Iran and surrounding regions. Both of these aims could be achieved using satellite radar (InSAR), and the recent launch of the European Space Agency's Sentinel-1 satellites have enabled the measurement of interseismic crustal velocity on the tectonic-plate scale and at spatial high-resolution.

In addition, whilst the dynamic model suggests that spatial variations in present-day crustal-thickness exercise a key control on the distribution of deformation and seismicity, it does not explain how these variations in crustal thickness developed in the past, and therefore how patterns of mountain-building, seismicity, and seismic hazard have changed since the initial collision between the Arabian and Eurasian plates. Published palaeo-altitude and paleomagnetic data from Iran (e.g. Cifelli et al., 2015) can help constrain the timing and extent of mountain-building and deformation throughout this interval.

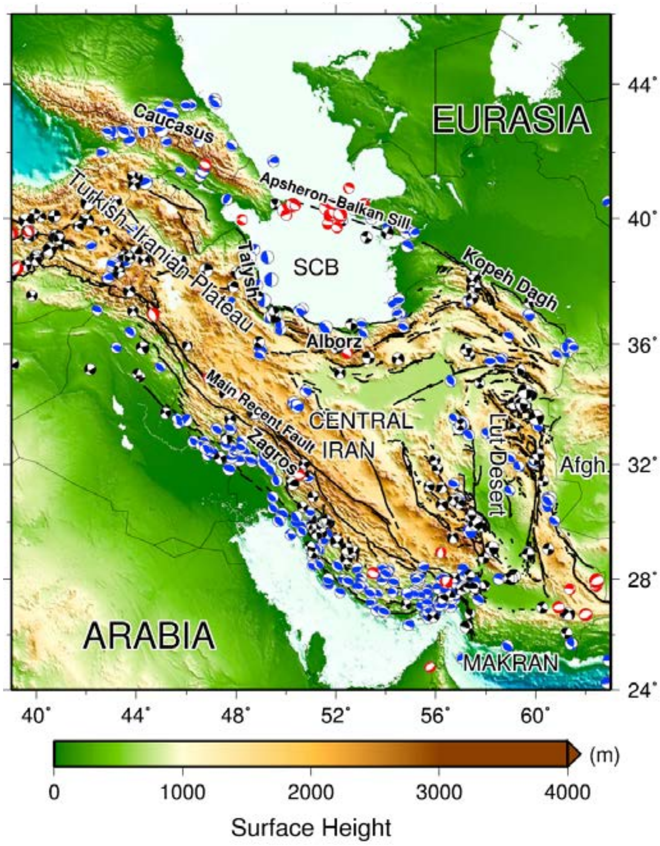

Figure 1: Shaded relief map of Iran showing active faults and seismicity from the Global Centroid Moment Tensor Catalog. Blue, black, and red focal mechanisms show thrust-, strike-slip-, and normal-faulting events, respectively

The main aims of this project are:

- to use satellite radar to estimate the distribution of present-day interseismic velocity and strain-rate across Iran and surrounding regions
- to use this high-resolution velocity field to test existing and develop new numerical models of present-day continental deformation
- to use palaeo-altitude and paleo-magnetic data to constrain numerical models of how continental plate-boundary zones evolve and develop, and predict how patterns of deformation and seismic hazard will change in future.

Methodology

Interferometric SAR (InSAR) will be used to map crustal interseismic velocity across Iran and surrounding regions by combining archived and new SAR observations from multiple satellite systems look directions. The small tectonic signal will be extracted by using advanced atmospheric correction techniques (e.g. GACOS, Yu et al., 2017) to mitigate sources of noise in the radar data. The UK Facility for Climate and Environmental Monitoring from Space (CEMS) at the International Space Innovation Centre (ISIC) has a direct pipeline to the Sentinel-1 processing and archive facility, based at Farnborough. Newcastle and Durham Universities are members of the Centre for the Observation and Modelling of Earthquakes, Volcanoes and Tectonics (COMET) and can exploit this unique resource for processing large volumes of Sentinel-1 SAR data.

The InSAR crustal velocities will then be used to constrain numerical models of continental deformation, run using the BASIL software package. BASIL will also be used to model the evolution of distribution of deformation in Iran, and these models will be compared to and constrained by published geological data.

This project also involves a collaboration with Prof. Greg Houseman, of the University of Leeds.

Timeline

Year 1: Training in space geodesy techniques, in particular the handling of satellite radar data. In parallel, training will be provided on programming skills. Processing of radar data across a portion of the study region, and analysis of initial results.

Year 2: Finish processing radar data across whole of study region. Training in use of BASIL for modelling continental deformation. Comparison of model results with updated InSAR velocity field. The work from Years 1 and 2 should lead to at least one publication in an international journal.

Year 3: Modelling of geological evolution of plate boundary zone with BASIL and comparison to published geological constraints. This work should lead to an additional publication.

Year 4 (6 months only): Focus on combining the published outputs and associated material into a PhD thesis.

Training & Skills

The student will receive training in space geodesy techniques, in particular the handling of satellite radar data, in modelling interseismic deformation, and in developing and running numerical simulations of continental deformation. Training in a wide range of essential skills (e.g. presentation skills, paper/thesis writing, and enterprise skills) important both for life as a PhD student and afterwards is provided by the Department of Earth Sciences at Durham University, and the student will also benefit from cross-disciplinary training provided as part of IAPETUS.
The student will become a member of the Centre for the Observation and Modelling of Earthquakes, Volcanoes and Tectonics (COMET) and she/he will therefore also benefit from the shared expertise of Geosciences staff in several universities, and will attend regular meetings where the research of these various groups is presented and discussed.
The student will have opportunities to work with other partners in the UK and internationally and they are encouraged to travel to national and international scientific meetings to present results. We aim to see all students publish at least two papers in leading scientific journals during their PhD. Upon completion, the student will be well equipped for a career in academia or in a range of industries.

References & Further Reading

Cifelli, F., Ballato, P., Alimohammadian, H., Sabouri, J. and Mattei, M., 2015. Tectonic magnetic lineation and oroclinal bending of the Alborz range: Implications on the Iran-Southern Caspian geodynamics. *Tectonics*, *34*(1), pp.116-132.

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Yu C, **Li Z**, Penna NT., 2017. Generic interferometric synthetic aperture radar atmospheric correction model, under review for Journal of Geophysical Research: Solid Earth.

Further Information

Please contact Dr Richard Walters
richard.walters@durham.ac.uk, +44 (0)1913 341727
https://www.dur.ac.uk/directory/profile/?id=14664