The origin, active tectonics and fate of the South Caspian Basin

Department of Earth Sciences, Durham University

Supervisory Team

- Jeroen van Hunen, Durham University
- Richard Walters, Durham University
- Mark Allen, Durham University

Key Words

1. South Caspian Basin
2. Hydrocarbon Exploration
3. Geodynamical modelling
4. Tectonics
5. Subduction initiation

Overview

The South Caspian Basin (SCB) is one of the world's deepest (>20 km sediments in places) and most productive hydrocarbon basins. Its basement has the geophysical properties of oceanic crust, but the age and origins of this crust are debated. Compression during Arabian-Eurasian collision formed fold-and-thrust belts which surround the relatively rigid SCB (Jackson et al., 2002; Allen et al., 2003). Rapid sedimentation since the Pliocene has been attributed to a combination of tectonic subsidence of the SCB and a significant sea level drop due to the Messinian Salinity Crisis. Seismicity patterns and GPS velocities indicate that the SCB moves in a ~northerly direction as a relatively rigid block with respect to Eurasia (Jackson et al., 2002; Walters et al., 2017). Regional compression has resulted in large thrusts surrounding almost the entire SCB. Its northern boundary appears to be developing into a new subduction zone, which may eventually destroy the basin.

While the hydrocarbon potential of the SCB has led to many extensive studies of its tectonics, several major first-order questions remain. The nature of the basin itself is unclear, and while it is mostly assumed that it is formed of oceanic lithosphere (with a thicker-than-usual oceanic crust), it could also be a high-density, relatively thin continental lithosphere (Egan et al., 2009). The cause of the tectonic subsidence is also unknown, and the relative roles of tectonic shortening (with flexural isostatic response to tectonic loading), density structures and of densification within the crust and lithosphere, and sediment loading are uncertain. Finally, while it is known that the overall motion of the SCB relative to its surroundings is to the north, there is major debate over whether this motion includes a significant rotational component. A better understanding of the regional tectonics will not only help to improve our understanding of the source rock maturation and migration of the SCB, but also those of other ultra-deep basins, like the Black Sea and the Barents Sea.

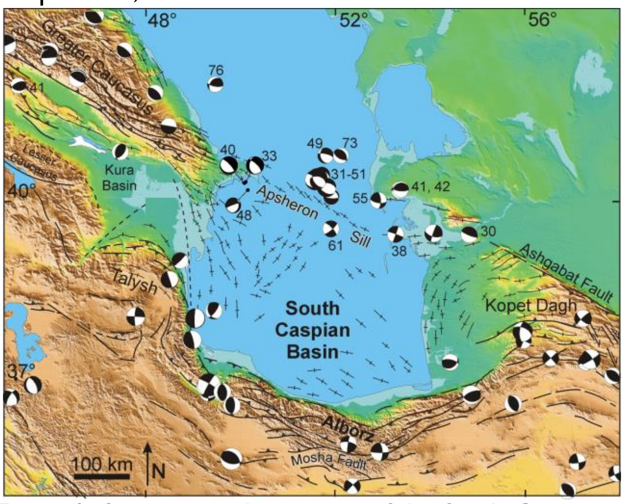

Figure 1: Structure and seismicity of the South Caspian Basin (from Allen et al., 2003)

The overall objective of this project is to understand the movement and deformation of the SCB and surrounding orogenic belts through 2D and 3D geodynamical modelling of the region. This can be sub-divided into the following project aims:

- To provide new constraints on the nature of the SCB basement, which has significant implications for hydrocarbon modelling of source rock maturation and migration
- To better constrain the characteristics of incipient subduction at the Apsheron Sill, at the northern margin of the basin.
- To better constrain the present-day motion of the SCB.
- Investigating the roles of tectonics and basin infill as underlying causes for basin subsidence: this will provide new insight into the hydrocarbon development of the region.

Methodology

The active kinematics of the area will be investigated using available regional seismicity and geodetic datasets (GPS & InSAR). Present-day crustal deformation will be assessed through analysis of existing earthquake catalogues and GPS velocities, and through generation of new crustal deformation fields with InSAR.

Geodynamical modelling will be done using the community code ASPECT, and has been applied to a wide variety of tectonic and geodynamical modeling projects. ASPECT uses cutting-edge numerical techniques for optimal performance, is very well documented, and is extensible to tailor for individual needs. The results of the geodynamic models will be compared to the kinematic observations of present-day deformation, and to geological constraints through the basin's history.

Timeline

Year 1) Training, model setup, and background literature study

Years 2+3) Analysis of existing and new observables (seismicity, subsidence, GPS and InSAR data); Integration and comparison of geodynamical models with these observables; publication of first key results

Year 4) Further publication of research outcomes and thesis completion

Training & Skills

The student will become part of a vibrant research culture in the department of Earth Sciences, in which ~80 PhD students work on a wide range of Earth Science research projects. In particular, the student will closely collaborate with the academic staff, postdoctoral researchers and fellows, and postgraduate students in the tectonics and geodynamics research groups.

Training will be provided in geodynamical modelling (programming, code development, model setup, and usage), as well as analysis of a variety of tectonic deformation datasets. The project is an opportunity for the student to become proficient in computer programming and large dataset analysis, with support from an enthusiastic ASPECT community. The code is open source with an importance placed on member participation in development (which is done in the open at https://github.com/geodynamics/aspect), allowing for worldwide collaboration and education (e.g., through Hackathons and public meetings). In addition, the student will receive training in general and transferable skills.

The student is expected to attend national and international conferences to disseminate research results.

References & Further Reading

Allen, M. B., Vincent, S. J., Alsop, I. G., Ismail-Zadeh, A. & Flecker, R. (2003). Late Cenozoic deformation in the South Caspian region: effects of a rigid basement block within a collision zone. *Tectonophysics*, 366, 223–239.

Egan, S. S., Mosar, J., Brunet, M.-F., Kangarli, T. (2009). Subsidence and uplift mechanisms within the South Caspian Basin: insights from the onshore and offshore Azerbaijan region. Geological Society, London, Special Publications, 312, 219-240.

Jackson, J., K. Priestley, M. Allen, and M. Berberian (2002), Active tectonics of the south Caspian basin, *Geophys. J. Int.*, 148, 214–245.

Walters, R. J., P. C. England, and G. A. Houseman (2017), Constraints from GPS measurements on the dynamics of the zone of convergence between Arabia and Eurasia, *J. Geophys. Res. Solid Earth*, 122, 1470–1495.

Further Information

For any information on the project, the tectonics or geodynamics research groups, the department of Earth Sciences or, more generally, matters related to doing a PhD in Durham, please feel free to contact Jeroen van Hunen (jeroen.van-hunen@durham.ac.uk).