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EVOLUTION OF THE SOUTH CASPIAN BASIN – EVIDENCE FROM OFFSHORE SEISMIC AND ONSHORE ACTIVE TECTONICS

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Summary. The South Caspian Basin is a deep-water basin containing one of the thickest accumulated sedimentary sequences on the Earth, with up to 25 km of sediments, overlying thin oceanic crust. To understand the nature of the South Caspian Basin we build model of the tectonic motion of the South Caspian Basin, an enigmatic aseismic "block" within the Arabia-Eurasia collision, which moves relative to both Iran and Eurasia. The model integrates subsurface interpretation in the Caspian Basin with active tectonics studies from outcrops. Understanding basin tectonics also has applied value as it helps to understand and potentially reduce earthquake hazards.

Introduction

The study combines geologic and geodetic studies, field-based and remote-sensing study of active faults, and the interpretation of offshore seismic reflection data in the central and southern Caspian to examine the timings and styles of deformation in its interior and along its margins. The results of study show that the presently active tectonics of the South Caspian began abruptly at 1.8 Ma ago. In the east and west, this onset involved a change from shortening to oblique lateral slip, and along the northern margin (the Absheron Ridge), it involved the oblique strike-slip and shortening reactivation of structures that had been quiescent since 6.0 Ma. The tectonic history of the South Caspian Basin (SCB) is hence one of northward subduction until 6.0 Ma, followed by rapid oroclinal bending and plateau growth in the ranges surrounding the basin until 1.8 Ma. At that time, the basin began to be expelled to the northwest, with underthrusting and incipient subduction beneath the Kura basin along its western margin. The various short-lived stages in the destruction of the South Caspian give insight into the late-stages of oceanic closure and the transition to continental collision.

Different styles in the offshore sector separate Caspian into several structural domains: Absheron domain of subduction tectonics, West Kura domain of strike-slip and deep basin interior (fast subsidence). We interpret the west Kura domain as linking northwards to onshore to lateral strike-slip faults within the Kura basin.

Method and / or theory

The South Caspian Basin (Fig. 1) is a deep-water basin containing one of the thickest and most rapidly accumulated sedimentary sequences on the Earth, with up to 20 km of sediment overlying an enigmatic basement of possible back-arc basin origin (Zonenshain and Le Pichon, 1986). SCB have been studied in detail using regional seismic reflection data and potential field and subsidence modelling (Abdullayev et al., 2017; Egan et al., 2009; Green et al., 2009).

Results and discussion

Over half of the sedimentary thickness has accumulated in the last 5.5 Ma, or less (Abdullayev et al, 2017), with many kilometers of clastic sediment (the Pliocene productive series) overlying mobile Miocene mudstones of the Oligo-Miocene Maykop formation. The interior of the basin is aseismic in the instrumental period, though active faults and earthquakes occur around the margins of the South Caspian, showing that the basin is moving relative to its surroundings.

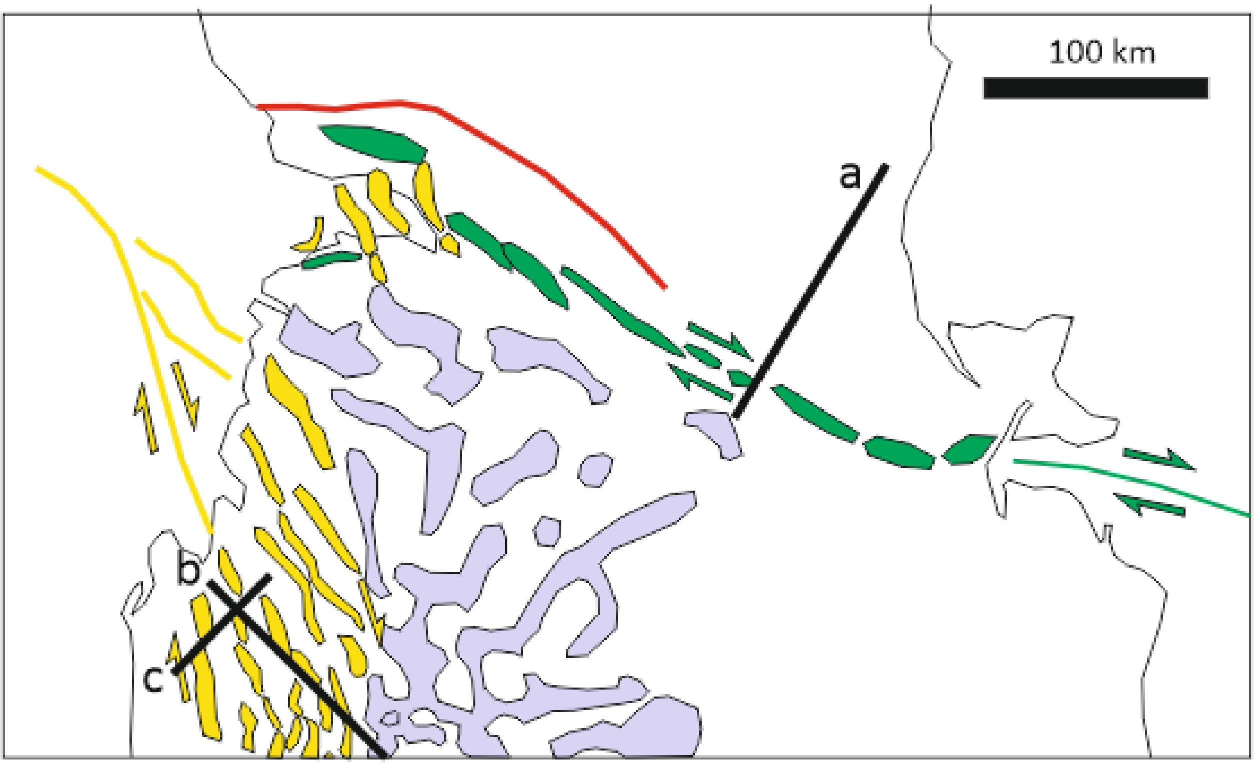

Fig. 1. Map of folds within the Absheron domain (green), West Kura domain (yellow) and deep basin interior (purple). We interpret the west Kura domain as linking northwards to onshore right-lateral strike-slip faults within the Kura basin. The Absheron domain links eastwards to the right-lateral Main Kopetdag strike-slip fault

Jackson et al. (2002) estimated the relative motion of the South Caspian Basin relative to both Eurasia and Iran by constructing a velocity triangle. Green et al., (2009), use a deep seismic reflection line across the central Caspian to show that the major shortening across the Absheron Ridge ended in the Miocene, ~6.0 Ma, and so does not correlate with the onset of rapid basin sediment accumulation. Ages constraining deposition of Productive Series have been summarized in Abdullayev et al. (2019) putting a boundary on deposition of Productive Series at somewhere between ~6.0 Ma to 4.0 Ma.

We studied relative plate movements and faulting in the eastern Caspian lowlands on the eastern shores of the Caspian. If the eastern Caspian lowlands move coherently with the South Caspian Basin, and are not internally deforming rapidly, it implies that the widespread east-west folding observed within the lowlands is no longer active. As these folds have formed due to north-south shortening, it is apparent that the currently active tectonics should have initiated after folding, and that the tectonic configuration has changed from one involving predominant shortening to one involving NNW expulsion of the South Caspian relative to its surroundings. The absence of deformation within the Caspian lowlands also implies that the sense and rate of motion across the Kopetdag should be consistent with the motion across the Absheron Ridge offshore, as they both accommodate relative motion between the South Caspian Basin and Eurasia.

From 1.8 Ma we see a rapid onset of the present tectonic phase, with transpressional faults in the east cutting through the older folded terranes, and the development of new north-south transpressional systems within the Kura basin.

The identification and mapping of major strike-slip faults accommodating relative motion between the South Caspian Basin and its surroundings has an applied interest, as these faults constitute a large seismic hazard both to population centers and to infrastructure, including gas production facilities in the offshore, pipeline crossings, and terminals.

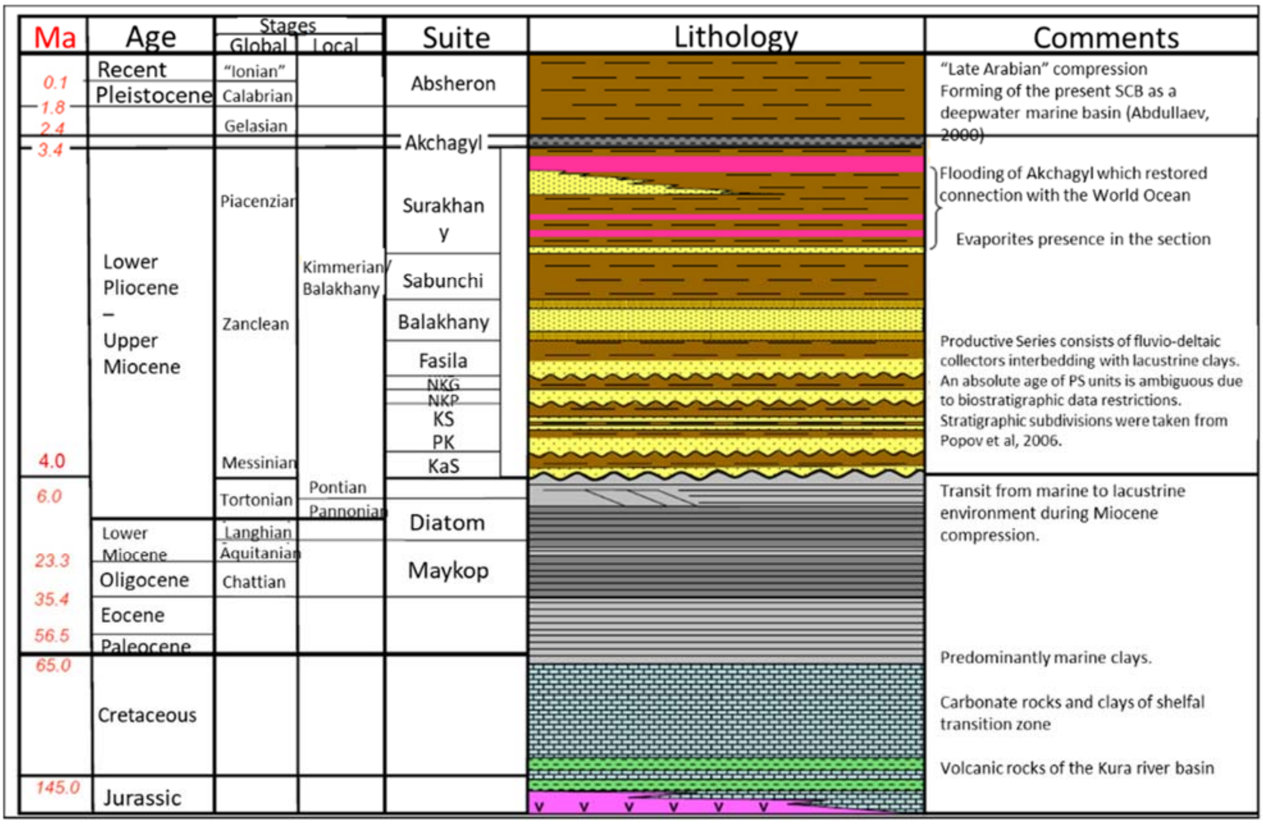

Fig. 2. Stratigraphic and structural event chart of the South Caspian highlighting ages discussed. Rapid oroclinal bending (6-4Ma), initial subduction (pre 6.0 Ma) and formation of modern anticinal trends (after 1.8 Ma). Dates are obtained from Abdullayev et al. (2017)

Conclusions

The study has revealed several domains of folding and faulting within the South Caspian that are likely related to "thick skinned" faulting, based on their wavelength and asymmetry, as opposed to the thin-skinned deformation observed in the deeper basin, which is more likely related to movement within the mobile Maykop deposits. The thick-skinned structures of the Absheron Ridge in the central Caspian started to grow at 1.8 Ma and are related to onset of the present-day tectonic regime. The structures in the proximal offshore Kura domain are interpreted as the result of strike-slip deformation that can be traced onshore to structures that display prominent right-lateral displacement in Holocene age deposits. The anticlines started to form at 1.8 Ma with the folding and then replaced by faulting that continues to the present-day. Altogether, observations from seismic reflection data suggest an onset of strike-slip tectonics along both the Absheron Ridge and in the Kura basin at 1.8 Ma. Shortening along the western margin of the basin has been occurring for the last 3.8 Ma. Along the Absheron Ridge the presently active faulting followed from a period of tectonic inactivity that began at 6.0 Ma. Prior to 6.0 Ma there, was intense south-vergeant folding and thrusting within the central Caspian, likely related to northward subduction of the basement of the South Caspian basement under Absheron Ridge.

Our results refine our understanding of the present-day kinematics of the South Caspian Basin, and of the factors that may have helped cause an evolution in the tectonic configuration through time. The initial phase of shortening lasted until 6.0 Ma, when subduction of the South Caspian basement stalled and there was a "quiet period related to Low Pliocene Productive Series.

The stalling of subduction in the central Caspian at 6.0 Ma was followed by a period of rapid oroclinal bending (6-4 Ma) with thewestern and eastern parts of the Alborz mountains rotating respectively clockwise and anticlockwise around the southern margins of the South Caspian, and with clockwise rotation of the Kopetdag and Binalud ranges. It is likely that continued mountain building along the southern margins of the Caspian during this time would have led to basement involved shortening at the basin margins, which we see in the offshore Kura basin from 3.8 Ma, and in the fold and thrust belts of the Kopetdag in Turkmenistan.

REFERENCES

Abdullayev N.R. Guliyev I.S., Kadirov F.A. Subsidence history and basin-fill evolution in the South Caspian Basin from geophysical mapping, flexural backstripping, forward lithospheric modelling and gravity modeling. In: Brunet, M.-F., McCann, T. and Sobel, E. R. (Eds), Geological Evolution of Central Asian Basins and the Western Tien Shan Range. Geol. Soc. Lond., Spec. Publ., № 427, 2017, pp. 175-196.

Egan S., Mosar J., Brunet M-F., Bochud M., Kangarli T. Subsidence and Uplift Mechanisms within the South Caspian Basin: Insights from the Onshore and Offshore Azerbaijan Region. Geological Society, London, Special Publications, Vol. 312, 2009, pp. 219-240.

Green T.N., N.R.Abdullayev, J.Hossack et al. Sedimentation and subsidence in the South Caspian Basin, Azerbaijan. In: Brunet, Wilmsen, Granath eds. South Caspian to Central Iran Basins. Geological Society, London: Special Publication, Vol. 312, 2009, pp. 241-260.

Jackson J., Priestley K., Allen M., Berberian M. Active tectonics of the South Caspian Basin. J. Geophys. Int., Vol. 148, 2002, pp. 214-245.

Zonenshain L.P., Pichon X. Deep basins of the black sea and Caspian Sea as remnants of Mesozoic back arc basins. Tectonophysics, Vol. 123, 1986, pp. 181-211.