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Structural analogies and homologues of the West Mediterranean and circum-Black Sea regions tectonic tailoring: Re-evaluating the uniform tectonic development model

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SUMMARY

An analysis of comparative tectonic evolution of two entailing regions of the Alpine belt - Black Sea and Western Mediterranean - reveals profound analogies and homologues in their structure and development. Though both back-arc basins under comparison have many distinctions and differ each from other due to their linear dimensions (nearly twofold), a certain time shift for the lithological spectra during some epochs, present state of volcanic activity etc., they, nevertheless, reveal a striking morphological coincidence and notable genetic analogy in their spatial, kinematic, undercrustal, palaeogeographic, and other features.

The above comparison allows consideration of the circum-Black Sea region as a minor and simplified tectonic copy of the Western Mediterranean area being evolved in similar way and caused by similar tailoring of its structural units that stipulated by uniform stress/fault pattern inherited from the Meso-Tethys tectonic realm demonstrating kind of self-similarity or crustal scaling effect. Two prominent mega-sutures, the Teisseyre-Tornquist Zone and South Armorican Shear zone, represent axial alignments along which a distorted symmetry could be traced for both basins under comparison. The above similarities can help elaborate new trends for oil and gas exploration in the circum-Black Sea basin using geological knowledge on the Western Mediterranean and vice versa.

Introduction

Twenty years passed from the first publication of this hypothesis speculating about very similar style and tectonic development of these two related tectonic domains – greater one, composite super-basin and smaller and subordinate one in the Alpine belt (Kitchka, 1999). Nowadays, some correlations were discarded as doubtful ones but the core elements of comparison have received much stronger support with advance of new data.

The idea of historical likeness for geological evolution of the Western Mediterranean and Black Sea was pointed out for the first time 36 years ago (Khain, 1984) and based mostly on basin-to-basin perspicacious generalizations issuing from the analysis of subsidence rates, and now it looks more reliable thanks to modern exploration data – mostly from marine geophysics – to reconsider existing tectonic models for the Black Sea evolution from the standpoint of their compliance with the Mediterranean counterparts. Although both regions are immature, underdeveloped hydrocarbon-prone provinces (East Mediterranean region represents quite different story nowadays), the certain similarities in their petroleum systems can be pointed out too.

This paper represents inductory notes describing the radicals of a quite new approach to resolve complex problems related to tectonic evolution and petroleum potential of the Black Sea mega-basin. It is speculated, that these two regions have, despite of a number of essential differences, many profound analogies in their geological structure and development so those found similarities can help elaboration of new prospecting trends for oil and gas exploration in the circum-Black Sea basin using geological knowledge on the Western Mediterranean and *vice versa.*

Problem statement

Such numerous analogies cannot be result of accidental coincidence. They are deeply rooted in common kinematical style reproducing the pretty similar crustal ensemble of tectonic terrains and fault patterns of different scale in remote segments of the Western Neo-Tethys as a whole and its Ponto-Caspian segment in particular. For example, minor counterclockwise rotation and eastward thrusting/drifting of the Andrussov Ridge could represent equal to the Adriatic microplate relative motion, and well-known manifestations of strike-slip tectonics in the Pyrenees can be scalably observed in the Dobrogea and the NW Black Sea shelf and Crimea.

Understanding of cohesive evolving of the circum-Black area structural constituents and driving forces of its tectonic development represents the longstanding and intriguing geological problem. Over the past two decades, much has been published concerning structural development of the Black Sea region as consequence of modern geodynamical modeling employing plate tectonic reconstructions and new phases of exploration activity. On the other hand an existence of mutually exclusive scenarios for structural development of the area, timing of its onset and reconciliation of different data (e.g. Okay et al., 1994, Nikishin et al., 2015) raise many questions puzzling the assessment of hydrocarbon charge of its sub-basins and prospecting efforts to determine top-priority trends for petroleum exploration.

Comparing the West Mediterranean and circum-Black Sea regions

For example, minor counterclockwise rotation and eastward drift of the Mid-Black Sea (Andrussov-Arkhangelsky) ridge with thrusts at the toe of its NE flank (Rangin et al., 2002) could represent equal to the Apennines chain relative motion, and well-known manifestations of strike-slip tectonics in the Pyrenees can be scalably observed in the Dobrogea and the NW shelf and Crimea. It should be mentioning also the important role of the Late Cimmerian tectonism and Late Variscan tectonic lines as well in controlling the Alpine structural style and evolution of the NW shelf.

Following by the above correlation NE flank of the Andrussov ridge could be equivalent to the Bradanic Trough position (see also similar Roussanov's idea, 1996). The western slope (Bug-Podilla depression) of the East European Craton and Trans-European Shear zone (TESZ) with Teyseire-Tornquist Lineament (TTL) can be compared to the western slope of the Armorican Basin (Armorican + Western

Approaches margins and Parentis and Mauléon basins) which is bounded by the South Armorican Shear zone (SASZ) and its southwestern strands.

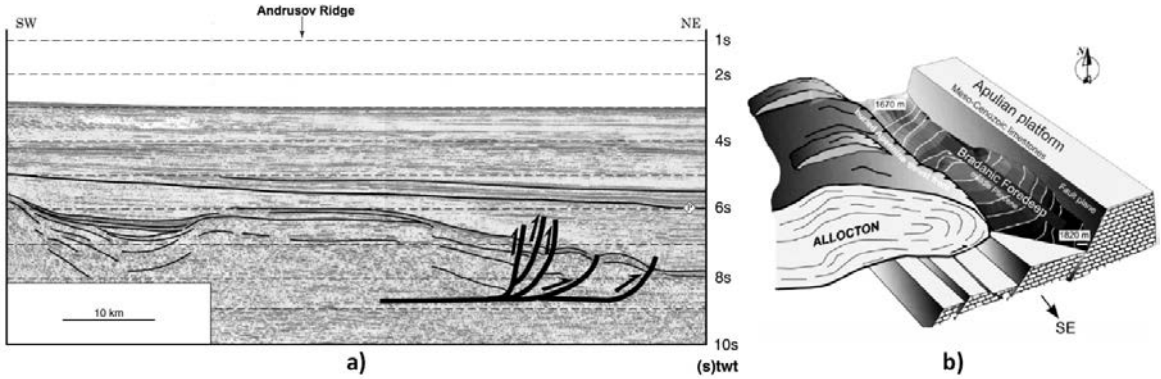

Figure 1 *Structure of the Mid-Black Sea ridge and East Black sea basin (Rangin et al., 2002) vs. Apennines alochthonous and Bradanic foredeep (Benetatos et al., 2015).*

While comparing main geostructural terraines of the basins with their surroundings it could be proposed the inventory of possible tectonic equivalents or homologues (numbers in brackets correspond to the cross-correlation arrows on the Fig. 2) as follows (taking into account that northern halves of both lithospheric domains have more similarity than their southern edges):

- Iberian – Moesian microplates (1)
- Nevado-Fillabride complex – Strandja zone(2)
- Betic Cordillera – Balkanides (3)
- Alboran Sea basin – Thrace basin & Sea of Marmara (4)
- Guadalentin depression – Burgas depression (5)
- Carboneras faults / West Trans-Aboran Shear zone– West Midia / West Black Sea fault
- Pyrenees Mts., core zone – North Dobrogean orogen (6)
- Catalan coastal ranges – Dobrogea plateau
- Valencia trough – Lower Kamchia depression (7)
- Roussillon basin – Babadag basin (8)
- Tell-Rif (Maghrebides) – Western Pontides (9)
- North Pyrenean fault of Catalan Transfer zone – Peceneaga-Camena fault (10)
- Gulf of Lion shelf– Gulf of Odessa shelf (11)
- South Atlas fault - North Anatolian fault (12), active mega-shears of dextral type
- West Kabylie massif – Istanbul zone (13)
- Ligurian + Provençal + Tyrrhenian basins - West Black Sea basin (14)
- Western Alps paleo-basin – Karkinit-Sivash trough (15), failed rift arm
- Crimean Mts. - Southern Alps (16)
- East Kabylie massif – Kastamonu complex (17)
- Po basin – Sorokin trough (18)
- Incipient paleo-cordilleras of Apennines – Mid-Black Sea (Andrussov) ridge(19)
- Adriatic/Apulian microplates – Shatsky swell / Dzirulia massif (20)
- Albanian foredeep – Tuapse trough (21)
- Incipient Bradanic trough – East Black Sea basin (22)
- Paleozoic core of the Alps, deformed – Paleozoic basement of Plain Crimea
- Dinarides-Albanides-Hellenides – Greater Caucasus (23)
- Peri-Adriatic (Durres) basin – Rioni basin (24)

Analyzing the role of strike-slip tectonics for the origin of fault-and-fold pattern of the structural units tracing from Romanian offshore to the Plain Crimea and comparing their essential details with its equivalents from the Pyrenees and surrounding areas it has been found many direct analogies that testify an existence of similar driving mechanisms and topological constraints for structural anatomy of these

regions. Trying to answer why on earth there was not any rigid indenter or uplift/land in the hinterland area of the Kalamit-Tarhankut swell to produce those compressional folds can be observed now the first remarkable likeness between dominating structural styles of Gulf of Odessa and Gulf of Lion has been established. Synchronous to the thrusting events thick Tertiary strata (likewise to south of Gulf of Lion) lie quietly and flat in the West Black Sea basin. Then, more correlative relationships have been found, for instance between structures and petroleum systems of late Jurassic carbonate reservoirs of offshore Bulgaria and Valencia basin (Tulenovo vs. Casablanca oilfield). The only solution proposed to the date is a far-field collisional-derived strain transmission from rigid indenters that requires, however, inherited lateral strength variations in the back-arc domain like weak layers (oblique to the present-day structural grain) in the lower crust at the time of structural inversion (Munteanu, 2012).

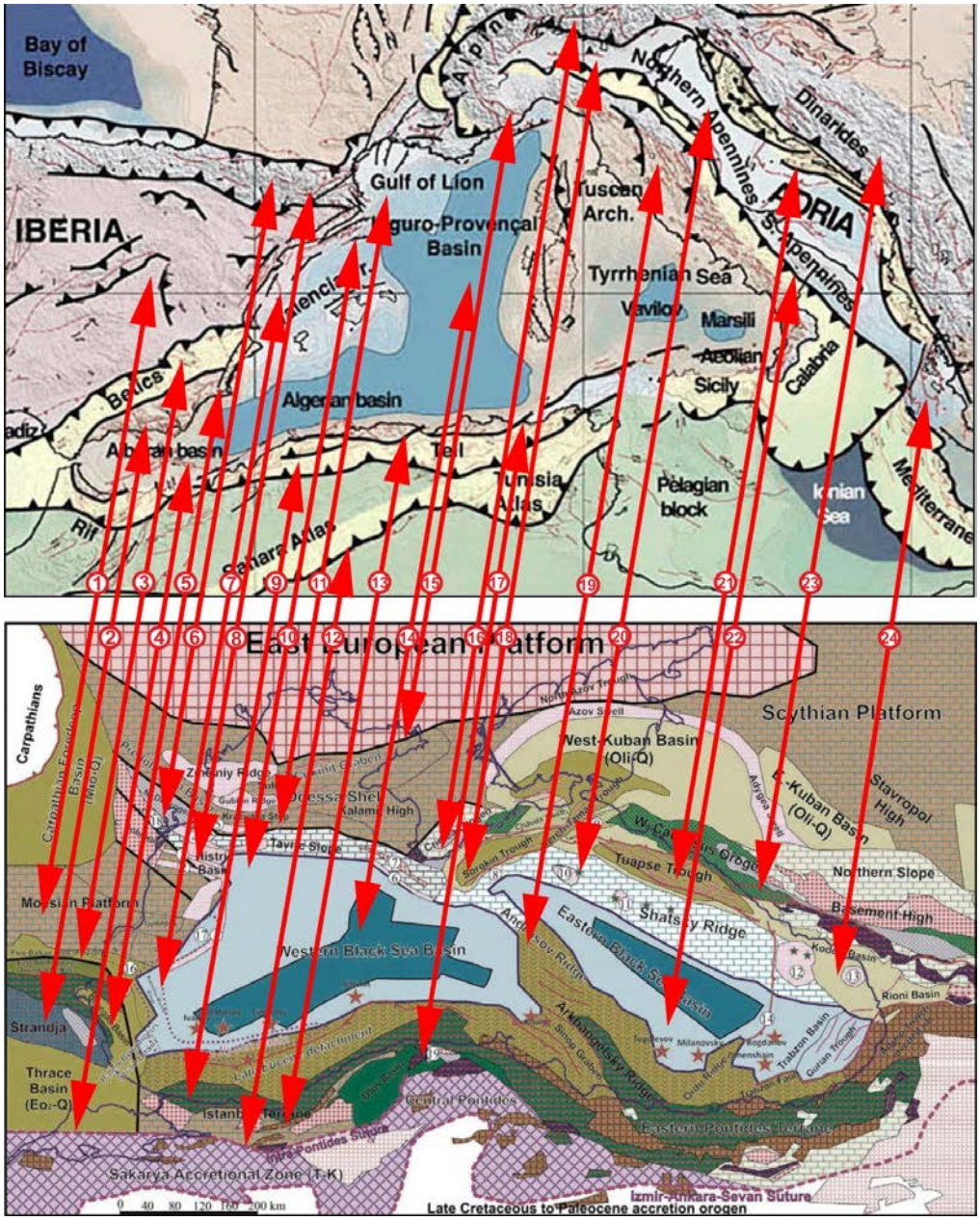

Figure2 *Cross-correlation of main geostructural units of the Western Mediterranean and Black Sea based on maps by Faccenna et al., 2014 and Nikishin et al., 2015.*

The state-of-the-art knowledge on the Mediterranean tectonics (Faccenna et al., 2014; van Hinsbergen, et al., 2020) leads to support the model featuring present NW Black Sea as an inactive passive continental margin where listric pre-rift and rifting normal faults form steep southward tilted blocks of

the Aptian-Albian incipient half grabens at the base of Campanian-Maastrichtian drift basins of climax extension phase suffered minor to medium-scaled northverging inversion related to the early Pyrenean/Illyrian/Trialetian compressional phase with possible dextral slip along their strike. It is also necessary to take into account the westward drift of decoupling lithosphere producing prominent deep structural asymmetry and difference between W-directed and E-directed subductions/obductions (Carcaterra & Doglioni, 2018) caused by rotational forces (tidal ratchet).

Conclusion

The above comparison allows consideration of the circum-Black Sea region as a minor and simplified tectonic copy of the Western Mediterranean area being evolved in similar way and caused by similar tailoring of its structural units that stipulated by uniform stress/fault pattern inherited from the Meso-Tethys tectonic realm demonstrating kind of self-similarity or crustal scaling effect. Two prominent mega-sutures of SE-striking, the Teisseyre-Tornquist Zone and South Armorican Shear zone, represent axial alignments along which a distorted symmetry could be traced for both basins under comparison. Searching for similar tectonic pattern while passing eastward, one can recognize next similar mega-shear boundary zone, the Urals-Oman lineament bordering the East European Craton and controlling position of the Lut Block (Yazd-Tabaz-Lut micro-continent) in the Eastern Iran, an analog of the Adriatic-Apulian and Shatsky-Dzirulian crustal slivers.

The kinematics associated with the Late Triassic western Tethyan rifts produced the detachment of a large composite fragment from the northern margin of Gondwana caused by hemispheric-like sinistral counter-movement of two super-continents, Gondwana and Laurasia. Quite the reverse, that movement was complicated through geological time by regional right-lateral relative motion of the Nubia and Europe sialic masses (as parts of the above super-continents, respectively) have produced a repeating structural style of deformation and crustal blocks tailoring along their Alpine collision suture lines (belts) caused by initial indentation of plate contact demonstrating quite regular structure, semi-vortical patterns, back-arc basins, curved orogenic belts, and residual oceanic crustal spots like beneath the Ionian Sea and South Caspian basin.

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