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Spatial and temporal variability of Paleocene–Miocene organofacies of the Kura Basin, eastern Azerbaijan, and implications for basin evolution and petroleum generation

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ABSTRACT

Fine-grained Paleocene–Miocene strata of eastern Azerbaijan record the evolution of the Kura Basin from an open marine system connecting the South Caspian Basin to the Paratethys of eastern Europe to an isolated epicontinental sea. Tectonic uplift associated with the Greater Caucasus mountains in Azerbaijan resulted in exposure of these strata over much of the northeastern part of the basin, allowing detailed observation and sampling over a broad area. Four hundred Paleocene–Miocene samples collected in eastern Azerbaijan demonstrate spatial and temporal geochemical heterogeneity within the predominately mudstone succession, indicating a complex evolution of this elongate basin. Through detailed organic geochemical analysis of samples, trends can be seen in the distribution of total organic carbon (TOC), pyrolysis characteristics, and biomarker results from a subset of twenty-four samples. In addition to confirming the well-documented regional basin restriction during the Oligocene to early Miocene deposition of the Maikop Series, heterogeneity of these geochemical indicators across the study area shows spatial variability in oxicity and terrestrial organic input within the basin on a sub-regional scale.

Observed geochemical variability suggests a complex evolutionary history of the Kura Basin during the Paleocene–Miocene, and this has important implications for hydrocarbon prospectivity in the region. Within the 400 collected samples, total organic carbon (TOC) values range from 0.3 to 6.3%, with Oligocene–Miocene samples showing average values of 1.4%, compared to lower TOC values found in Paleocene–Eocene strata (average = 0.3%). Rock-Eval pyrolysis shows that the majority of strata are organic lean, immature, and mixed oil/gas to gas prone (Type II/III to Type III), with a smaller group of latest Eocene–Early Miocene samples having better oil prone source potential. Gas chromatography and biomarker analysis of 24 samples reinforces the immaturity of most samples, shows varying levels of terrestrial input in all samples, suggests well-oxygenated waters prevailed with periodic suboxic to dysoxic/anoxic events, highlights gross differences between the Paleocene–Eocene and Oligocene–Miocene stratigraphic intervals, and shows generally good lateral correlation between samples. These interpretations reinforce what is seen through inorganic geochemical evaluation of trace metals, bulk composition, and stable isotopic ratios, and offer more detail as to the evolution of this basin and the implications for oil and gas prospectivity of the region.

1. Introduction

As the South Caspian Basin was isolated from the world ocean during the Cenozoic, the Kura Basin served as an important, and likely the final, connection between the Caspian and the Paratethys to the west (Brunet et al., 2002; Johnson et al., 2009). Fine-grained Paleogene–lower Neogene strata exposed along the flanks of the Greater Caucasus record the evolution of this basin and the depositional conditions that were present through this transitional time. Additionally, these strata are the major source rock interval for the petroleum accumulations both onshore and offshore (Guliev and Feyzullayev, 1996; Abrams and Narimanov, 1997; Guliyev et al., 1997, 2001; Inan et al., 1997; Klosterman et al., 1997; Wavrek et al., 1998; Devlin et al., 1999), and a lack of penetrations of the source interval, especially within the offshore realm,

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make the onshore outcrop exposures of eastern Azerbaijan (Fig. 1) key to understanding this part of the petroleum system.

The Maikop Series in particular (Fig. 2), has been identified through numerous organic geochemical evaluations as the major oil source rock interval for the South Caspian region, with a secondary contribution from strata of the Upper Miocene Diatomaceous Suite (Guliev and Feyzullayev, 1996; Abrams and Narimanov, 1997; Guliyev et al., 1997, 2001; Inan et al., 1997; Klosterman et al., 1997; Wavrek et al., 1998). Generation of hydrocarbons from this interval began ca. 4–4.5 Ma as the result of rapid subsidence and burial during the Late Miocene–Holocene (Devlin et al., 1999). Reservoirs range in age from Oligocene to Pliocene, with the principal productive reservoirs located within the fluvial to lacustrine sandstones of the Pliocene Productive Series (Reynolds et al., 1998; Feyzullayev et al., 2001; Smith-Rouch, 2006). The major hydrocarbon traps of the basin are anticlinal, buckle-fold features (Devlin et al., 1999), which began forming ca. 3.4 Ma (Chumakov et al., 1988). Large hydrocarbon accumulations are present both offshore and onshore in the South Caspian Basin (21–24 BBOE both produced and proven, Devlin et al., 1999; Smith-Rouch, 2006) as a result of the correct timing of petroleum system element emplacement – source maturation, migration, reservoir deposition and trap formation (Fig. 3).

Despite the amount of work done to characterize the likely source interval in the South Caspian Basin, there is still much that remains uncertain. A wealth of geochemical information has been gathered from fluid samples of migrated oils during exploration and development drilling, but less data has been collected directly from the source rocks, which are often inaccessible due to their depth of burial in the offshore segment of the basin. Among studies that do investigate potential source rock samples in outcrop from onshore Azerbaijan (Guliev and Feyzullayev, 1996; Abrams and Narimanov, 1997; Guliyev et al., 1997; Inan et al., 1997; Wavrek et al., 1998; Bechtel et al., 2013, 2014), few detailed biomarker results are available, with most studies focusing on Rock-Eval and pyrolysis methods. Furthermore, previous biomarker work primarily represents the Oligocene–Miocene Maikop Series, with few detailed investigations of other stratigraphic intervals. Additional information from organic geochemical evaluation of a larger potential source rock suite collected during this study helps bolster the oil-source rock correlation between produced oils of the South Caspian Basin and the suggested major source interval of the Maikop Series.

In addition to aiding petroleum correlations and predictions, organic geochemical analysis reinforces paleoenvironmental predictions made using inorganic geochemical methods (Johnson et al., 2009). Others have used a combination of detailed inorganic and organic geochemical analyses to evaluate fine-grained intervals (e.g., Alberdi-Genolet and Tocco, 1999; Glynn et al., 2006), but these complimentary techniques are rarely used in tandem. Bulk, trace metal and stable isotope geochemistry have shown clear differences in depositional conditions between the Paleocene–Eocene and the Oligocene–Miocene time periods (Hudson et al., 2008), and many biomarker ratios offer further clues as to the conditions that existed during deposition of these sediments.

The Cenozoic strata of eastern Azerbaijan record the evolution of the eastern Paratethys as the basin transitioned from an open marine basin, which was well-connected to the Tethys Sea, to an isolated epicontinental sea, due to impingement of the Arabian Peninsula upon Eurasia (Abrams and Narimanov, 1997; Rögl, 1999; Brunet et al., 2002; Golonka, 2004; Kaz'min and Tikhanova, 2006; Vincent et al., 2007; Forte et al., 2013; Afandiyeva, 2014). This study shows that through careful geochemical analysis of these strata, spatial and temporal trends can be seen in eastern Azerbaijan that reflect the evolution of the larger South Caspian Basin during this important time. Additionally, the data collected show important heterogeneities in the preserved organofacies of this world-class petroleum source interval, with important implications for regional resource exploration.

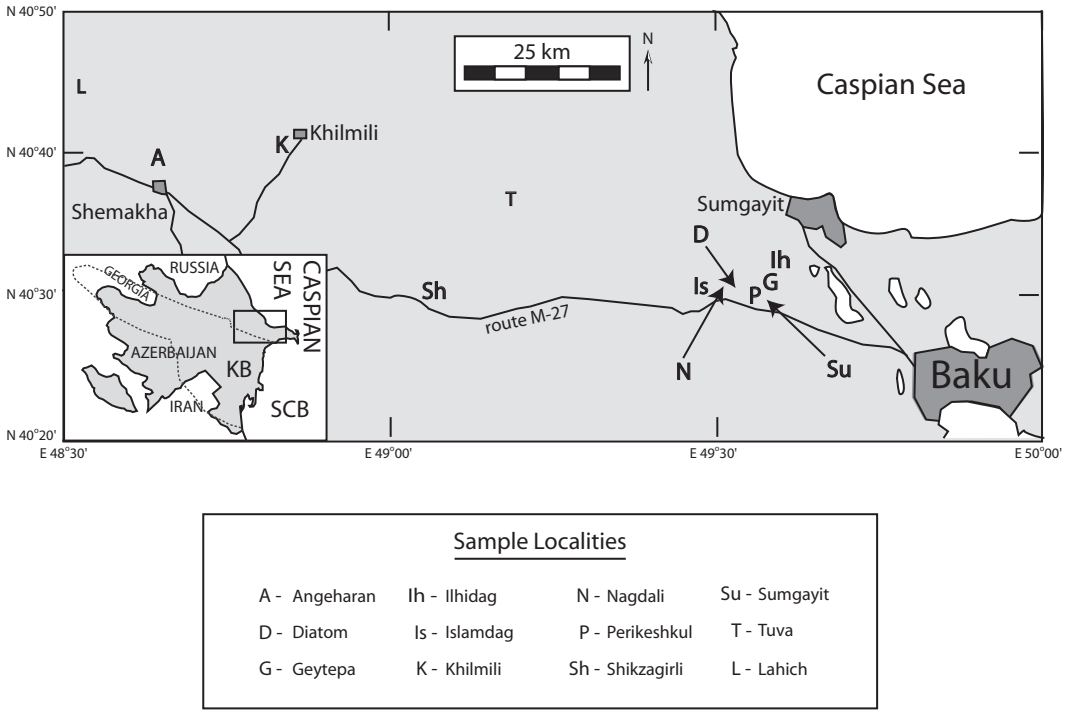

Fig. 1. Locality map of eastern Azerbaijan, showing section localities. Azerbaijan is highlighted in gray, and the approximate outline of the Kura Basin (KB) is outlined by a dashed line (inset), with the South Caspian Basin (SCB) offshore to the southeast.