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Research paper

Petroleum source rock potential of the Silurian Dadaş shales in the Hazro and Korudağ regions of Southeast Anatolia, Turkey

S.S. Öztürk [a, *], İ.H. Demirel [b], Y. Günay [c]

[a] Turkish State Railways, Permanent Way Department, Ankara, Turkey
[b] Hacettepe University, Department of Geological Engineering, 06800 Beytepe, Ankara, Turkey
[c] Tavuskuşu Sokak No: 26/15, Dikmen-Çankaya, Ankara, Turkey

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ABSTRACT

Shales of the Silurian Dadaş Formation exposed in the southeast Anatolia were investigated by organic geochemical methods. The TOC contents range from 0.24 to 1.48 wt% for the Hazro samples and 0.19 to 3.58 wt% for the Korudağ samples. Tmax values between 438 and 440 °C in the Hazro samples indicate thermal maturity; Tmax values ranging from 456 to 541 °C in the Korudağ samples indicate late to over-maturity. Based on the calculated vitrinite reflectance and measured vitrinite equivalent reflectance values, the Korudağ samples have a maximum of 1.91%$R_{(g\text{-}v)}$, in the gas generation window, while a maximum value of 0.79%$R_{(amor\text{-}v)}$ of one sample from the Hazro section is in the oil generation window. Illite crystallinity (IC) values of all samples are consistent with maturity results.

Pr/Ph ratios ranging from 1.32 to 2.28 and C_{29}/C_{30} hopane ratios > 1.0 indicate an anoxic to sub-oxic marine-carbonate depositional environment.

The Hazro shales do not have any shale oil or shale gas potential because of their low oil saturation index values and early to moderate thermal maturation. At first glance, the Korudağ shales can be considered a shale gas formation because of their organic richness, thickness and thermal over-maturity. However, the low silica content and brittle index values of these shales are preventing their suitability as shale gas resource systems.

1. Introduction

The North Africa, Arabia including Turkey, and central and northwest Iran were parts of the long and wide northern passive margin of Gondwana from the latest Proterozoic to the Late Palaeozoic (Beydoun, 1991).

The Late Ordovician (Hirnantian) glaciation affected the intracratonic basins in North Africa and the Middle East. After the short-lived (<0.5 Myr) Hirnantian glaciation, shelf seas over the craton margins became nutrient-rich and fresh marine environments as a result of coastal upwelling (Lüning et al., 2000; Armstrong et al., 2005; Le Heron et al., 2009; Torsvik and Cocks, 2011). These excellent depositional conditions led to the development of the Lower Silurian graptolite-bearing black shales across the entire region.

In southern Turkey (Taurids) and southeastern Turkey (Border Folds of the Arabian Plate), four major sedimentary sequences are defined according to the main transgressions and subsequent shelf progradations Fig. 1. Monod et al. (2003) showed the relationships between Ordovician and Silurian units and the presence of the glacial lithologies belonging to the Late Ashgill episode.

The Silurian Dadaş Formation, based on lithological compositions, is divided into three members (Bozdoğan et al., 1988) based on lithological compositions. The hydrocarbon source rock potential of the Lower (Tanf Formation; in Telhasan-1 well, TPAO) and Middle-Upper Silurian shales (Dadaş Fm) was evaluated geochemically by İztan (1991) and Bozdoğan (1992). In the Hazro area, Dadaş samples from two deep wells were evaluated by Soylu et al. (2012). These studies indicate that the Silurian shales are rich-in marine algal and amorphous organic matter and thermally mature to over-mature for hydrocarbon generation. Since 2011, seven exploration studies have been focused on discovering new conventional and unconventional Silurian hydrocarbon resources (Mitchell, 2013).

This study was undertaken with two aims. The first is to determine the organic geochemical characteristics of the Silurian

* Corresponding author.
E-mail address: s.serkan.ozturk84@gmail.com (S.S. Öztürk).

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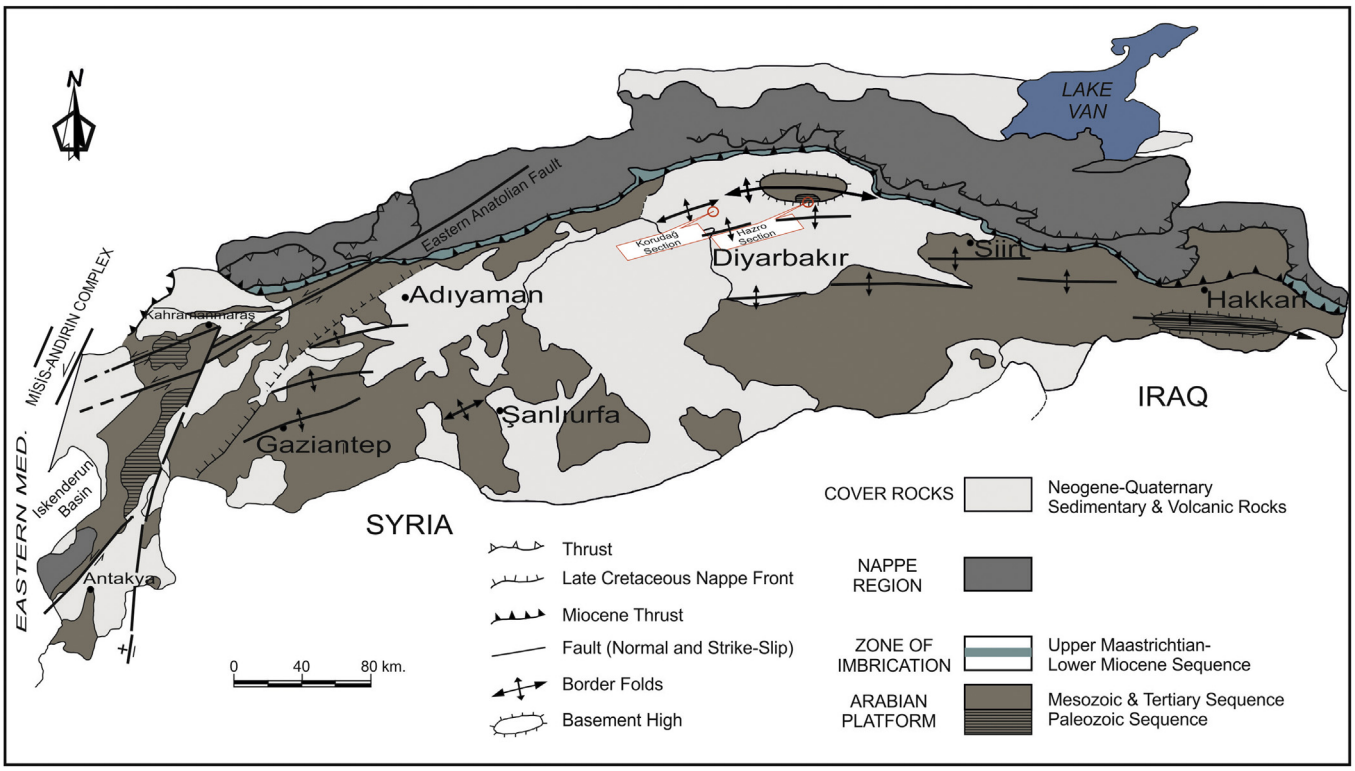

Fig. 1. Regional geological map showing the location of the Hazro and Korudağ areas in the southeast Anatolia (modified after Yılmaz, 1993).

Dadaş Formation shales in two locations, including the total organic carbon (TOC) content, organic matter type, molecular composition, thermal maturity, and whole rock mineral assemblages, to obtain a regional assessment of their hydrocarbon source rock potential; the second is to compile the optimal knowledge to guide unconventional gas exploration in the organic-matter-rich shales of the Dadaş Formation.

2. Palaeozoic stratigraphy

The Southeastern Anatolian region constitutes the northern part of the Arabian Platform, and from south to north it can be divided into three east-west trending zones. These are the Arabian Platform units, a mélange zone formed by different thrusts, and the Upper Cretaceous and Miocene Nappes (Fig. 1).

In this region, there is a continuous sedimentary succession of variable lithology and thickness from Precambrian to Tertiary (Fig. 2). The Precambrian-Cambrian units deposited on a stable platform near the Mardin-Derik area are referred to as the Derik Group (Günay, 2007). The Lower-Middle Ordovician Seydişehir and Upper Ordovician Bedinan Formations are referred to as the Habur Group. The Seydişehir Formation outcrops in the lower part of the Habur Group and is composed of shallow marine greyish-brown sandstone and dark-coloured shales. The Bedinan Formation lithologies are widespread in southeast Anatolia and unconformably overlie the Seydişehir Formation. The Bedinan Formation, newly defined as a continuation of the Late Ordovician glaciogenic Halevik Formation in the eastern Taurus region and Mardin-Derik area (Monod et al., 2003), does not have glaciogenic lithologies at the Hazro and Korudağ anticlines (Ghienne et al., 2010).

In southeast Anatolia, the Silurian Dadaş Formation is exposed only in cores of the Hazro and Korudağ anticlines near Diyarbakır (Fig. 1; Günay, 1996). It disconformably overlies the Bedinan Formation (Tolun, 1951; Kellogg, 1960). Detailed palaeontological determinations were made, and three different lithostratigraphic members were identified by Bozdoğan et al. (1988). The Dadaş-I member consists of grey-coloured, 10–15 cm thick sandstones interbedded with dark brown shales. The Dadaş-II member is the most widespread and thickest member of the Silurian units, and consists mostly of shales with pyrite nodules. The Dadaş-III member is marked by a regressive layers with shales at the base followed by alternating shale, limestone, siltstone, passing to sandstone and sandy dolomites in the upper part of the sequence (Günay, 2007).

The Early-Middle Devonian Hazro Formation conformably overlies the Dadaş Formation (Günay, 1996, 2007). Certain palaeontological age determinations were made by Soylu et al. (2012) utilizing spores, cryptospores, chitinozoans, acritarch assemblages, graptolites, conodonts and ostracoda for each member of the Dadaş Formation. Palynofacies definitions based on the abundance ratio of phytobenthic to phytoplanktonic (blue-green algae) were made by Bozdoğan et al. (1988). Based on the fossil contents, the age of the Dadaş Formation is identified as Silurian-earliest Devonian (Soylu et al., 2012).

The last lithostratigraphic unit of Diyarbakır Group is the Middle Devonian Kayayolu Formation. This formation does not outcrop in the study area. Its first definition was made by Bozdoğan et al. (1988) in Kayayolu-1 well of TPAO. The Upper Devonian Yığınlı Formation, is well known from outcrops in Hakkari, was deposited transgressively in a shallow-marine environment. It is overlain unconformably by Mardin Group units near the Derik area. The overlying Upper Devonian-Lower Carboniferous Köprülü Formation and the Lower Carboniferous Belek Formation were determined as lithostratigraphic units of the Zap Group (Günay, 1996). There is an interruption in sedimentation between the end of the Lower Carboniferous and the Permian.

The Permian units are referred to as the Tanin Group. The Early Permian Kaş Formation unconformably overlies the Silurian units and has a widespread distribution near Diyarbakır. It is overlain