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Research paper

# Geochemical characteristics and hydrocarbon generation modeling of the Kazhdumi (Early Cretaceous), Gurpi (Late Cretaceous) and Pabdeh (Paleogene) formations, Iranian sector of the Persian Gulf

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ABSTRACT

The marls and argillaceous limestones of the Early Cretaceous Kazhdumi, Late Cretaceous Gurpi and Paleogene Pabdeh formations are considered as potential source rock candidates in this area. The present study characterizes hydrocarbon potential, type of organic matter and thermal maturity of these three formations in the Iranian sector of the Persian Gulf. Also, 1D basin modeling was used to analyse the burial history and timing of hydrocarbon generation in these formations. A total of 179 cutting samples from 25 wells were evaluated through Rock–Eval pyrolysis and organic petrography. Average total organic carbon (TOC) content for the samples of the Kazhdumi, Gurpi and Pabdeh formations that were analyzed for the current study is 1.2, 0.9 and 1 wt.%, respectively. All three formations show lower TOC contents in central part relative to eastern and western parts of the study area. Rock–Eval pyrolysis and organic petrography show that the organic matter in all three formations is mainly composed of Type II and mixed Type II–III kerogen. This study shows that the Kazhdumi, Gurpi and Pabdeh formations in Iranian offshore areas are not as rich as onshore areas, and specifically in the Dezful Embayment, in terms of organic matter quantity and quality. Thermal history modeling indicates that constant heat flow values in the range of 64–73 $mW/m^2$ gives the best fit between measured and calculated vitrinite reflectance and bottom hole temperature. The Rock–Eval $T_{max}$, vitrinite reflectance and the generated models suggested that in the eastern parts of the study area, the Kazhdumi Formation is at the last stage of oil generation and the Gurpi and Pabdeh formations are within the main oil generation window. Hydrocarbon generation began in the Early Eocene, Middle Eocene and Early Miocene in the Kazhdumi, Gurpi and Pabdeh formations, respectively. In the western parts of the Persian Gulf, the Kazhdumi Formation is within the main oil window with hydrocarbon generation took place during the Oligocene and the Gurpi and Pabdeh formations are early mature and immature, respectively. All three formations are thermally immature in the central part of the Persian Gulf. The Kazhdumi Formation shows positive correlation with the crude oils of the Cretaceous and Tertiary reservoirs taken from the northwestern Persian Gulf. The Pabdeh and Gurpi formations show no correlation with crude oils produced in the northwestern and southeastern Persian Gulf.

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## 1. Introduction

The Persian Gulf and neighboring countries contain approximately two thirds of the world's oil proven reserves, and one third of the global gas reserves due to coexistence of several layers of excellent source rocks, porous and permeable limestone and sandstone reservoirs, excellent cap rocks, huge anticlinal and salt-related domes (Fig. 1).

Bordenave and Hegre (2005, 2010) identified several petroleum systems in the Zagros Foldbelt and adjacent Persian Gulf, among them, the prolific Middle Cretaceous to Early Miocene Petroleum system. Early Cretaceous Kazhdumi, Late Cretaceous Gurpi and Paleogene Pabdeh formations are important source rock candidates of this petroleum system. For this system, the Asmari and Bangestan carbonates are the main reservoirs; the Asmari reservoir is efficiently capped by evaporites of the Gachsaran Formation of the

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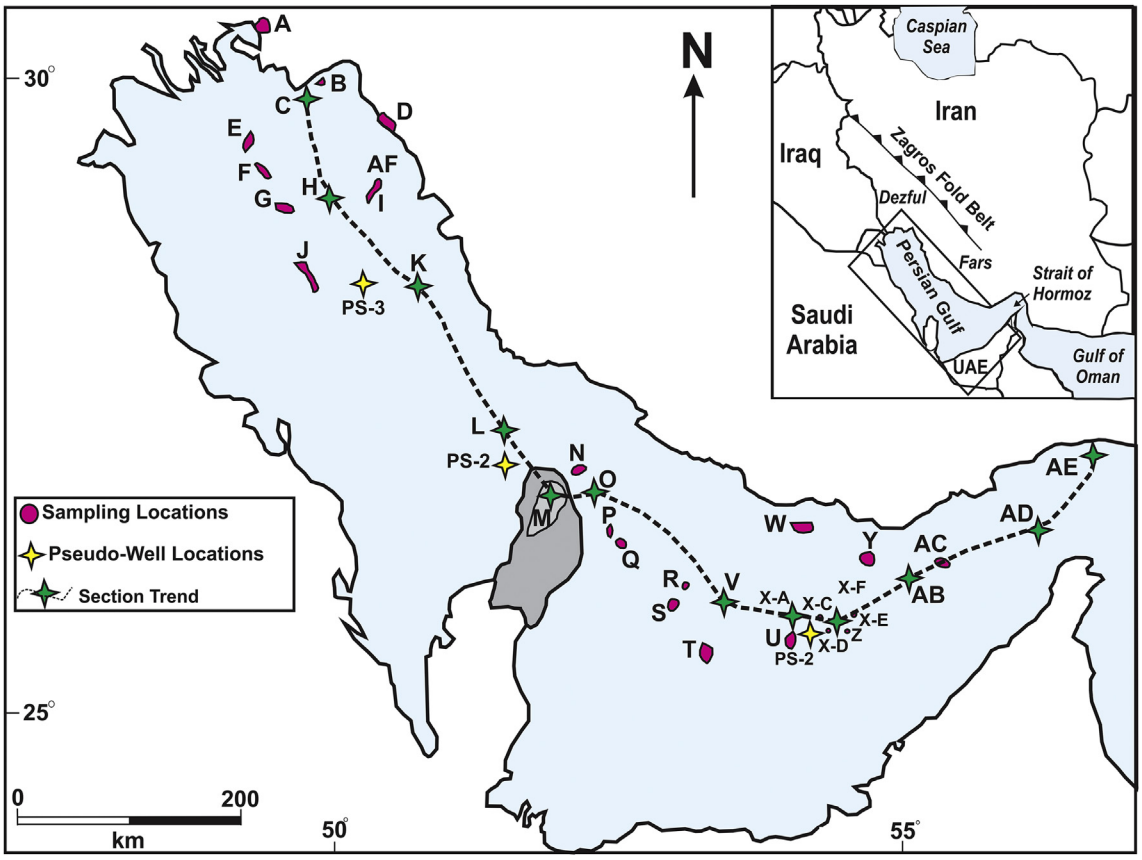


**Fig. 1.** Location of the studied fields in the Iranian sector of the Persian Gulf.

Early Miocene age. These reservoirs contain 330 billion barrels of original oil in place, corresponding to more than 7% of the current global reserves (Bordenave and Burwood, 1995).

The source rock potential of the Kazhdumi, Gurpi and Pabdeh formations has been thoroughly investigated through several studies in the Dezful Embayment which is located in south-western Iran (Fig. 1). According to these studies, the Early Cretaceous Kazhdumi and Paleogene Pabdeh formations are excellent source rocks in terms of organic matter richness, while the Late Cretaceous Gurpi Formation has been identified as a marginal source rock in the Dezful region (Bordenave and Burwood, 1990; Bordenave and Huc, 1995; Bordenave, 2002; Bordenave and Hegre, 2010; Rabbani and Tirtashi, 2010; Alizadeh et al., 2012; Opera et al., 2013). On the other hand, burial and thermal history modeling in both the Dezful Embayment and Fars region showed that the Gurpi and Pabdeh formations are early mature and the Kazhdumi Formation is early-mid mature for hydrocarbon generation (Carminati et al., 2013; Opera et al., 2013; Aldega et al., 2014).

In contrast, the hydrocarbon generation potential and thermal maturity of the Kazhdumi, Gurpi and Pabdeh formations have not been studied comprehensively within the offshore areas. Investigations of geochemical properties of produced oils in the Iranian sector of the Persian Gulf have shown that the Cretaceous Kazhdumi and Gurpi and Paleogene Pabdeh formations together with Sargelu (Middle Jurassic), Hanifa-Tuwaiq Mountains (Late Jurassic) and Garau (Early Cretaceous) formations could be considered, at least locally as source rocks for the crude oils trapped in the Late Cretaceous Ilam and Sarvak and Oligo-Miocene Asmari reservoirs in the Persian Gulf (Rabbani and Kamali, 2005; Rabbani, 2008; Rabbani et al., 2014).

The objective of this study is to provide additional information on analyses of the source rock characteristics, hydrocarbon generation potential and thermal maturity of the Kazhdumi, Gurpi and Pabdeh formations, in the Iranian sector of the Persian Gulf (Fig. 1). For this purpose, well cutting samples were analyzed by Rock–Eval pyrolysis and organic petrography. In addition, 1D thermal modeling was performed by the PetroMod-1D software to estimate the time of oil generation and thermal evolution of these three formations.

## 2. Geological framework

The Persian Gulf is part of the anticlockwise-moving Arabian Plate and has been formed during the Late Miocene (Alavi, 2004). It is structurally a foreland basin filled by terrigenous clastics transported from adjacent lands and carbonate sediments generated across the ramp surface. The gulf is limited by the Zagros Fold Belt toward north and northeast and bordered by the Arabian Shield to the west. A series of events commencing in the Turonian resulted in the closure of the Tethys Ocean at the Mesozoic/Cenozoic boundary (Ziegler, 2001; Bordenave and Hegre, 2005). These events led to the formation of Mesopotamian Foredeep consisting of the Zagros Foldbelt (Lurestan, Dezful, and Khuzestan provinces in Iran and adjacent areas in Iraq), the Fars Block (Fars Platform) in the southwest of Iran, the northern slope of the Qatar Arch and most of the Persian Gulf area, including the Rub-Al-Khali Basin (Fig. 2). From the end of the Early Miocene and during the Late Miocene, the Zagros block thrust over the eastern edge of the Arabian plate as the

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