



Research article

Study and comparison of biomarker and isotopic characteristics of Garau source rock in southwestern Iran and adjacent areas

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Keywords

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Sulaiy Formation
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Biomarkers
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English Extended Abstract

Summary

The Zagros Basin ranks among the world's most prolific hydrocarbon provinces, featuring multiple active petroleum systems and a dense concentration of oil and gas fields. The Cretaceous Garau Formation represents a regionally extensive, organic-rich source rock that spans southwestern Iran, Iraq, and Kuwait. This study presents a regional investigation of the biomarker and isotopic characteristics of the Garau source rock from southwestern Iran and the northeastern and southeastern sectors of Iraq. The dataset includes biomarker indices and isotopic measurements from 33 fields and outcrops located within the Lorestan Basin, Dezful Embayment, Abadan Plain, and northern and southern Iraq. Biomarker patterns and isotopic signatures are indicative of deposition under normal-salinity, carbonate-dominated marine conditions. Organic geochemical evidence points to the dominance of Type II kerogen, highlighting a strong hydrocarbon generation potential. Thermal maturity assessment reveals that the Garau Formation in the eastern Lorestan sub-basin remains immature, whereas in other studied areas it has entered the peak to late oil window, generating substantial hydrocarbons over geological timescales. These findings underscore the major role of the Garau Formation in regional petroleum systems and offer valuable insights for exploration-risk assessment and development strategies in the Zagros Basin and contiguous areas.

Introduction

The Zagros sedimentary basin is one of the world's major hydrocarbon provinces, largely located in Iran and neighboring countries such as Iraq. In Iran, it is subdivided into several sub-basins, including the Abadan Plain, Lorestan, Izeh Zone, Dezful Embayment, and Fars. Multiple active petroleum systems in the basin have generated numerous oil and gas fields (Figure 1) [1]. The organic-rich shales of the Garau Formation act as a key source rock within the Early Cretaceous petroleum system. Moreover, it can be considered an unconventional hydrocarbon reservoir in some locations [2]. The formation extends into neighboring regions, where its lower part is recognized as the Sulaiy Formation in southern Iraq and the Chia Gara Formation in northern Iraq [2]. Previous studies on the geochemical characteristics of the Garau Formation in southwestern Iran and adjacent areas have mostly focused on hydrocarbon potential at field scale [3–5]. The present study provides a regional comparison of biomarker and stable carbon isotope features of the Garau source rock across southwestern Iran, northeastern and southeastern Iraq.

Methodology and Approaches

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Biomarker and stable carbon isotope data were employed to evaluate the depositional environment, lithology, and thermal maturity of the Garau source rock and to enable regional comparison across the Zagros Basin. High-quality results from GC, GC-MS, and carbon isotope analyses of bitumen extracted from the Garau Formation in Iran and Iraq were compiled for this purpose. The study area covers the Lorestan Basin, Dezful Embayment, Abadan Plain, and northern and southern Iraq. Data were collected from both outcrops and field samples. Investigated Iranian fields include Sahand, Anjir, Baba Ghir, Veyznahar, Dareh Baneh, Sarkan, Mahi Dasht, North Shahabad, Kabir Kuh, Holilan, Qalikh, Asmari, Dehloran, Masjed Soleiman, Haftkel, Marun, Juffir, Azadegan, Darquein, Kushk, Hendijan, Yadavaran, and Omid. In Iraq, the focus was on Kirkuk, Baiji, Tikrit, Rumaila, Amara, and Noor (Figure 1).

Results and Conclusions

Depositional Environment and Lithology

The Pristane/Phytane ratio was used to infer the depositional environment and organic matter input. Measured values in the Garau Formation range from 0.5 to 1.2, with most samples below 1, indicating deposition under reducing marine conditions [6]. Pr/n-C17 and Ph/n-C18 ratios, together with relative abundances of C27, C28, and C29 steranes (as shown in Figure 2), confirm the presence of Type II kerogen and a predominantly marine depositional environment, with some northern Iraq samples suggesting shallower settings [7]. Tricyclic triterpane ratios (C22/C21, C24/C23), hopane ratios (C31R/C30H, C29/C30), and aromatic ratios (DBT/P, Gam/C30) further support carbonate-rich lithology and normal-salinity marine deposition for the Garau Formation [7]. Stable carbon isotope composition and CV values indicate a dominant marine organic matter input [8].

Thermal Maturity

Thermal maturity was assessed using CPI, sterane isomerization ($20S/(20S+20R)$, $\alpha\beta\beta/(\alpha\alpha\alpha+\alpha\beta\beta)$), Ts/Tm , and methyl phenanthrene index (MPI-1). CPI values range from 0.2 to 1.3, with most samples near 1, indicating oil-window maturity [7]. Sterane isomer ratios and MPI-1 confirm that the Garau source rock in western Lorestan, Abadan Plain, Dezful Embayment, and northern Iraq has reached peak to late oil-window maturity, whereas eastern Lorestan remains less mature [2]. Ts/Tm values are consistent with other maturity indicators, showing slightly lower thermal maturity in the eastern sub-basin.

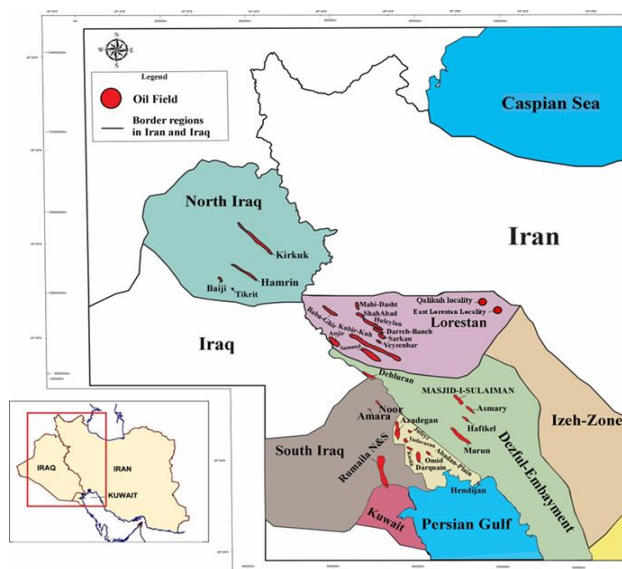


Fig. 1. Map of sedimentary basins and studied oil fields in Iran and Iraq.

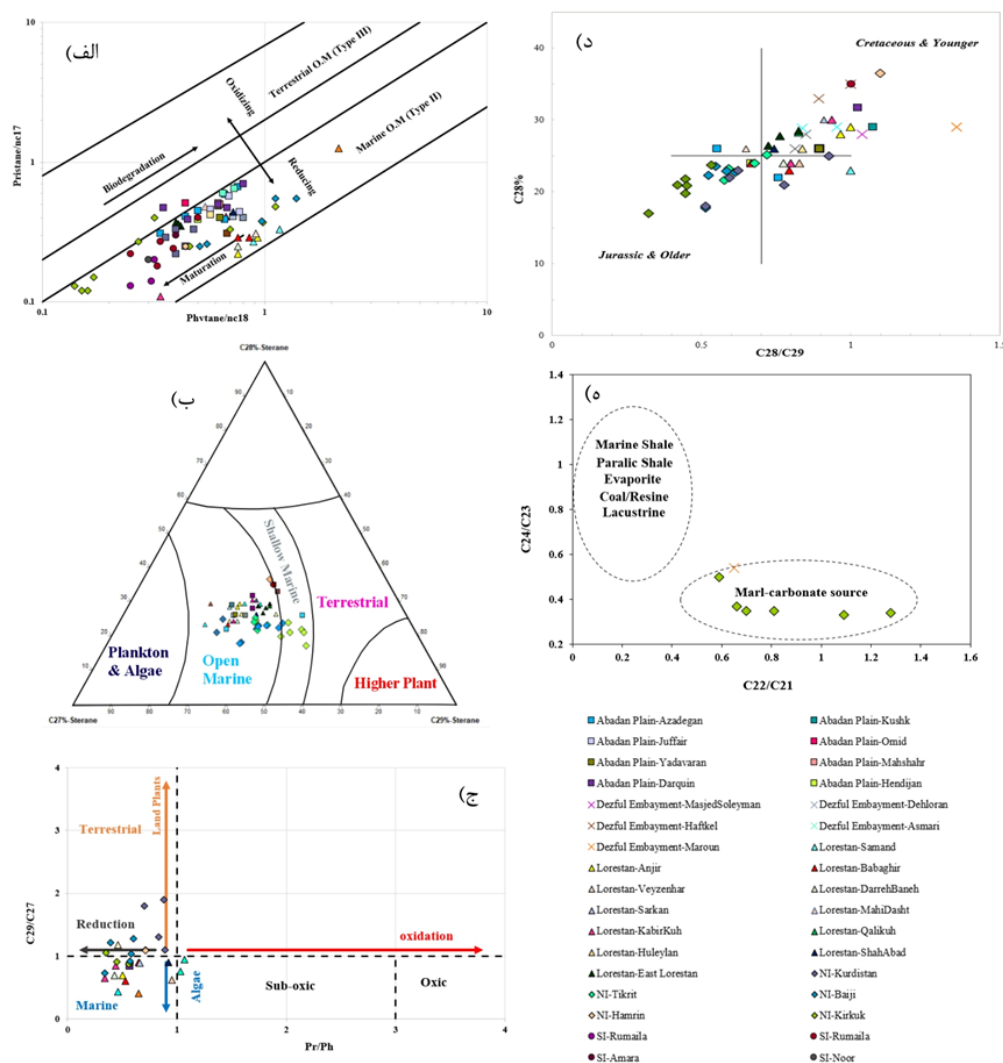


Fig. 2. The isoprenoid to normal alkanes ratios, b) Triangular diagram of C27, C28 and C29 isoesteranes, c) C29/C27 regular esteranes ratio versus Pr/Ph ratio, d) C28 to C28/C29 ratio used to determine the age of the source rock. e) The plot of C24/C23 vs C22/C21 tricyclic terpanes.

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