Geochemical Characterization, Depositional Environment, and Controlling Factors of β-Carotene - A Case Study of Jimsar Depression, Junggar Basin of China*

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Abstract

Relatively high abundance of β-carotene has been detected in some source rock extracts from Lucaogou Formation (LCG) of Jimsar Depression, Eastern Junggar Basin. A combined investigation of bulk geochemical study and molecular geochemical observation on 31 source rocks samples from LCG were carried out. The LCG is defined as good source rock with high hydrocarbon generation potential, indicated by high TOC (0.27%-13.90%), high hydrocarbon potential index (S1+S2, 0.15–109.01 mg HC/g) and low-maturity to maturity. The biomarkers of LCG source rocks extracts are characterized by short to long chain n-alkanes, a wide range of Pr/Ph (0.74-1.42) and β-Carotane (β-Carotane/Maximum Carbon, 0.16-1.92), high concentrations of C29 sterane, the presence of relatively low tricyclic terpanes and middle gammacerane index values (0.14-0.29). These are consistent with a relatively low oxidizing to low reducing depositional environment of fresh to brackish water conditions, with a major contribution of terrigenous organic matter input and a low contribution of aquatic algal-bacterial organic matter. Based on the correlation relationship between β-Carotane abundance and depositional environment and thermal maturity, it can be concluded that the β-Carotane of LCG is mainly derived from terrigenous organic matter and distributed in the brackish water conditions, low reducing depositional environment, but not affected by thermal maturity. However, β-carotane is mostly associated primarily with anoxic, saline lacustrine environment, and its biological origin was cyanobacteria and algae, historically. This study could provide a new research perspective for geological and geochemical significance of β-carotane and its application in oil-source correlation.

References Cited


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1. Introduction

Historically, \( \beta \)-carotene is associated primarily with anoxic, saline lacustrine, or highly restricted marine settings, and its biological origin is contentious and widely debated (Peterson et al., 2015). \( \beta \)-carotene has important significance in geology, geochemistry, and oil-source correlation, whereas previous studies on the geochemical characterization, depositional environment, and controlling factors of \( \beta \)-carotene within the Lower Permian Lucao Formation in the Jimsaar Sag of Junggar Basin were limited and not known. We have conducted a comprehensive investigation of bulk geochemistry and molecular geochemistry on the Lower Permian Lucao Formation in the Jimsaar Sag of Junggar Basin to reveal that the \( \beta \)-Carotene of Lucao Formation source rocks in Jimsaar Sag is mainly derived from terigenous organic matter and mainly distributed in the brackish water conditions and low reducing depositional environment, not affected by thermal maturity.

2. Geologic setting

The Jimsaar Sag with the total area of 1273 km² is located in the eastern uplift of Junggar Basin (Fig. 1a). The Sag is a deep-shaped depression with faulting in the west (Fig 1a) and has been the focus of oil exploration and development in China.

3. Organic matter abundance and Rock-Evap pyrolysis

Lucao Formation source rocks exhibit a wide range in TOC contents, typically from 0.37% to 13.90%, and with an average value of 2.01%. The average value of \( \delta^{13}C \) and \( \delta^{15}N \) of source rock samples are -3.20‰ and 10.22‰, respectively, showing that the source rocks have high organic matter abundance. Most of source rock samples have Rock-Evap \( T_{m} \) of 436-451°C, suggesting a low-maturity to maturity.

4. Molecular analysis

The source rocks extracts contain a full range of \( C_{13}, C_{17}, \) n-alkanes and isoprenoids, pristane and phytane. And the source rock samples of Lucao Formation display wide variation in \( \beta \)-Carotene. Terrestrial terpenoids are low as the \( m/z \) 191 chromatograms of the Lucao Formation source rock extracts (Fig. 5).

### Figures

- Fig. 1: Map of Junggar Basin in Northwestern China, showing the location of Jimsaar Sag. (a) Structural contour map of the sequence of the Lucao Formation; (b) Location map showing well distribution in the Jimsaar Sag. (After Zhang et al., 2010).

- Fig. 2: Ternary diagram of the lower Permian Lucao Formation source rocks. The amount of terrestrial terpenoids (TP) and the amount of terigenous terpenoids (TP') are compared to the sum of the amount of pyrolyzed hydrocarbons \( T_{m} > 400°C \). (After Zhang et al., 2010).

- Fig. 3: Molecular distribution of the source rock of Lucao Formation in the Jimsaar Sag. (After Zhou et al., 2019).

- Fig. 4: Organic carbon versus Rock-Evap biothermal plots of the source rocks of the lower Permian Lucao Formation in the Jimsaar Sag. (After Zhou et al., 2019).

The samples show a higher proportion of \( C_{13}, C_{17} \) (35%–56%) compared to \( C_{20} \) (11%–32%) and \( C_{20} \) (9%–37%) inres; reflecting a low contribution of aquatic algal-bacterial organic matter and major terrigenous organic matter input, as indicated by regular intervalary ternary diagram (Fig. 5).
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5. Relationship between thermal maturity and β-carotane
It is also critical to note that there is no obvious correlation between β-Carotane and the commonly used thermal maturity parameters (%Ro, %Rt, %Rmax) and %Ro (200-250°C). Therefore, we can conclude that the wide variations in β-Carotane could not have been caused by thermal maturity in the Jimsar Sag.

6. β-carotane depositional environment
The β-Carotane decreases with increasing Pr/Ph and increase with increasing C25/C29. Therefore, the correlation of β-Carotane with Pr/Ph, C25/C29, C19/C18, and Pr/Ph indicate that the high abundance of β-Carotane is mainly distributed in the brackish water conditions and low reducing depositional environment, although low β-Carotane content is existed in the fresh water andoxic depositional environment.

7. Relationship between organic matter origin and β-carotan
The β-Carotane increases with increasing CPI, C27/30 T/C20 T and decreases with increasing C19 sterane and C27/30 T/C20 T. The correlation of β-Carotane with CPI, C27 sterane, C19 T/C18 T, C18 sterane and C27/30 T/C20 T indicate that the biological origin of β-Carotane is mainly terrigenous organic matter input to the Jimsar Sag, not aquatic algal-bacterial and algal organic matter.

8. Conclusions
Based on our bulk geochemical study and molecular geochemical observation on 31 source rocks samples, we inferred the geochemical characteristics, depositional environment and controlling factors of β-carotane within the Lower Permian Lucaogou Formation in the Jimsar Sag of Junggar Basin. The following conclusions can be drawn:

(1) The source rock in the Lucaogou Formation are defined as good and with high hydrocarbon generation potential, indicated by high TOC (%2.7-13.9%), high hydrocarbon potential index (S1+S2: 0.19-10.09 mg HC/g) and low-maturity to maturity.

(2) The biomarkers of Lucaogou source rock extracts are characterized by short to long chain n-alkanes, a wide range of Pr/Ph (0.74-1.42) and β-Carotane (β-Carotane / Maximum Carbon, 0.16-1.92). This is consistent with a relatively low oxidizing to low reducing depositional environment of fresh to brackish water conditions, with a major contribution of terrigenous organic matter input and a low contribution of aquatic algal-bacterial organic matter.

(3) Cross-plots of biomarker parameters and β-Carotane show that the β-Carotane of Lucaogou source rocks in Jimsar Sag is mainly derived from terrigenous organic matter and mainly distributed in the brackish water conditions and low reducing depositional environment, not affected by thermal maturity.

Key references

Appendix
- TOC, Total organic carbon (% of);
- %Ro, %Rt, %Rmax, the amount of hydrocarbons of free;
- %Ro, %Rmax, the amount of generated hydrocarbon;
- Tmax (°C), the temperature of the maximum generation rate of kerogen cracking;
- CPI, the amount of primary productivity in the Jimsar Sag showing the different organic matters contribute to the origin of β-Carotane.

Key references