

Molecular Indicators of Paleoenvironmental Conditions for the Carboniferous Sardar Formation in the Tabas Basin, Central Iran

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Abstract

Biological markers have shown promise in interpreting the paleodepositional environment of hydrocarbon source layers, typing their contributing microorganisms and determining their level of organic transformations. Biomarker fingerprinting of organic extracts from two outcrop sections of Carboniferous age in the Central Iranian Basin helped in establishment of their paleoenvironmental conditions and identification of their major organic precursors. The studied Sardar Formation is indicated to have been deposited under a stronger marine influence in Section-2 relative to Section-1, with noticeable input of terrestrially sourced organic matter into the latter. Diagnostic biological marker parameters suggest that the studied Carboniferous strata were deposited in a well-aerated water body as evidenced by Pr/Ph ratios higher than 1.0 at both sections, very low concentration of C₃₅-homohopanes with respect to the C₃₄ homologues (C₃₅-homohopane Index values around 0.5) and lower values for the ratio of Dibenzothiophene/Phenanthrene (0.1-0.4). In addition, very low values for the moretane/hopanes ratios (0.08-0.3) and very low concentrations of tricyclic terpanes are indicators of the lower salinity of the depositional environment at both sections. Absence of gammacerane over the m/z 191 chromatograms may disprove water column stratification within the basin, which further proves the higher oxicity and lower salinity of the environment. Results from the Rock-Eval analysis of a larger number of samples from these sections are further supporting the above findings. Samples are generally falling near the horizontal axis of the HI versus OI diagrams, suggesting that the studied area was a dysoxic marine setting where terrestrial matter could be deposited along with autochthonous algal/bacterial organic matter.

Introduction

The two sections selected for the purpose of this study are located over the so called Shotori Swell (5, 12, 13, 14) where Section-1 is located at E57°07', N33°38' and Section-2 lies at E57°18', N33°21' (Fig. 1). The studied sections comprise of the Sardar Formation, which is lithologically composed of alterations of sand and silt with intercalations of gray/black shale.

Experimental Details

A total of 30 samples were collected from outcrop sections at the given locations (15 samples from each section) and were subjected to Rock-Eval analysis. Selected samples were further characterized by GC and GCMS analyses of the extracted organic fractions (2 samples from each section). The analytical procedures are given elsewhere (1).

Results and Discussion

The similar level of thermal maturity for the studied sections is indicated by the uniform values for ratios of steranes C₂₉ααα 20S/(20S+20R), hopanes C₃₂ 22S/(22S+22R) and TAS/(TAS+MAS) from Table 1. Hence, variations observed in various ratios are assumed to reflect changes in the

depositional conditions and/or organic input. The HI and OI data obtained for the Rock-Eval pyrolysis suggest a type IV OM; however, this may not be the ultimate conclusion considering the difficulties in using the modified Vankrevlen diagrams for typing indigenous organic matter (4, 7). According to the gas chromatograms of selected samples from section 1 and 2 (Fig. 2), the encountered organic matter displays input from both algal and terrestrial sources, a fact that is also displayed on diagrams of Pr/n-C₁₇ versus Ph/n-C₁₈ of Hunt (6) and appreciable quantities of both C₂₇ and C₂₉ regular steranes on the m/z 217 fragmentograms. Among the gas chromatograms, samples from Section-1 are characterized by higher percentages of HMW n-alkanes relative to samples from Section-2, which is also supported by the higher C₂₉/C₂₇ αββ regular sterane and the lower short/long n-alkane ratios in Table 1.

The generally high Ts/Tm ratio of samples from both sections is believed to be an indication of the relatively higher level of thermal maturity, which is also evident from the sterane and hopanes isomerization ratios (Table 1). However, the lower Ts/Tm value for the lower part of the Section-1 (1A sample) can be a result of the strongly oxic conditions in the environment (9) as is also supported by the very high Pr/Ph ratio for this sample. Generally, samples from both locations are deposited under well-aerated fresh-water conditions as suggested by the very low homohopane indices (10) and comparatively high ratios of the Shot/(Short+long) MAS (9), relatively high Pr/Ph ratios (6), very low concentrations of gammacerane (8) and absence of bisnorhopanes (11) (Table 1).

Based on the m/z 217 fingerprints of the samples (illustrated in Figure 2), samples from Section-2 indicate significantly higher concentrations of short-chain steranes compared to those from Section-1. This can be an indication of the reducing depositional conditions in Section-2 relative to Section-1 (11). Moreover, the higher tricyclic terpane concentrations in samples from section 2, suggests depositional conditions favoring organisms which are precursors of tricyclic terpanes (3). Finally, the higher ratios of Sat/Aro for Section-1 can be a result of the higher terrestrial input, implying a near-shore well-oxygenated setting (higher Diasterane/Sterane ratios for the samples from Section-1).

Generally speaking, Section-2 is concluded to be deposited in a deeper, more stable marine setting compared with the Section-1. This conclusion is supported by the molecular indicators of marine environment, such as the higher tricyclic terpane ratios for the Section-2 (2). In addition, variations in the geochemical parameters of Section-2 occur in a narrow range, which can be a consequence of its more or less stable depositional setting. Taking various geochemical parameters, we observe a sharp variation from base to the top of the Sardar Formation in Section-1; whereas the same ratios are relatively uniform for the Section-2 (see Table 1). It is axiomatic that difference in the level of maturation of OM cannot be held to account for the observed variations throughout the studied sections. Hence, these variations can be tied to variations in the depositional conditions within the two studied locations.

Conclusions

Based on the detailed geochemical data obtained by analyzing the extractable organic matter from the Carboniferous Sardar Formation, interesting conclusions can be made about the paleo-depositional conditions. Results suggest that the Sardar Formation was deposited in a dysoxic marine environment with some contribution of terrestrial organic matter from adjacent landmasses. Assuming that the overall occurrence of the Carboniferous sediments in Iran is very limited due to the Hercynian orogeny, these results can be of critical importance for reconstruction of the past conditions. Unequivocally, results provided by this study alone may not be very conclusive regionally; however, when combined with the similar results from other possible source layers they can be useful in mapping the main sources of organic contributions and hence locating the areas with highest potential for HC generation.

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Table 1: Organic geochemical data obtained for selected samples of the Sardar Formation.

Ratio	Section-1		Section-2	
	1A	1B	2A	2B
Liquid Chromatography (LC)				
Saturate (%)	46.6	39.5	41	41.9
Aromatic (%)	10	24.5	17.5	15.6
Saturate/Aromatic ratio	4.44	1.61	2.34	2.69
Gas Chromatography (GC)				
Pr/Ph	1.32	0.86	1.14	1.05
CPI	1.11	1.02	1.51	1.16
TAR	0.31	0.84	0.29	0.32
Short/Long n-alkane ratio	2.70	1.15	4.0	3.80
Saturate Fraction GCMS (m/z 217)				
C ₂₉ /C ₂₇ αββ regular steranes	1.2	1.19	1.06	1.18
Steranes (%)	16.62	19.60	20.56	20.28
(C ₂₁ +C ₂₂)/(C ₂₇ +C ₂₈ +C ₂₉) steranes	0.13	0.08	0.19	0.20
%C ₂₇ ααα 20R	31.78	36.58	43.94	40.06
%C ₂₈ ααα 20R	21.66	26.19	21.90	24.38
%C ₂₉ ααα 20R	46.56	37.23	34.16	35.56
Sterane/Terpane	0.20	0.24	0.26	0.25
C ₂₇ Dia/(Dia+Reg)	0.54	0.61	0.54	0.49
C ₂₉ ααα 20S/(20S+20R)	0.48	0.47	0.48	0.47
Saturate Fraction GCMS (m/z 191)				
C ₂₃ tricyclic terpane/C ₃₀ Hopane	0.09	0.19	0.38	0.31
C ₁₉ /C ₂₃ tricyclic terpane	0.19	0.05	0.25	0.22
C ₂₄ Tetracyclic/C ₂₃ tricyclic terpaene	1.17	0.39	0.29	0.36
C ₂₉ /C ₃₀ hopane	0.95	0.47	0.51	0.54
Moretane/Hopane	0.37	0.10	0.08	0.08
Ts/(Ts+Tm)	0.12	0.61	0.60	0.61
Pentacyclic Terpanes (%)	72.81	58.53	53.31	54.91
Tricyclic Terpanes (%)	10.58	21.88	26.13	24.82
C ₃₅ Homohopane Index	0.48	0.55	0.71	0.61
C ₃₂ 22S/(22S+22R)	0.59	0.57	0.57	0.58
Aromatic Fraction GCMS				
DBT/Phen	0.4	0.4	0.25	0.19
TAS(C ₂₀ +C ₂₁)/all TAS	0.26	0.25	0.23	0.22
TAS/(TAS+MAS)	0.9	0.91	0.8	0.71
Short/(Short+Long)MAS [(ΣC ₂₀ ,C ₂₁)/(ΣC ₂₀ ,C ₂₁ ,C ₂₆ ,C ₂₇ ,C ₂₈)MAS]	0.27	0.26	0.24	0.22

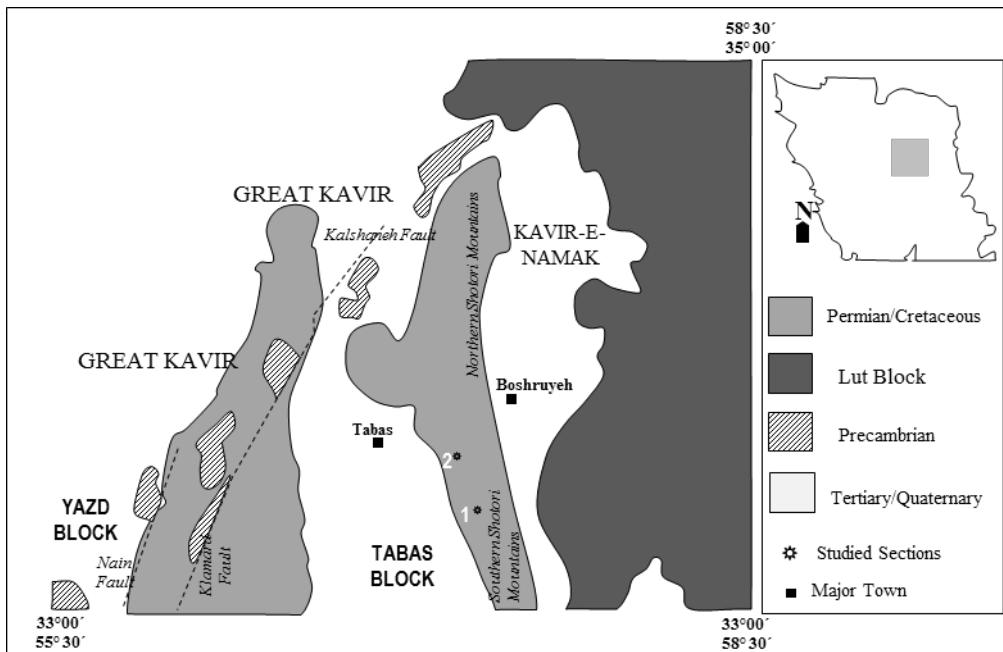


Figure 1. Generalized representation of the studied area (modified after Seyed-Emami et al., 2004) with locations of the studied sections displayed.

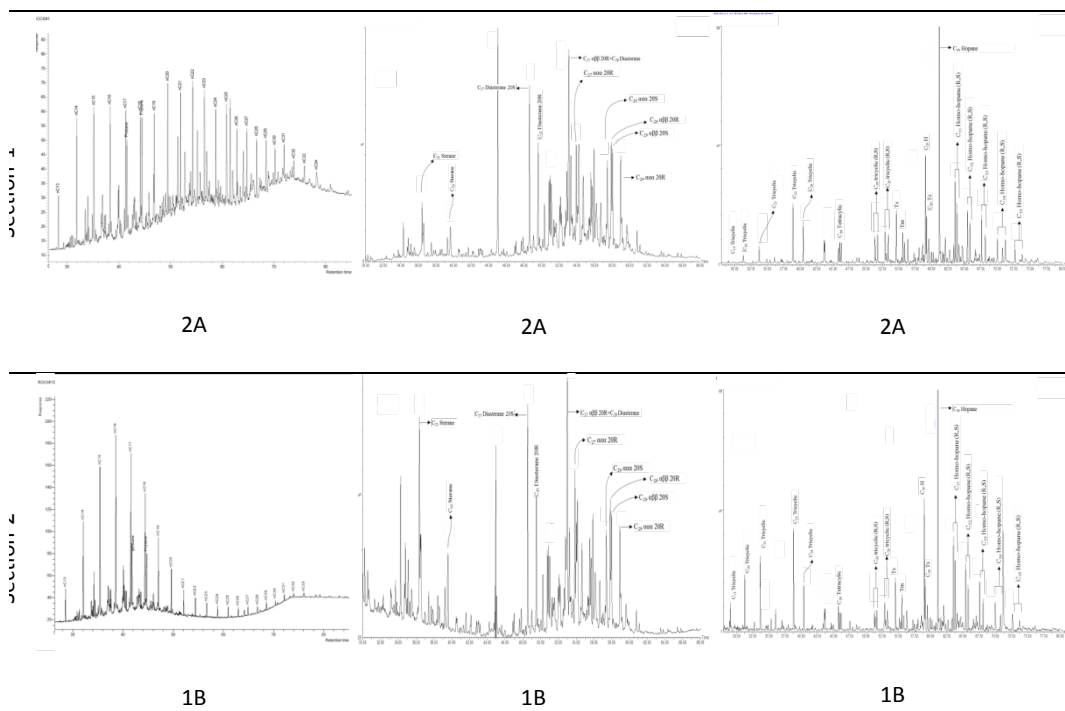


Figure 2. Representative gas chromatograms and m/z 217 and 191 mass chromatograms for selected samples from studied sections.