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Full Length Article

TSR, deep oil cracking and exploration potential in the Hetianhe gas field, Tarim Basin, China

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ABSTRACT

Oil and gas in deep and ultra-deep strata has been a hot topic in both research and exploration. The understanding of reservoirs in relatively shallow strata may be of significance for deep exploration. The Hetianhe gas field is the only large gas field discovered yet in the southwest region of the Tarim Basin, with a small quantity of condensate oil penetrated and a burial depth ranging from 1035 m to 2885 m, and the origin and source of the oil and gas has long been unclear. By using comprehensive 2D gas chromatography/time of flight mass spectrometry (GC × GC-TOFMS), abundant diamondoids and some thiadiamondoids were detected in condensate oil samples collected from 3 wells, additionally, the features, including dry gas with a trace amount of hydrogen sulfide, heavy carbon isotopes, and similar sulfur isotopes in hydrogen sulfide and Cambrian gypsum, indicate that the oil and gas has undergone the thermochemical sulfate reduction (TSR) and thermal cracking. The current reservoir temperature, from 35 °C to 83 °C, does not meet the condition for the onset of these secondary geochemical alterations, therefore, the oil and gas may originate from deep strata. According to the reconstruction of the geologic evolution, deep oil and gas may have migrated vertically along faults and accumulated in the Hetianhe structure formed after 10 Ma to form the secondary gas reservoirs; hence it is inferred that favorable petroleum plays may exist in deep strata. The thick evaporite in the Middle Cambrian and the high-quality dolomite reservoirs in the Lower Cambrian constitute a favorable reservoir-seal assemblage, with the current depth between 8500 m and 10000 m and reservoir temperature above 200 °C, where the TSR and thermal cracking may occur. The sulfur isotope of hydrogen sulfide also demonstrates the occurrence of TSR process in the Cambrian strata. Therefore, large-scale of oil and gas reserves may be preserved in the stable zones in the Cambrian sub-salt strata, and it is suggested to strengthen hydrocarbon exploration in the Cambrian sub-salt strata in the southwest region of the Tarim Basin.

1. Introduction

Due to the improvements in exploratory drilling techniques and promotions in the exploration activities, oil and gas in deep and ultra-deep strata has been a hot topic in both research and exploration and will be important fungible field for rising reserves in the future [1–4]. In view of the great increasing of drilling cost, deep hydrocarbon exploration mainly focuses on those prospects with high abundance and yield, thus, it is of significance to fully understand the process of hydrocarbon generation, accumulation and enrichment. Advanced geochemical experimental techniques including comprehensive 2D gas chromatography/time of flight mass spectrometry (GC × GC-TOFMS) and carbon and sulfur isotope analysis [5–10] are widely used by geochemists to provide theoretical support for the hydrocarbon exploration in deep strata. The long-period of complex sedimentary evolution in marine basins in China led to the complex and diverse origins of oil and gas [11–13]. All the hydrocarbon accumulations were proceeded and completed along with the geological evolution of the basin, and the geological evolution in each stage may attach alterations on the pre-basins [14–17]. Therefore, the preservation of the oil and gas accumulations may be greatly influenced by the tectonic movements during the geological evolution in the basins. Hydrocarbon adjustment and redistribution may frequently occur in old superimposed basins. In general, reservoirs formed after the continuous process of hydrocarbon

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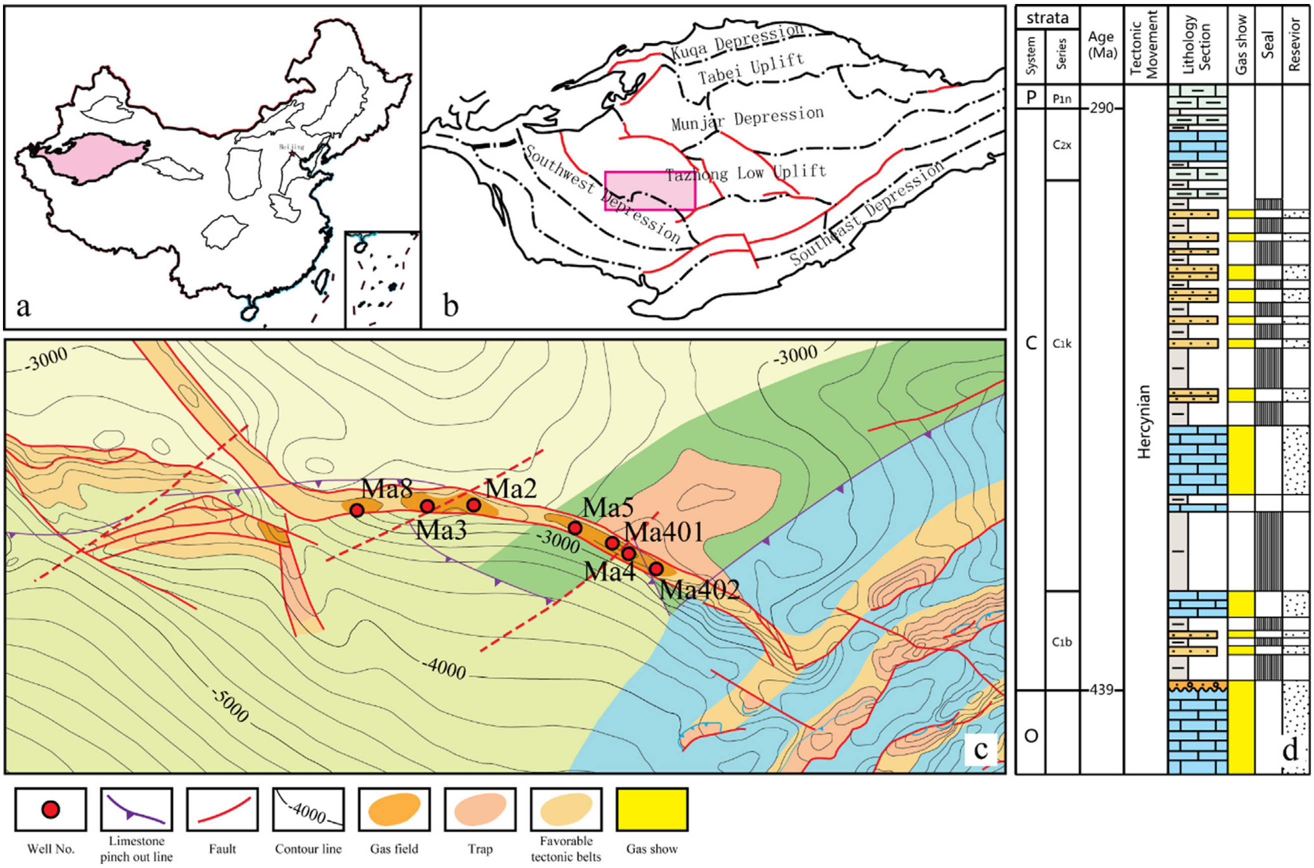

Fig. 1. Comprehensive geologic maps of the Hetianhe gas field in the Bachu uplift, Tarim Basin. *Notes:* (a) the location of the Tarim Basin; (b) the location of the Hetianhe gas field; (c) the structural map of the Hetianhe gas field; (d) the stratigraphic column of the Bachu uplift.

Table 1
Physical property of the condensate oil in the Hetianhe field.

Well	Depth (m)	Density (g/cm^3)		Viscosity (mPa·s)	Wax (%)	Sulfur (%)	Resin (%)	Asphaltene (%)	Asphaltene + Resin (%)
		20 °C	50 °C						
Ma2[a]	1501	0.79		0.78	0	0.01	9.09	0	9.09
Ma3[a]	1424	0.80		0.77	0	0.02	5.26	0	5.26
Ma3[a]	1518	0.82–0.84		–	0	0.02	8.00	0	8.00
Ma401[a]	2015	0.80		1.15	0	0.09	1.66	0	1.66
Ma401[a]	2165	0.82		–	0	0.01	4.67	0	4.67
Ma401	2223	0.78	0.76	0.59	2.20		0.51	0.03	0.54
Ma401[a]	2223	0.81		1.17	0	0	2.81	0	2.81
Ma4[a]	2041	0.77		0.73	0	0.01	23.68	0	23.68
Ma4[a]	2041	0.80		0.96	0	0.01	28.46	0	28.46
Ma4[a]	2140	0.82		0.82	0.69	–	4.78	1.97	6.75
Ma4-10H	3439	0.80	0.78	0.82	0.90	0.52			
Ma4-12H	2649	0.78	0.76	0.60	0.60	0.37	0.38	0.12	0.50
Ma4-8H	2748	0.78	0.76	0.59	2.50				
Ma4-B2H	2885	0.76	0.74	0.49	0.20	0.14	0.09	0.07	0.16
Ma4-H2	2785	0.78	0.75	0.56	1.48	0.20			
Ma4-H3	2670	0.76	0.74	0.54		0.02			
Ma4-H4	2840	0.78	0.75	0.59	3.90				
Ma4-H6	2765	0.76	0.74	0.49	5.90				
Ma5[a]	1967	0.75–0.80		0.63	0	0.08–0.20	21.43	0	21.43
Ma8[a]	1521	0.75		0.73	0	0.42	6.70	0	6.70
Ma5-1	2272	0.81	0.79	0.74	2.24	0.44			
Ma5-1H	3315	0.76	0.73	0.51	2.90				
Ma5-2H	2459	0.79	0.77	0.67	2.90		0.07	0.02	0.09
Ma5-4H	2589	0.82	0.80	0.86	3.20		0.04	0.03	0.07
Ma5-8H	2630	0.80	0.78	0.61					

Note: a, the data is from Ref. [38]. The rest of the data is from this study.