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Relationship between total organic carbon content and sedimentation rate in ancient lacustrine sediments, a case study of Erlian basin, northern China

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ABSTRACT

Relationship between total organic carbon content (TOC) and sedimentation rate (SR) had been studied mainly in marine sediments, which is generally thought to be positive or negative correlation. Based on the data sets of sediment intervals from 111 exploration wells of 8 subbasins in Erlian lacustrine basin, northern China, the relationship between TOC and SR in ancient lacustrine sediments has been studied. The result points out that accompanied with increasing SR, TOC tends to increase and then decrease. The turning point of SR in all subbasins approximates 5 cm/ka. Based on the research on biomarker and carbon isotope data, it has been found that the relationship between TOC and SR is controlled by the redox conditions when SR is lower than 5 cm/ka, while SR is higher than 5 cm/ka, the relationship is controlled by the paleoproductivity. When SR is lower than 5 cm/ka, TOC tends to increase with increasing SR in all subbasins, indicating that it is the degradation that controls the TOC. Under the oxidation conditions, the degradation is intense, higher SR gets bigger TOC growth, while in reduction conditions, the degradation is weak, higher SR gets smaller TOC growth. When SR is higher than 5 cm/ka, TOC tends to decrease with increasing SR in all subbasins, indicating that clastic dilution, instead of degradation, is the key factor controlling the TOC. The dilution effect is more significant in low palaeoproductivity environment than in high palaeoproductivity environment. Higher SR gets bigger reduction in low palaeoproductivity environment while it gets smaller TOC reduction in high palaeoproductivity environment.

1. Introduction

The deposits of lacustrine basins account for a growing segment of current petroleum exploration and exploitation opportunities, especially in areas of rapid market growth such as China, Southeast Asia and western Africa (Carroll and Bohacs, 2001). The hydrocarbon potential of a lacustrine basin depends on the presence of favorable petroleum source rocks. One of the major problems in petroleum exploration is evaluating source rocks in low-explored lake basin which presently has limited geochemical data available for traditional petroleum source rock evaluation. Sedimentation rate can be determined by seismic reflection records in frontier basin where there is limited well control and petroleum exploration depends largely on the analysis and interpretation of seismic reflection records. The study of relationship between total organic carbon content (TOC) and sedimentation rate (SR) in ancient lacustrine basin has great significance for petroleum exploration in frontier lacustrine basin.

Relationship between TOC and SR had been studied for 40 years mainly in marine sediments (Betts and Holland, 1991; Coleman et al., 1979; Heath et al., 1977; Henrichs and Reeburgh, 1987; Ibach, 1982; Katz, 2005; Muller and Suess, 1979; Tyson, 2001). There are two opinions on the relationship in marine sediments. One view is that TOC tends to increase with increasing SR. Heath et al. (1977) and Muller and Suess (1979) defined the relation between TOC and SR for fine grained sediments in modern environments. It was demonstrated that TOC of recent marine sediments increases quantitatively with SR. Coleman et al. (1979) noted slow SR prolonged exposure time, decreased organic matter preservation and resulted in low TOC of marine fine grained sediments. He proposed that more rapid rates of sedimentation reduced the time spent in diagenetic zones by the organic matter, resulting in preservation of a higher TOC. Betts and Holland (1991) also concluded that the TOC is a function of SR, but this effect is the most pronounced in low SR. Little change in TOC was observed in their data set when SR exceeded 10 cm/ka. Since then, many researchers held the opinion that increasing SR

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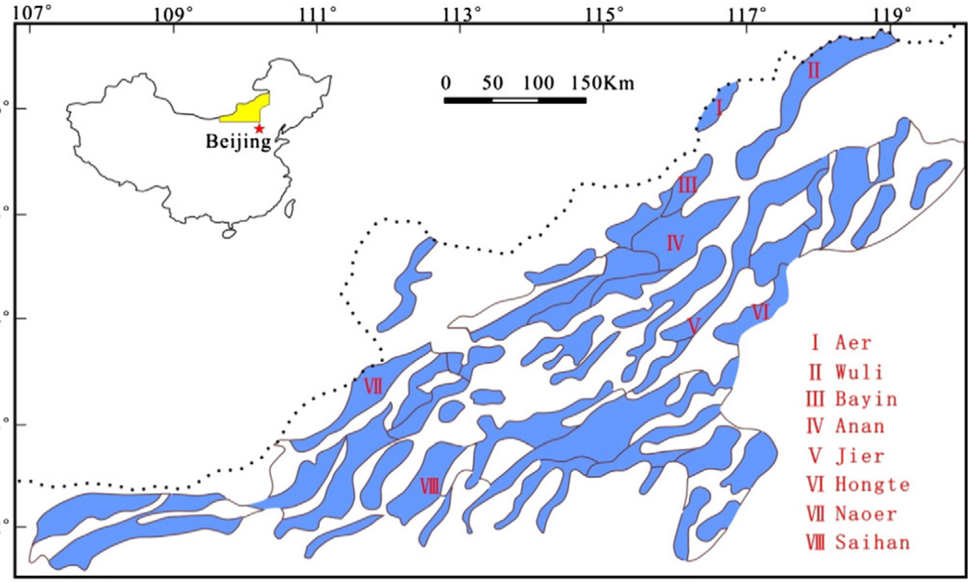

Fig. 1. Tectonic units of Erlian basin and the location of each study subbasin. The Erlian basin is an important oil prospecting basin, which is located on the northern China. This article focuses on the 8 subbasins: Aer, Wuli, Bayin, Anan, Jier, Hongte, Naoer and Saihan.

shortened degradation time of organic matter and yielded higher TOC content in sediments (Collins et al., 1995; Hartnett et al., 1998; Henrichs and Reeburgh, 1987; Keil et al., 1994a,b; Mayer, 1994, 1999, 2005; Ransom et al., 1998).

The second view is quite the opposite. Some researchers conclude that high SR has negative effects on the accumulation of organic matter because of the influence of clastic dilution. Clastic dilution occurs at high rates of sedimentation when the input of organic matter from primary

Table 1
Uniform SR and average TOC data from 111 wells, 8 subbasins, Erlian basin.
We selected sediment intervals which had the largest number of TOC analyses. The TOC analyses were averaged over each sedimentation interval. A uniform SR and an average TOC value for each sediment interval were generated.

Subbasin	Well	SR	TOC	Subbasin	Well	SR	TOC	Subbasin	Well	SR	TOC
Aer	Ae63	6.64	1.91	Bayin	B45	9.29	2.19	Jier	J38	3.84	2.3
Aer	Ae52	6.68	2.36	Bayin	B14	9.92	3.36	Jier	J43	5.26	2.44
Aer	Ae51	7.80	1.79	Bayin	B19	11.40	2.55	Jier	J85	5.70	2.16
Aer	Ae61	7.83	2.22	Bayin	B39	11.99	3.49	Jier	J19X	5.97	1.56
Aer	Ae2	8.75	1.81	Bayin	B6	12.94	2.83	Jier	J91	6.01	2.38
Aer	Ae13	8.95	2.45	Bayin	B21	14.14	2.84	Jier	J4	6.51	2.3
Aer	Ae6	9.00	2.17	Bayin	B35	14.31	2.11	Jier	J35	8.01	1.66
Aer	Ae62	9.45	2.25	Bayin	B57	14.83	2.99	Jier	J5	9.27	1.49
Aer	Ae1	9.66	2.03	Anan	An20	1.18	1.05	Naoer	N61	1.60	0.53
Aer	Ae3	10.14	1.7	Anan	An13	1.40	1.1	Naoer	N98	2.20	0.95
Aer	Ae5	12.05	2.74	Anan	An54	1.59	1.7	Naoer	N5	2.49	0.51
Wuli	T11	6.44	2.82	Anan	An62	3.47	1.6	Naoer	N19	2.90	1.2
Wuli	T3	9.05	3.2	Anan	An1	3.78	1.9	Naoer	N48	4.29	0.55
Wuli	T13	9.11	2.25	Anan	An2	3.89	1.5	Naoer	N33	4.58	0.55
Wuli	T25	10.00	1.94	Anan	An80	4.38	2.7	Naoer	N53	4.60	1.29
Wuli	T1	11.51	3.54	Anan	An82	4.44	1.6	Naoer	N21	5.08	2.14
Wuli	T6	13.21	3.19	Anan	An59	4.45	2.1	Naoer	N47	5.95	1.2
Wuli	T21	14.33	2.43	Anan	An68	5.05	2.1	Naoer	N9	6.20	1.17
Wuli	T59	14.51	2.46	Anan	An36	6.24	2	Naoer	N41	6.86	1.04
Wuli	T53	14.63	3.03	Anan	An3	6.65	2.1	Naoer	N97	6.97	0.94
Wuli	T51	14.93	1.83	Anan	An24	6.88	1.6	Naoer	N13	7.04	1.27
Wuli	T17	15.74	2.67	Anan	An16	7.23	1.7	Naoer	N1	8.44	0.56
Wuli	T2	17.10	2.69	Anan	An12	7.36	2.1	Naoer	N16	11.14	0.47
Wuli	T5	17.17	2.59	Anan	An18	9.08	1.8	Saihan	S20	2.09	1.17
Bayin	B23	5.42	2.16	Anan	An20	10.60	1.5	Saihan	S16	2.52	1.72
Bayin	B48	5.47	4.6	Hongte	H107	1.52	1.47	Saihan	S68	2.68	1.54
Bayin	B41	5.55	4.35	Hongte	H14	2.00	1.78	Saihan	S4	2.97	1.07
Bayin	B1	6.29	3	Hongte	H38	2.47	2.75	Saihan	S50	3.45	1.4
Bayin	B34	6.75	1.75	Hongte	H28	4.14	2.46	Saihan	S42	3.68	1.52
Bayin	B43	7.06	1.29	Hongte	H63	4.91	1.89	Saihan	S80	3.74	1.44
Bayin	B71X	7.11	3.95	Hongte	H20	4.93	2.17	Saihan	S12	3.87	1.44
Bayin	B5	7.21	3.45	Hongte	H2	5.75	2.31	Saihan	S66	4.32	1.53
Bayin	B9	7.38	2.73	Hongte	H61	7.75	1.94	Saihan	S71	5.47	1.74
Bayin	B15	7.68	2.33	Hongte	H36	9.05	1.37	Saihan	S23	5.79	1.38
Bayin	B10	7.78	3.27	Jier	J2	2.45	1.72	Saihan	S14	6.18	1.2
Bayin	B18	8.85	2.16	Jier	J1	3.68	1.95	Saihan	S1	6.68	1.26
Bayin	B2	8.95	2.85	Jier	J65	3.81	2.64	Saihan	S69	6.68	1.14

Note: SR = Uniform sedimentation rate of K_1t_1, cm/Ka; TOC = Average total organic carbon of K_1t_1, %.