煤系地层中有机质碳同位素组成特征

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提要　本文研究了我国几个含油气盆地中煤系地层干酪根碳同位素组成和氯仿抽提物族组份碳同位素组成特征. 研究结果表明, 在煤系地层中干酪根相对均较富集重碳同位素; 不同煤系地层中干酪根碳同位素组成差异不大. 煤系地层中可溶有机质烷烃、芳烃、非烃和沥青质的碳同位素组成与非煤系地层源岩中可溶有机质的碳同位素分布特征有明显的差别, 其分布特征不是随着族组份极性的增加而逐渐富集重碳同位素, 而是烷烃组份相对其它三个组份明显富集轻碳同位素; 芳烃组份相对非烃要稍富集重碳同位素. 煤系地层中有机质碳同位素组成与现代沼泽沉积中的有机碳同位素组成存在明显的差别.

关键词　碳同位素　煤系地层　干酪根　氯仿抽提物

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引　言

近年来由于煤成气理论的提出, 更加重视了对煤系地层的研究, 对煤系地层中有机质碳同位素的研究前人已做了一些工作, 国内外都有报道 (Compston, 1960; Rigby, 1981; Smith J.W., 1982; Xu et al, 1989) . 为了更进一步了解煤系地层中有机质的碳同位素组成特征, 笔者对我国海陆过渡环境形成的陕甘宁盆地石炭—二叠系, 濮阳坳陷石炭—二叠系和四川盆地三叠系的煤系地层及内陆沼泽环境形成的陕甘宁侏罗系的煤系地层中干酪根和氯仿抽提物族组份的碳同位素组成进行了研究.

本文中 $\delta^{13}C$ 值为相对 PDB 标准, 分析误差为 ±0.1%.

一、煤系地层中干酪根的同位素组成特征

表1中列出陕甘宁盆地侏罗系延安组煤系地层中不同岩性—泥岩、碳质泥岩和煤的干

表1　陕甘宁盆地侏罗系延安组含煤地层中干酪根碳同位素组成

Table 1　$\delta^{13}C$ of kerogen in coal–bearing strata of Jurrasic Yan'an Formation, Shaan–Gan–Ning Basin

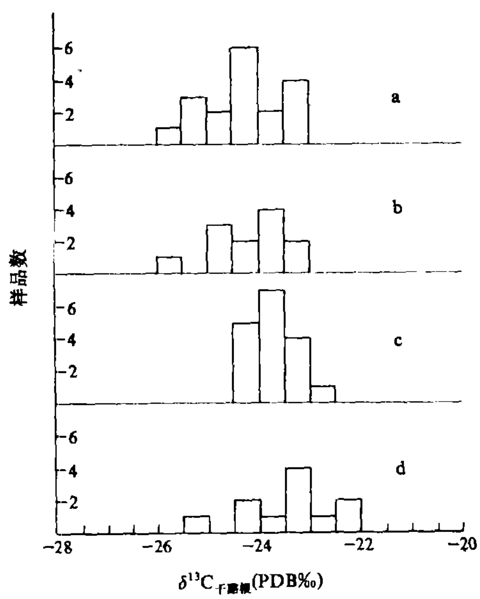
样号	岩性	$\delta^{13}C$ (‰PDB)	样号	岩性	$\delta^{13}C$ (‰PDB)
SJ01	泥岩	−22.3	SJ07	碳质泥岩	−23.1
SJ02	泥岩	−24.1	SJ08	碳质泥岩	−23.2
SJ03	泥岩	−23.5	SJ09	碳质泥岩	−22.3
SJ04	泥岩	−25.5	SJ10	碳质泥岩	−23.7
SJ05	泥岩	−24.5	SJ11	煤	−23.5
SJ06	泥岩	−22.4	SJ12	煤	−22.9

酪根碳同位素值. 从表中可以看出，在煤系地层中无论是泥岩、碳质泥岩还是煤及其干酪根均是相对富集重碳同位素. 其 δ^{13} 值分布范围为−25.5——22.3%. 三种不同岩性的样品中干酪根碳同位素组成没有明显的差别.

笔者所研究的几个含油气盆地煤系地层中干酪根碳同位素组成如图 1 所示，从图中可知不同煤系地层中干酪根碳同位素组成差别不大，相对均较富集重碳同位素，其 δ^{13}C 值的分布范围为−21.5——26.0‰.

二、煤系地层中可溶有机质碳同位素组成特征

对非煤系地层源岩中可溶有机质的碳同位素组成研究表明，其抽提物族组分碳同位素分布特征是：随着族组分极性的增加从烷烃、芳烃、非烃到沥青质依资富集重碳同位素. 而煤

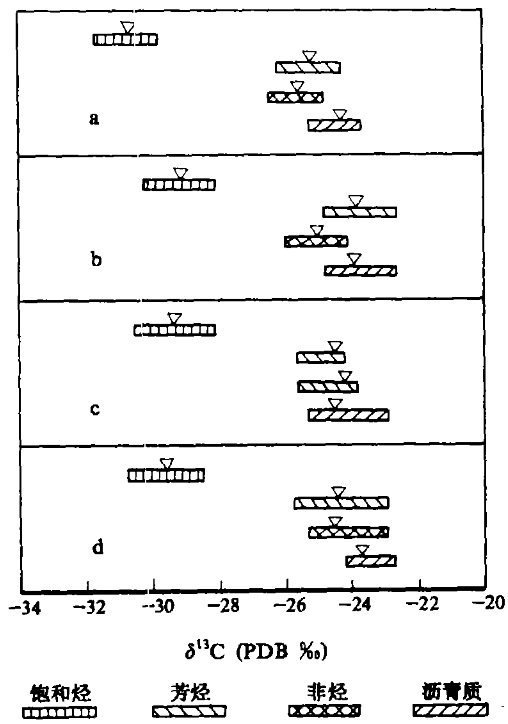


a.陕甘宁 C−P　b.东濮 C−P　c.四川中坝 Tx

d.陕甘宁 Jy

图 1　煤系地层中干酪根碳同位素分布

Fig. 1 Distribution of carbon isotope in coal−bearing strata



a.四川盆地中坝 Tx　b.东濮 C−P　c.陕甘宁 C−P

d.陕甘宁 Jy

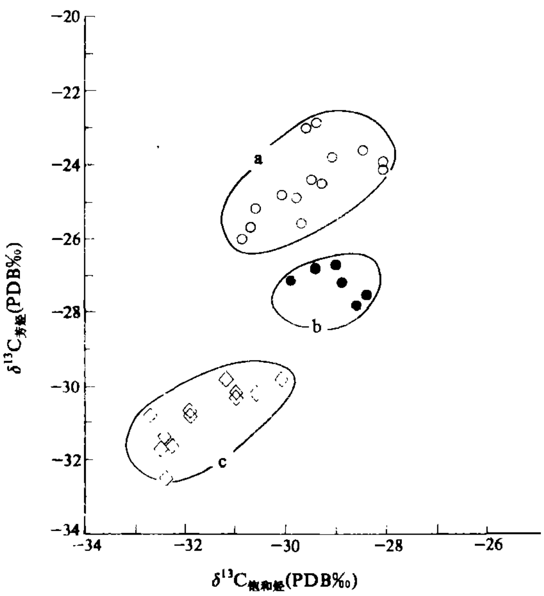
图 2　煤系地层中抽提物族组分碳同位素组成

Fig. 2　Carbon isotopic distribution in fractions of stracts

系地层氯仿抽提物族组份碳同位素组成分布特征与非煤系地层不同，如图 2 所示，从图中可以看出在煤系地层中氯仿抽提物族组分的碳同位素组成不是从烷烃到沥青质随着族组份极性的增加而

逐渐富集重碳同位素，其分布特征是烷相对其它三个组份明显地富集轻同位素，芳煤相对非烃要稍富集重碳同位素.

图3为我国几个含油气盆地源岩氯仿抽提物族组分烷烃—芳烃碳同位素组成关系图. 从图中可以清楚地看出煤系地层中抽提物烷烃芳烃的碳同位素组成与非煤系地层有明显的差别.



a.煤系地层　b.盐湖沉积　c.淡水湖盆

图3　煤系地层和非煤系地层抽提物族组烷烃—芳烃碳同位素组成关系图

Fig. 3　Carbon isotopic distriboltion in alkane and aromatic fractions of coal—bearing and non—coal—bearing strata

三、煤系地层中有机质碳同位素组成特征与原始有机光质碳同组成的关系

在煤和煤系地层中有机质类型均为Ⅲ型干酪根、其原始有机先质主要为陆源高等植物. 对现代生物的碳同位素组成研究表明高等植物的碳同位素组成分布范围较大，$\delta^{13}C$ 值从−5‰到−35‰（Schidlowski 等，1983）. 陈践发等（1986）对沼泽环境的主要植被和泥炭的碳同位素研究表明、沼泽环境中的优种植物 $\delta^{13}C$ 值为−25.4～−29.1‰，泥炭的 $\delta^{13}C$ 值为−27.5～−29.0‰，依据和煤系地层主要为沼泽环境形成的观点，可见煤系地层中有机质的碳同位素组成与现沼泽环境中的植物和沉积物中的碳同位素组成存在明显的差异. 即现代沼泽环境中有机质的碳同位素组成与古代沼泽环境形成的煤系地层的碳同位素组成不能直接进行对比，笔者认为造成这种差别的原因主要是由于沉积物中的有机质在埋藏过程中富含轻同位素的基团和化合物优先分解，残留部分由于芳构化程度增强而富集重碳同位素. 大量的研究结果表明腐殖型有机质从未成熟阶段(褐煤阶段)到高成熟阶段(无烟煤阶段)，其碳同位素组成随成熟度的增加无明显的变化. 也就是说泥炭在埋

藏成煤过程中主要是从泥炭到褐煤阶段明显地富集了重碳同位素.

Deines (1980) 研究了植物中不同化学组分的碳同位素组成，发现在不同组分中脂类化合物相对明显富集轻同位素，而木质素，半木质素，酸类和果胶等相对富集重碳同位素. 将煤系地层可溶有机质烷烃、芳烃、非烃、沥青质的碳同位素分布特征与 Deines 的研究结果对比可知，煤系地层中可溶有机质族组分中烷烃相对非常富集轻碳同位素的这种分布特征明显地继承了其有机先质的碳同位素分布特征. 煤系地层中可溶有机质芳烃相对富集重碳同位素的特征主要是由于煤系地层中芳烃类化合物为多环芳烃为主.

结 论

1. 在煤系地层中分散状态的有机质（泥岩中的有机质）和煤中的有机质碳同位素组成没有明显的差别.

2. 笔者所研究的煤系地层中干酪根均较富集重碳同位素，其 $\delta^{13}C$ 值分布范围为−26°—−21.5‰.

3. 煤系地层中氯仿抽提物族组份的碳同位素与非煤系地层有明显不同的分布特征. 煤系地层中的分布特征为烷烃相对其它三个组份非常富集轻碳同位素；芳烃相对非烃要稍富集重碳同位素.

4. 煤系有机质的碳同位素从泥炭到褐煤阶段明显地富集了碳的重同位素.

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Characteristic of Organic Carbon Isotope Composition in Coal-bearing Strata

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Abstract

In recent years, more and more geologists have accepted the view that coal and coal-bearing sequence may be an important source rock of oil and natrural gas. This paper discusses the organic carbon isotopic composition variation in coal and coal-bearing sequence witch considered to be potenual source rock in Shaan-Gan-Ning Basin, Sichun Basin and Puyang Basin, China. The coal-bearing sequenc in Sichun Basin is Triassic paralic deposits, with 0.8 to 1.2% of vitrinite reflectance. The Carboniferous to Permian coal-bearing sequence in Puyang Basin and Shaan-Gan-Ning Basin are deposited in paralic environment, with a higher than 1.5% of vitrinite refelectance. The Jurassic coal-bearing sequence of Shaan-Gan-Ning Basin is marsh deposits, with a 0.6 to 0.9% of vitrinite reflectance.

From the detail $\delta^{13}C$ values of kerogen in Jurassic coal-bearing sequence in Shaan-Gan-Ning Basin, it can be shown that the carbon isotope composition of kerogen of different lithotype (mudstone, carbonaceous rock and coal) in coal-bearing sequence varies sightly. Base on our result, the carbon isotope cmposition of kerogen in the four different coal-bearing sequences are not sizable different. They are all relatively enriched in heavy isotope. The range of $\delta^{13}C$ value of kerogen is between -26.0 to -22.0‰, with a -25.0 to -23.0‰ of mainly range. In the other words, the maturity of organic matter inconsiderably influence the carbon isotope composition of kerogen in coal-bearing sequence; and also the carbon isotope composition of kerogen from the coal-bearing sequence formed in different sedimentary environment——marsh and paralic environment is not significantly different.

A great deal of work has been done on the carbon isotopic composition of extract and extracts fractions of non-coal bearing source rock, and it was proposed that the fractions of extract from saturate to aspheltene graduatel enriched in heavy carbon isotope with increasing polarity of fractions. However, the characteristics of carbon isotope composition of extract from coal-bearing sequence sizably diflfer from non-coal-bearing source rock. Base on the result, it can be shown that in the extracts of coal-bearing strata the saturate is strongly eniched in lighter isotope composition relative to other fractions, the aromatic is lightely enriched in heavey isotope relative to NSO.

It is considered that coal and coal-bearing sequence formed in marsh or paralic sedimentary enviroment. It is known from this research that the carbon isotope of kerogen in coal-bearing strata considerably differ from the carbon isotopic composition of kerogen present in recent marsh. The former is significantly rich in heaver isotope.