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古生物在下古生界烃源岩有机质成熟度研究中的重要作用*

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中文提要　对江苏下古生界动物化石有机碎屑(笔石、胞石和虫牙)反射率进行系统研究的结果表明,它们与镜质组反射率有着极为相似的光性特征和变化规律,即随埋深的增加而增高,因而它们均可作为有机质成熟度指标;并进而以牙形刺色变指标(CAI)为纽带,分别建立它们与镜质组反射率之间的良好对应关系,提出它们的成熟度划分标准,为它们的实际应用奠定基础。

关键词　牙形刺 CAI　动物化石有机碎屑　反射率　有机质成熟度　下古生界　江苏

IMPORTANCE OF ZOOLITE DEBRIS IN THE STUDY OF ORGANIC MATURITY OF HYDROCARBON-SOURCE ROCKS FROM LOWER PALEOZOIC

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Abstract　The reflectances of zoolite organic debris (including graptolites, chitinozoans and scolecodonts) from Lower Paleozoic in Jiangsu are well studied in this paper. The results show that they have extremely similar optical properties and variational regularities with vitrinite reflectances, that is, their reflectances increase with increasing of depth, thus, they all can be served as good indexes of organic maturity. Furthermore, the correlations between them and vitrinite reflectances are established respectively by using conodont CAI as a link, therefore, the criteria of their maturity are given, which has laid the foundations for their actual application.

Key words　conodont CAI, zoolite organic debris, reflectance, organic maturity, Lower Paleozoic, Jiangsu

INTRODUCTION

Evaluating organic maturity of hydrocarbon-source rocks from Lower Paleozoic is still a difficult problem in the study of oil-gas at present. The focus is how to establish the index of evaluating organic maturity. It is well known that the vitrinite reflectance is the universally accepted index in this regard, but it can not be applied to Lower Paleozoic for the general lack of vitrinite. For the same reason, spore-pollen color alteration index (SCI) which is another index of judging organic maturity can not be applied either to this period because it is determined generally by taking spores and pollen of higher plant as the object of statistics. So it is necessary to find out some replacing objects as indexes of evaluating organic maturity in Lower Paleozoic. Especially, advances in exploration of oil-gas and constant discovering of industrial oil-gas pool in Paleozoic in recent years have made this study very important economic significances and a prior task of oil-gas exploration at present.

Usually, there are zoolite organic debris including graptolites, chitinozoans, scolecodonts and conodonts in hydrocarbon-source rocks of Lower Paleozoic. They were

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undoubtedly protogenic as they were parts of marine animals, and have been subjected to the whole course of thermal alteration of hydrocarbon-source rocks. Some internal and external research workers have begun to study the optical characters of zoolite organic debris including graptolites, chitinozoans and scolecodonts since the eighties (Bertrand *et al*., 1987; Bertrand, 1990; Goodarzi *et al*., 1987; Goodarzi *et al*., 1992; Wang Xiaofeng *et al*., 1992; Xiao Xianming *et al*., 1995; Zhong Ningning and Qin Yong, 1995; Jin Kuili *et al*., 1997; Zhu Youhua, 1998; Zhu Youhua *et al*., 1998; Qi Yuping *et al*., 1998). The studies show that their microoptical characters may be used in evaluating organic maturity.

VARIATION REGULARITIES AND CORRELATIONS OF REFLECTANCES OF ZOOLITE ORGANIC DEBRIS

It has been over forty years since the beginning of petroleum exploration in the Lower Yangtze Valley in Jiangsu, and there are systematic materials of tens of cores drilling through marine Mesozoic and Paleozoic. We have accumulated abundant firsthand fossil materials, thus, the study of reflectances of zoolite organic debris in this area is of very good conditions. The authors (1998) discovered that there are very good correlative relations between the depths and reflectances of graptolites (GRo), chitinozoans (CRo) and scolecodonts (SRo), and that their reflectances increase with the increasing of depths respectively in several systematic wells from this area (Tab. Ⅰ) and can be served as good indexes of maturity.

Nearly 200 samples of this area have been analysed, and the reflectances of 25 correlative samples (Tab. Ⅰ) have been obtained, thus, the correlations of reflectances between graptolites and chitinozoans (Text-fig. 1), graptolites and scolecodonts (Text-fig. 2), chitinozoans and scolecodonts (Text-fig. 3) are established respectively according to the Tab. Ⅰ, and the regression equations are:

$$CRo = 1.0305GRo + 0.1652 \quad (1)$$

(correlative coefficient: $R = 0.99$)

$$SRo = 1.006GRo - 0.0585 \quad (2)$$

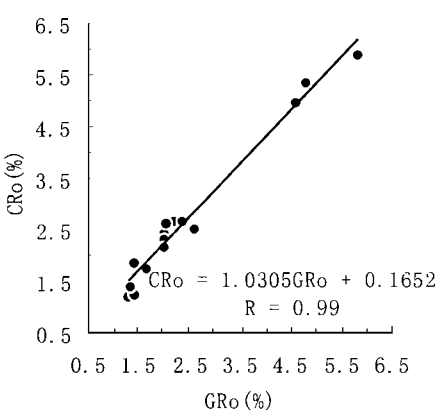
(correlative coefficient: $R = 0.93$)

$$SRo = 1.0436CRo + 0.1389 \quad (3)$$

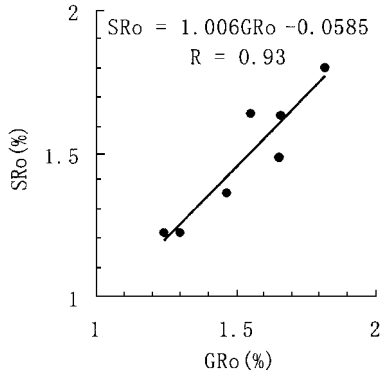
(correlative coefficient: $R = 0.99$)

Tab. Ⅰ　Data of reflectances of graptolites, chitinozoans and scolecodonts

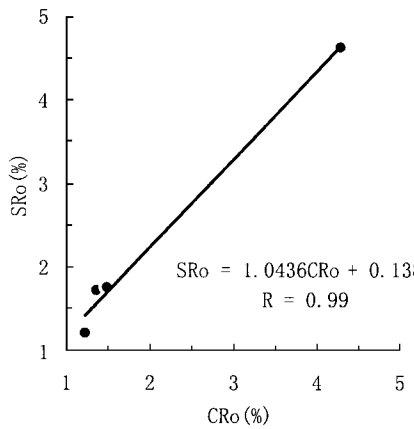
well	depth (m)	strata	graptolites GRo(%)	chitinozoans CRo(%)	scolecodonts SRo(%)
Nc2	2519.80-2519.96	$S_{1-2}f$	1.664		1.630
	2540.0	$S_{1-2}f$	1.413	1.556	
	2606.0	$S_{1-2}f$	1.467	1.715	1.358
	2650.75	$S_{1-2}f$	1.554		1.638
	2884.0	$S_{1-2}f$	1.817		1.799
S1	2443.06	S_1g	1.392	1.240	
	2445.20	S_1g	1.347	1.369	
D3	2890	S_1g	1.954	2.175	
D2	3000.1-3005.6	S_1g	2.000	2.150	
N4	2501.11-2504.60	S_2m	1.242		1.222
	2547.80	S_2m	1.300	1.208	1.221
	3039.50	S_1g	1.982	2.291	
	3108.50	S_1g	2.044	2.611	
	3325.69	S_1g	2.350	2.673	
S174	2430.38	S_1g	1.654	1.747	1.485
Nc4	2451.72	S_1g		4.608	4.294
Zc1	4386.73	S_1g	2.257	2.570	
X24	2064.50	O_3w	2.197	2.640	
	2162.96	O_3w	2.583	2.830	
Xg1	3360.01	S_1g	4.606	4.961	
	3586.54	S_1g	4.812	5.357	
	3604.95	S_1g	5.832	5.884	
R8	1454.6	S_1g	1.407	1.847	
	1841.9	S_1g	1.949	2.412	
	1844.3	S_1g	2.002	2.414	



Text-fig. 1　The correlation of reflectances between graptolites and chitinozoans



Text-fig. 2 The correlation of reflectances between graptolites and scolecodonts



Text-fig. 3 The correlation of reflectances between chitinozoans and scolecodonts

Obviously, there are good positive correlative relations among them.

CORRELATIONS OF REFLECTANCES BETWEEN ZOOLITE ORGANIC DEBRIS AND VITRINITES

The vitrinite reflectance (VRo) is the universally accepted comparable index of evaluating organic maturity at present, and by this criterion most other indexes of maturity adopted presently have been established, therefore, the reflectances of zoolite organic debris can really play active roles in the study of organic maturity of hydrocarbon-source rocks from Lower Paleozoic provided that the reflectances of graptolites, chitinozoans and scolecodonts are also compared with it and the correlations between them are established, but these correlations couldn't be established directly because they are restricted by the objective geological conditions, thus, many internal and external research workers have made unremitting efforts to study them in many ways since long ago in order to solve the difficult problem. For example, Bertrand (1990) studied the correlations between vitrinite reflectances and reflectances of graptolites, chitinozoans and scolecodonts by using bitument reflectances as a link; Wang Xiaofeng *et al*. (1992) studied the correlations between equivalent vitrinite reflectances and reflectances of graptolites and chitinozoans; Xiao Xianming *et al*. (1995) studied the correlation of reflectances between graptolites and vitrinites; Zhong Ningning and Qin Yong (1995) recognized that the correlation of reflectances between graptolites and vitrinites could be established by using desmoalginite reflectances as a link, which was the correct way in establishing the comparable index of maturity of zoolite organic debris; etc.. However, because that the bitument reflectance itself is affected by many factors and that the accuracy and reliability of equivalent vitrinite reflectance should be further verified, therefore, this problem hasn't been solved very well up to now.

The study of conodont CAI has been held in honour internationally, particularly in oil companies. It may be used as an index of organic maturity especially in marine strata without vitrinite, thus, conodont CAI is also the universally accepted index of organic maturity. We recognized that it should be a more direct and more reliable way that the correlations of reflectances between zoolite organic debris and vitrinites would be established by using conodont CAI as a link.

Qi Yuping *et al*. (1998) established the correlation between conodont CAI and vitrinite reflectance (VRo) in the article of "The correlation between conodont color alteration index (CAI) and vitrinite reflectance (Text-fig. 4)", the formula is:

$$VRo = 0.6175CAI - 0.1832 \quad (4)$$

(correlative coefficient: $R = 0.99$)

Zhu Youhua *et al*. (1998) established the correlation between graptolite reflectance (GRo) and conodont CAI (Text-fig. 5) in the article of "Study of reflectance for the graptolites from Lower Yangtze Region in Jiangsu, E China", the formula is:

$$GRo = 1.3048CAI - 0.7092 \quad (5)$$

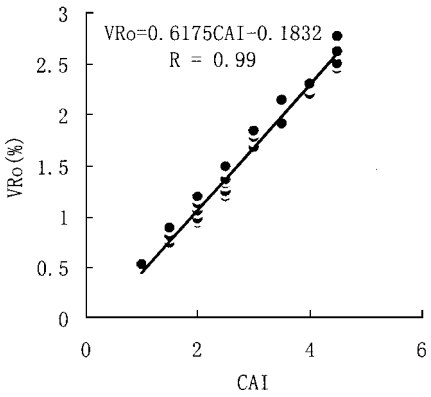
(correlative coefficient: $R = 0.96$)

The correlation of reflectances between graptolites and vitrinites (Text-fig. 6) may be reckoned from the former formula (4) and (5), the formula is:

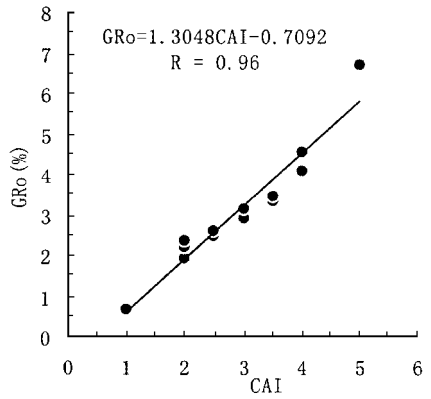
$$GRo = 2.113VRo - 0.3221 \quad (6)$$

Then, the correlation of reflectances between chitinozoans and vitrinites (Text-fig. 7) may be gotten according to the former formula (1) and (6), the formula is:

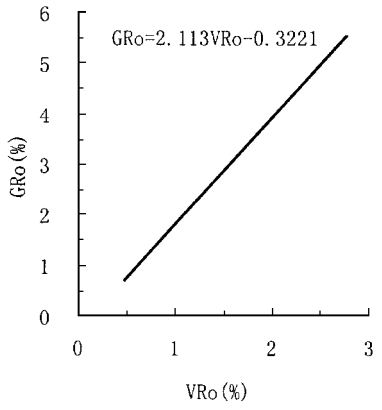
$$CRo = 2.1774VRo - 0.1667 \quad (7)$$



Text-fig. 4　The correlation between conodont CAI and vitrinite reflectance



Text-fig. 5　The correlation between graptolite reflctance and conodont CAI

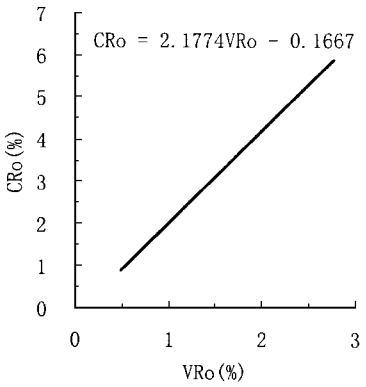


Text-fig. 6　The correlation of reflectances between graptolites and vitrinites

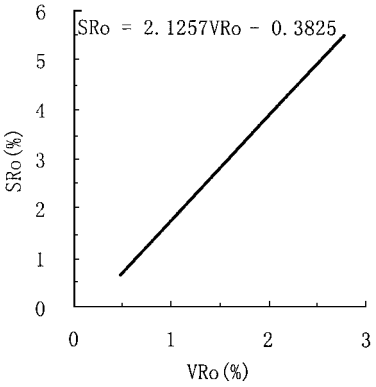
The correlation of reflectances between scolecodonts and vitrinites (Texit-fig. 8) may be gotten according to the former formula (2) and (6), the formula is:

$$SRo = 2.1257VRo - 0.3825 \quad (8)$$

It is seen that the reflectances of graptolites, chitinozoans and scolecodonts all are of good positive correlative relations with vitrinite reflectances, and that each of them has its own evolving track of reflectances. The chitinozoan reflectances are higher than that of graptolites, and the graptolite reflectances are higher than that of scolecodonts under the conditions of same maturity.



Text-fig. 7　The correlation of reflectances between chitinozoans and vitrinites



Text-fig. 8　The correlation of reflectances between scolecodonts and vitrinites

Generalizing the above study results, we have established the correlations among the reflectances of graptolites, chitinozoans and scolecodonts, conodont CAI, vitrinite reflectances and the maturity of hydrocarbon-source rocks as follows (Tab. Ⅱ).

Tab. Ⅱ The correlations among the reflectances of graptolites, chitinozoans and scolecodonts, conodont CAI, vitrinite reflectances and the maturity of hydrocarbon-source rocks

GRo(%)	CRo(%)	SRo(%)	CAI	VRo(%)	maturity	Stages of the hydrocarbon generation
0.7—2.5	0.9—2.7	0.7—2.4	1.0—<2.5	0.5—1.3	maturity	oil
2.5—4.0	2.7—4.2	2.4—3.9	2.5—<4.0	1.3—2.0	high maturity	wet gas, condensate
>4.0	>4.2	>3.9	≥4.0	>2.0	over maturity	dry gas

CONCLUSIONS

Our studies show that the reflectances of graptolites, chitinozoans and scolecodonts and vitrinite reflectances have extremely similar optical properties and variational regularities, that is, their reflectances increase with increasing of maturity. Furthermore, the former value extents are broader than those of the latter, hence, their reflectances are good indexes of evaluating maturity. The correlations of reflectances between zoolite organic debris and vitrinites established by using conodonts CAI as a link have laid the foundations for actual application of the reflectances of zoolite organic debris. Moreover, the correlations of reflectances among graptolites, chitinozoans and scolecodonts may make complement each other, therefore, these results are of important values of actual application for the study of organic maturity of hydrocarbon-source rocks and oil-gas exploration of Lower Paleozoic, and of good social economic results.

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