CHARACTERIZATION OF RESIDUAL KEROGENS AND THE PORES IN SHALE ROCKS DURING THERMAL EVOLUTION

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During the past few years the exploration and development of shale gas has achieved great success in China. Much effort has been made to investigate the shale gas, and many key issues have been resolved. The evolution features of pores in shale rocks associated with residual kerogens are still poorly understood, while these are crucial for the evaluation, exploration and development of shale gas. In this work one low-mature shale sample from Middle Permian Lucaogou Formation in the Santanghu Basin, Xinjiang was selected. A series of semi-closed pyrolysis experiments were carried out, to investigate the evolution characteristics of pores and organic matter in shale rocks.

The geochemical information of the shale sample is listed in Table 1. The *TOC* value of the sample is very high and the R_o is low. The semi-closed experiments were carried out using bulk shale rock samples at 320, 350, 380, 420 and 450 ℃/50MPa for 72 h, respectively. A part of the pyrolysis sample was directly observed using scanning electron microscope (SEM), and the remains were extracted by dichloromethane and then analysed by SEM.

Table 1 The geochemical information of the shale sample used in this work

Sample	R_o (%)	T_{max} (℃)	TOC (%)	S_1+S_2 (mg/g)	I_H (mg/g)	I_O (mg/g)
P	0.52	439	10.97	60.69	564	45

The results showed that three forms of OM (organic matters) can be identified: OM in micron-scale intergranular space (OM_{inter}^m), OM in nano-scale intergranular space (OM_{inter}^n) and OM in micron-scale intragranular space (OM_{intra}^m). The OM_{inter}^m and OM_{intra}^m have been pyrolyzed at 0.82 %EasyR_o. OM_{inter}^m has disappeared at 1.45 %EasyR_o, but OM_{intra}^m still has hydrocarbon generation potential. OM_{inter}^n have been pyrolyzed at 1.45 %EasyR_o, and maybe still has hydrocarbon generation potential at 2.66 %EasyR_o. In addition, some OM were hardly affected by thermal stress.

Four types of pores can be identified: Shrinkage OM pore, interparticle mineral pore, intraparticle pore and OM pore (Figure 1). The results from the SEM image of extraction and unextraction shale rocks showed that the abundance and size of the shrinkage OM pore increased from 0.52%R_o to 1.08%$EasyR_o$, then the shrinkage OM pore translated to interparticle mineral pore due to the OM_{inter}^m consumption at 1.45%$EasyR_o$. OM pores can be grouped into the primary and secondary OM pores. The primary OM pore was independent of maturity, while the secondary OM pores cannot develop until the $EasyR_o$ of 0.82%. The abundance and size of interparticle mineral pore increased fast at 1.45%$EasyR_o$. The abundance of intraparticle pore gradually increased from 0.82%$EasyR_o$ to 2.66%$EasyR_o$, maybe resulted from the enhancement of mineral dissolution in rocks with thermal maturity.

There are three types of OM occurrence patterns in shale rocks, and the evolution of these OM are different from each other. The $OM_{inter}{}^{m}$ is the most susceptible to thermal stress, followed by $OM_{intra}{}^{m}$ and $OM_{inter}{}^{n}$. The secondary OM pore can be formed at 0.82%*EasyRₒ*, but there is no obvious correlation between the development of this kind of pores and shale rock maturity.

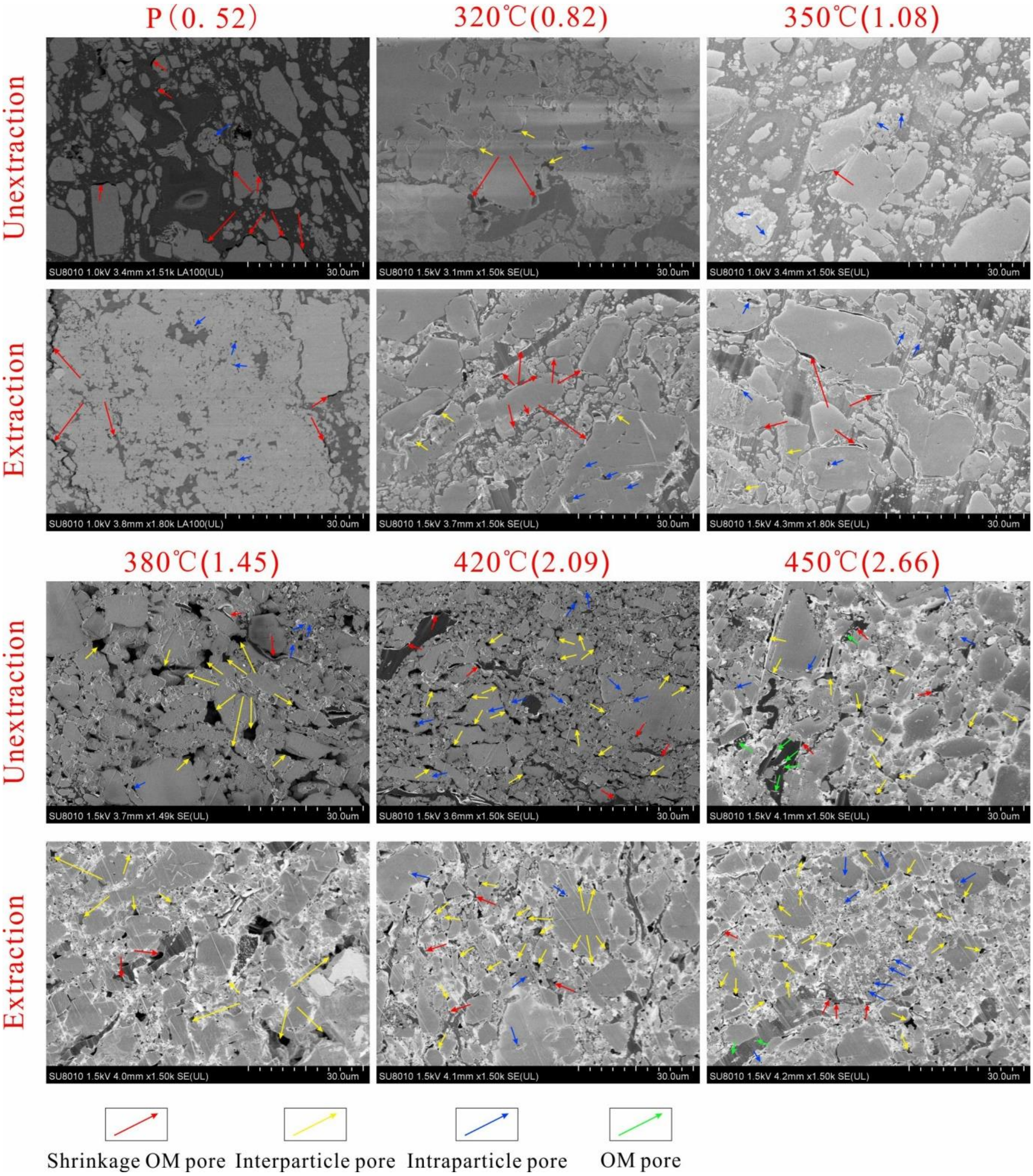

***Figure 1** The SEM images showing the evolution characteristics of pores in shale rocks from the pyrolysis experiments in this work (data in the parentheses showed the values of EasyR$_o$).*