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## Evaluation Indexes for High Quality Shale Reservoir of Lower Silurian Longmaxi Formation in Southeast Chongqing

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### 1 Introduction

High quality shale reservoirs are considered economically recoverable. Determination of evaluation indexes for high quality shale reservoirs is crucial to shale gas exploration and exploitation in China, where shale gas exploration and exploitation just started. Total organic content, quarts content, porosity and permeability, thickness and gas content are the main evaluation indexes for high quality shale reservoir of lower Silurian Longmaxi formation in Southeast Chongqing, the lower limits of which are determined by comparative analysis of geological indexes and production data of high production interval and low production interval of well QianYe 1 preliminarily.

### 2 General Information about Well QianYe 1

Well QianYe 1 is located at Ceshan Village, or at northeast axial of Sangtuoping syncline in Southeast Chongqing tectonically, its drilling formation is upper Ordovician Wufeng formation- lower Silurian Longmaxi formation. Well logging interpretation of well QianYe 1 unfolds 3 shale intervals, the thickness of which is 74.8m totally. The first interval is 727m-748m in depth, the second interval is 748m-792m in depth, the third interval is 792m-801.8m in depth. Production logging data indicates that the third interval has the highest production, it contributes 73.5% of the total production. The second interval contributes 25.5% of the total production. The first interval has the lowest production, it only contributes 1% of the total production. If the geological indexes of a target

formation are better than the third interval of well QianYe 1, the target formation will has preferable economic exploitation value. So, the paper below will determine the lower limits of each evaluation index according to the main geological indexes of the third interval of well QianYe 1.

### 3 Determination of Lower Limits of the Evaluation Indexes

#### 3.1 Total organic content

Total organic content is a key factor that influences gas bearing, it determines shale gas content. Total organic content test result of Longmaxi formation of well QianYe 1 indicates that total organic content of the first interval is in the range of 0.57%-2.03%, with an average of 1.3%. Total organic content of the second interval is in the range of 0.5%-1.5%, with an average of 1.0%. Total organic content of the third interval is in the range of 1.3%-4.4%, with an average of 3.2%. The third interval has a much higher total organic content than the other two intervals, which echoing the production logging data that the third interval contribute 73.5% of the total production. Based on the above, the lower limit of total organic content for high quality lower Silurian Longmaxi shale in southeast Chongqing is determined by 3.2%.

#### 3.2 Quarts content

Quarts are the main brittle mineral in shale reservoirs. Quarts content influences the development of natural fractures, which are important for gas enrichment and the formation of hydraulic fractures. In 2014, the ministry of Land and Resources issued «Requirements for shale gas resources/ reserves calculation and evaluation», which specified that shale reservoir with a brittle mineral content

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**Table1 Characteristics of evaluation indexes of each interval of well QianYe 1**

Interval	Production contribution (%)	Total organic content (%)		Quarts content (%)		Porosity (%)	Permeability (nD)	Gas content(m <sup>3</sup> /t)	
		Range	Average	Range	Average			Range	Average
First	1	0.57%-2.03	1.3	33%-47	41.4	--	--	0.2-1.02	0.67
Second	25.5	0.5%-1.5	1.0	41%-56	47.9	--	--	0.34-1.43	0.82
Third	73.5	1.3%-4.4	3.2	45%-70	54.4	4.17	186	0.63-2.0	1.46

**Table 2 Gas content of different shale reservoirs in China and the US**

Basin	Age	Unit	Gas content (m <sup>3</sup> /t)	
			Range	Average
Si Chuan	Silurian	Longmaxi	First interval	0.2-1.02
			Second interval	0.34-1.43
			Third interval	0.63-2.0
Fort Worth	Carboniferous	Barnett	--	8.49-9.91
Appalachian	Devonian	Ohio	--	1.69-2.83
Michigan	Devonian	Antrim	--	1.1-2.83
Illinois	Devonian	New Albany	--	1.13-2.26
Fort Worth	Cretaceous	Lewis	--	0.4-1.27

that above 30% will have preferable hydraulic effect. Harding Shelton had given a standard for China preferable shale reservoirs selection, in which the quarts content for preferable shale reservoirs is above 35%. Li Yanjun[1] had researched lower Paleozoic Longmaxi shale in southern Sichuan basin, he also thought than the lower limit of quarts content for shale that had preferable brittleness was above 35%, which was preferable for fracture formation and hydraulic fracture treatment. Experimental data for Longmaxi shale samples of well QianYe 1 indicates that quarts content of the first interval is in the range of 33%-47%, with an average of 41.4%. Quarts content of the second interval is in the range of 41%-56%, with an average of 47.9%. Quarts content of the third interval is in the range of 45%-70%, with an average of 54.4%. Even the lowest average quarts content of the first interval is much higher than the above quarts content standards. So, quarts content of the first interval of well QianYe 1 is preferable for natural fracture and hydraulic fracture formation in Lower Silurian Longmaxi shale reservoir. Based on the above, the lower limit of quarts content for high quality Lower Silurian Longmaxi shale in southeast Chongqing is determined by 41%.

### 3.3 Porosity and permeability

Shale reservoirs are tight, matrix pores of which are mainly nano-pores. Therefore, its porosity and permeability are low. Experimental data indicates that the third interval has the highest porosity and permeability, which echoing its much higher shale gas production. Shale of the third interval has an average porosity of 4.17% and an average permeability of 186nD. Based on the above, the lower limits of porosity and permeability for high quality lower Silurian Longmaxi shale are 4.2% and 180nD respectively.

### 3.4 Thickness of high quality shale reservoirs

Thickness of high quality shale interval determined well production. Thickness data of preferable shale reservoir found in previous studies is mainly from theoretical analysis and foreign statistical data, which may not be suitable for southeast Chongqing. Production of the third interval of well QianYe 1 is 2205m<sup>3</sup>/d. Therefore, shale reservoirs that have economic recoverable value need a thickness above 22m. Based on the above, the lower limit of high quality shale thickness for lower Silurian Longmaxi shale in southeast Chongqing is determined by 22m.

### 3.5 Gas content

Gas content is a key parameter for shale reservoir evaluation, it directly affect economic recoverable value. Total gas content data of shale reservoirs in the US is obtained from papers on line, these shale reservoirs are Carboniferous Barnett shale in Fort Worth basin, Devonian Ohio shale in Appalachian basin, Devonian Antrim shale in Michigan basin, Devonian New Albany shale in Illinois basin, Cretaceous Lewis shale in Fort Worth basin respectively. Gas content of these shale reservoirs are 8.49m<sup>3</sup>/t-9.91m<sup>3</sup>/t, 1.69m<sup>3</sup>/t -2.83m<sup>3</sup>/t, 1.1m<sup>3</sup>/t -2.83m<sup>3</sup>/t, 1.13m<sup>3</sup>/t -2.26m<sup>3</sup>/t, 0.4m<sup>3</sup>/t -1.27m<sup>3</sup>/t respectively. Gas content of Lewis shale is smaller than the other four shale reservoirs, the lower limits of the other four shale reservoirs are all above 1.1m<sup>3</sup>/t.

Gas content data from logging interpretation of well QianYe 1 indicates that gas content of the first interval is 0.2m<sup>3</sup>/t -1.02m<sup>3</sup>/t, with an average of 0.67m<sup>3</sup>/t. Gas content of the second interval is 0.34m<sup>3</sup>/t -1.43m<sup>3</sup>/t, with an average of 0.82m<sup>3</sup>/t, gas content of the above two intervals is all below 1m<sup>3</sup>/t. Gas content of the most productive interval ( third interval) is 0.63m<sup>3</sup>/t-2.0m<sup>3</sup>/t, with an average of

1.46m<sup>3</sup>/t, which is above 1m<sup>3</sup>/t. Combined with gas content data of shale reservoirs in the US and well QianYe 1, lower limit of gas content for lower Silurian Longmaxi shale in southeast Chongqing is determined by 1.5m<sup>3</sup>/t.

Based on the analysis above, an evaluating index system suitable for lower Silurian Longmaxi shale in southeast Chongqing is formed preliminarily, which can guide lower Silurian Longmaxi shale gas exploration and exploitation.

## References

- Li Yanjun, Liu Huan, Zhang Liehui, et al. Lower limits of evaluation parameters for the lower Paleozoic Longmaxi shale gas in southern Sichuan Province. *Science China: Earth Sciences*, 2013, 56: 710-717, doi:10.1007/s11430-013-4579-4