[PS]Diagenetic Reservoir Facies and Diagenetic Evolutionary Sequences of Extra-Low Permeability Reservoirs in the Upper Triassic Xujiahe Formation of Fenggu Structure, Western Sichuan Depression, China*

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Abstract

Diagenetic reservoir facies are integrated into some diagenesis and special reservoir pore spaces to describe reservoir properties. For predicting the distribution of high-quality reservoirs it is critical to analyze the evolutionary processes and sequences of different diagenetic reservoir facies and to explore reservoir forming mechanisms. This study focuses on reservoirs in the Upper Triassic Xujiahe Formation in Fenggu Structure of Western Sichuan Depression. They are buried deeply and classified as low porosity and extra-low permeability reservoirs.

Stages of diagenesis have been determined after study of the diagenetic reservoir facies types and diagenetic evolutionary sequences based on the analysis of petrologic characteristics, sedimentary facies, diagenetic types, apparent compacting rate, apparent cementing rate, combination of reservoir spaces, porosity, permeability and some other parameters. The diagenetic reservoir facies are divided into four types: (1) the residual intergranular pores-dissolved pores diagenetic reservoir facies with weak compaction and strong dissolution, (2) the dissolved pores diagenetic reservoir facies with compaction and dissolution, (3) the dissolved pores-microporosity diagenetic reservoir facies with middle to strong compaction and weak dissolution, and (4) the tight diagenetic reservoir facies with strong dissolution. The development of the relic primary intergranular pores and secondary dissolution pores is mainly controlled by the rock components, compaction of pores, the filling of authigenic minerals and the multi-stages of dissolution and the injection of acid fluid. These play an important role in the formation of the high-quality reservoir of Xujiahe Formation.

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Diagenetic Reservoir Facies and Diagenetic Evolutionary Sequences of Extra-Low Permeability Reservoir in the Upper Triassic Xujiahe Formation of Fenggu Structure, Western Sichuan Depression, China

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1 Background

Diagenetic reservoir facies, as a concept which is put forward firstly by professor Xiong, is a combination of some or more diagenesis and proper reservoir spaces to describe the effects on reservoir nature. According to particular geologic features of various regions,many scholars have finished some outstand work about diagenetic-reservoir facies from different perspectives during the past decade. At present, diagenetic-reservoir facies are classified mainly by description of reservoir rock characteristics,diagenesis types,quantitative analysis of approximate compacting rate, approximate cementing rate, integrative modulus of diagenesis and physical property. According to the features of Xujiahe Formation of Fenggu Structure, western Sichuan Depression,China, after research of diagenetic type and characteristic and its reconstruction mechanism on reservoir nature based on analysis assay data, this paper analyzes the evolutionary process and sequence of different diagenetic-reservoir facies and explores reservoir forming mechanisms of Xujiahe formation. The achievements lay the foundation for predicting fine reservoirs of Xujiahe formation around the area.

2 Reservoir Characteristics

Fenggu Structure lays on the southern of inherited uplift belt of Western Sichuan Depression, China(Fig.1), performs as a NEE-trending nosing structure. Xujiahe Formation is one of the principal gas-producing zones in this structure, which develops three rock types: conglomerate, sandstone and aleuvite.The sandstone occupies absolute proportion and is ulteriorly divided into calcarenaceous sandstone(39.5%),lithic sandstone(29.9%),feldspathic lithic sandstone(5.2%) lithic quartz sandstone according to the debris proporation. Reservoir pore space types of Xujiahe formation include residual intergranular pores，intergranular solution pores，intergrain solution pores, intercrystal pores and microfractures(Fig.1). The porosity of Xujiahe formation is between 0.66% to 13.96% and 5.47% in average, the permeability is between 0.001×10^{-3} μ m^2 to 70.8×10^{-3} μ m^2 and 1.131×10^{-3} μ m^2 in average. Correlation of por and perm is relatively good in general.

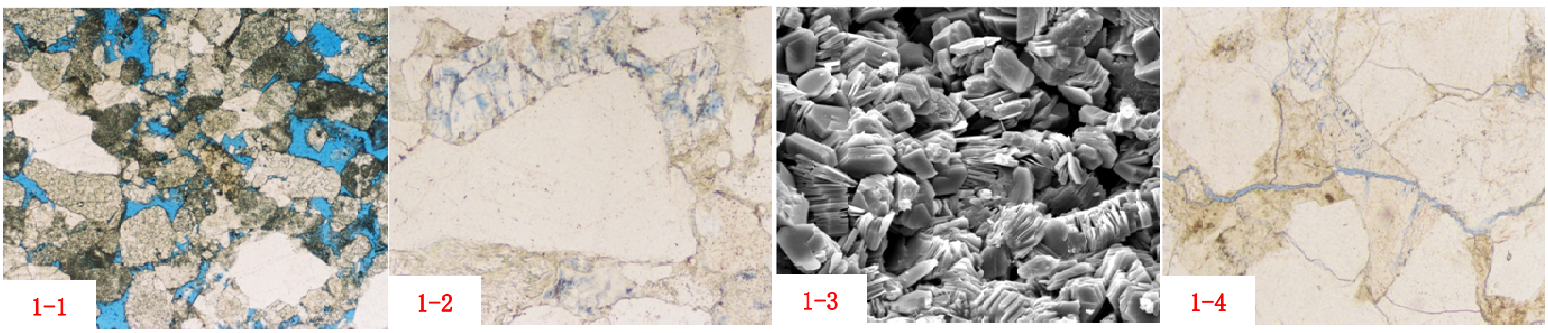


Figure.1 Reservoir pore space types

1-1 residual intergranular pores，intergranular solution pores, moderate calcareous sandstone, single polarizing;1-2 intergrain solution pores, moderate lithic quartz-sandstone, single polarizing, 1-3 intercrystal pores, moderate calcareous sandstone, SEM, 1-4 microfractures, kern lithic quartz-sandstone, single polarizing.

3 The type and characteristics of the diagenesis

The main diagenetic types of sandstone in Xujiahe Formation include compaction, the filling cementation, dissolution and fracturing.

3.1 Compaction

Mechanical compaction in clastic sandstone, clastic feldspar sandstone, clastic quartz sandstone and fine-grained calcareous sandstone is strong highly, but in coarse, medium-grained calcareous sandstone is relatively weak.The residual intergranular pores develop relatively in coarse, medium-grained calcareous sandstone.

3.2 filling cementation

The cements type of sandstone in Xujiahe formation mainly include carbonate minerals, siliceous, a variety of authigenic clay minerals and a small part of mineral salts (halite, gypsum and calcium mirabilite)(Fig.2).

3.3 dissolution

The dissolution types of sandstone in Xujiahe formation mainly are debris particles dissolution, the cements dissolution and miscellaneous dissolution. Of all the detrital grains,limestone debris, feldspar and volcanic debris are more prone to dissolution. Intergranular calcite cement is often dissolved to form intergranular dissolution pore. Matrix which is formed by alteration of volcanic ash often dissolved to form intergranular pore (Fig.2).

3.4 fracturing

Kinds of cracks which are formed by fracturing can greatly improve the permeability of the reservoir. There are two kinds of cracks in Xujiahe Formation.One type is micro-crack related to tectonic activity .The other type is crushed crack related to crushing.

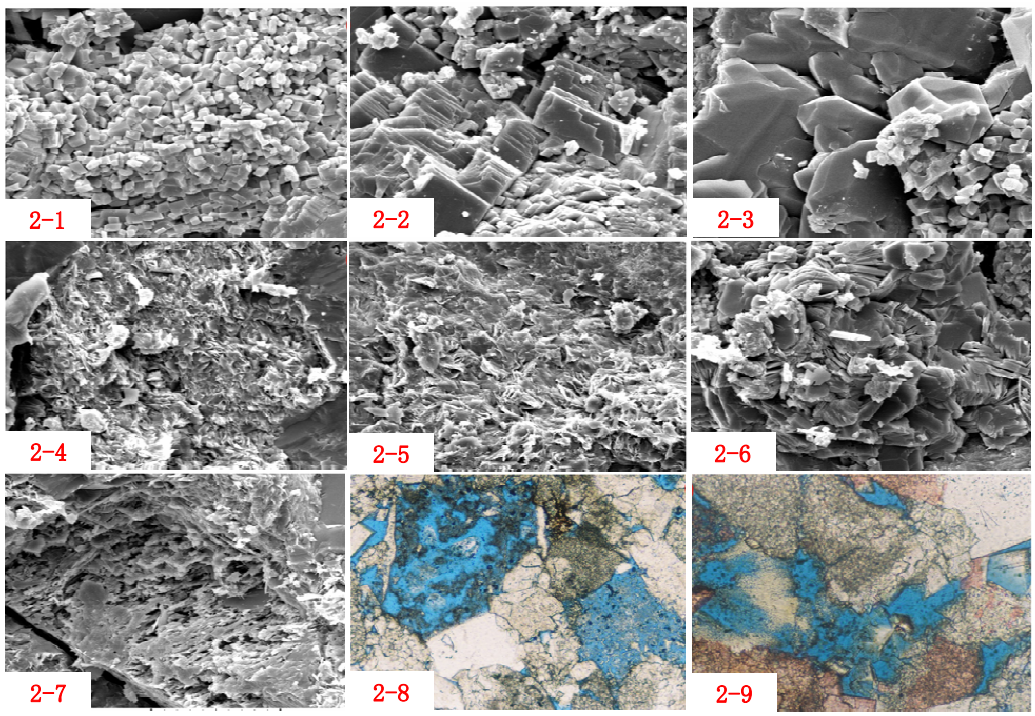


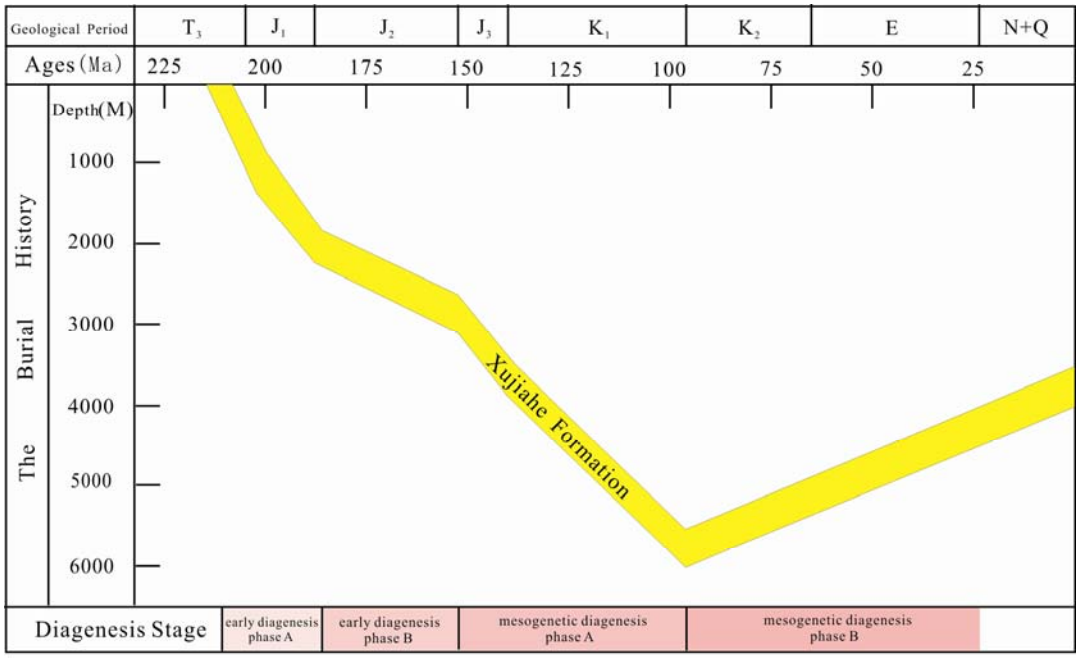
Fig.2 The type diagenesis of Xujiahe Formation in Fenggu Structure

2-1 intergranular powder crystal calcite, medium-grained calcarenaceous sandstone, scanning electron microscopy;2-2 intergranular ankerite crystals, medium-grained calcarenaceous sandstone, scanning electron microscopy;2-3 quartz overgrowth and authigenic quartz crystal, medium-grained calcarenaceous sandstone, scanning electron microscopy;2-4 intergranular chlorite, medium-grained lithic sandstone, scanning electron microscopy;2-5 smectite mixed layers and illite, medium-grained lithic quartz sandstone,scanning electron microscopy;2-6 intergranular kaolinite, medium-grained calcarenaceous sandstone, scanning electron microscopy;2-7feldspar intragranular dissolution, medium-grained lithic quartz sandstone, scanning electron microscopy;2-8 volcanic debris dissolution, medium-grained calcarenaceous sandstone, single-polarized light;2-9 calcite dissolution and dissolved residual, medium-grained calcarenaceous sandstone, plane polarized light.

4 Diagenetic facies and evolutional sequences

Xujiahe Formation has experienced syndiagenesis, early diagenesis phase A (T_3x_5~J_1) and phase B (J2) ,mesogenetic stage phase A (J3~ K1)and phase B (K2~ E)(Fig.3).

Fig.3 The burial history and diagenetic sequences of the Xujjiahe Formation



4.1 Diagenetic reservoir facies and their characteristics

The controlling factors of diagenetic facies mainly include sedimentary environment, structure background, depositional history of the basin,the diagenetic sequences,diagenetic conditions (media properties, temperature, pressure, PH and Eh and the influence of organic evolution during diagenesis), diagenetic processes and their intensity as well as duration.Based on petrological characteristics, depositional facies, diagenesis types,diagenetic processes, compaction ratio, cementation ratio, pore geometry and porosity/permeability, four reservoir rock types (diagenetic facies) can be recognized in the Xujiahe Formation (Table 1).

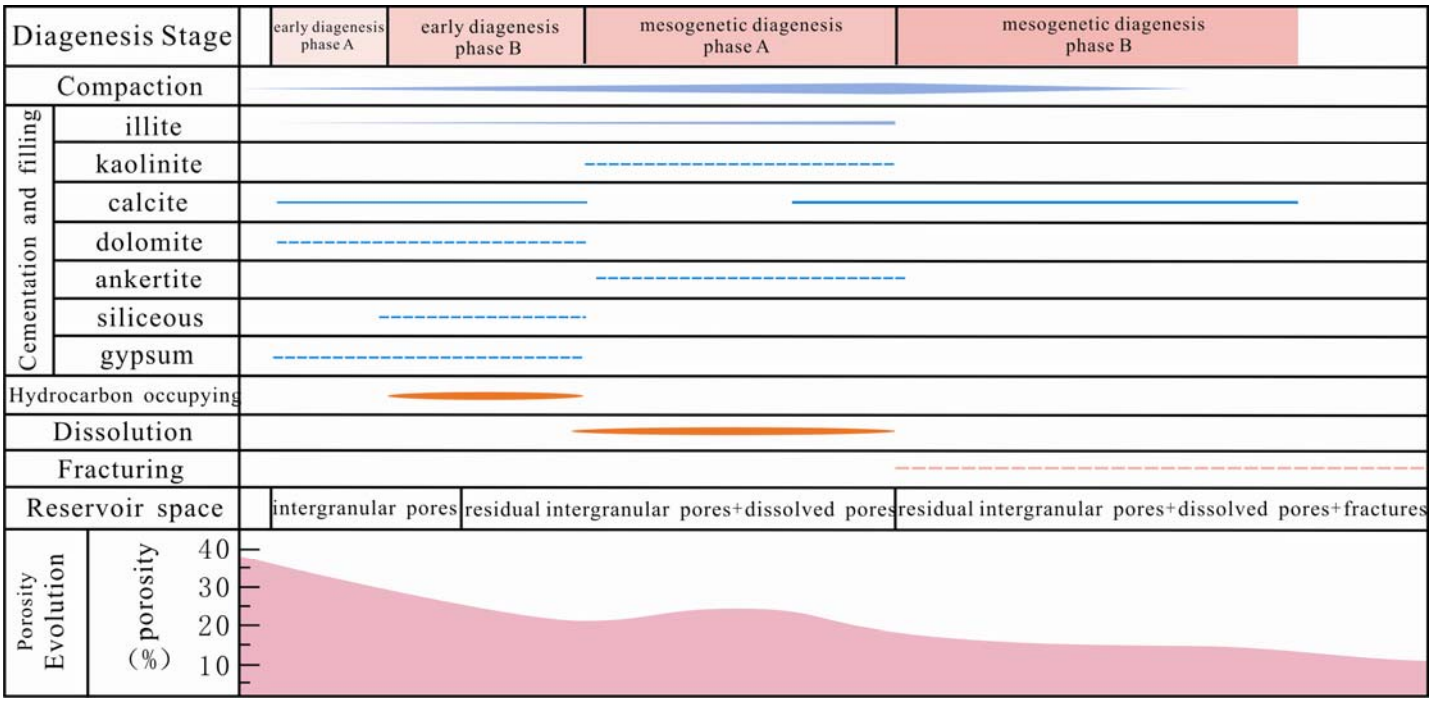
Table 1. Types and characteristics of different Diagenetic Reservoir Facies of the Xujiahe Formation

Diagenetic Reservoir Facies Types	**the residual intergranular pores-dissolved pores diagenetic reservoir facies with weak compaction and strong dissolution**	**the dissolved pores diagenetic reservoir facies with compaction and dissolution**	**the dissolved pores-micro pores diagenetic reservoir facies with middle to strong compaction and weak dissolution**	**the tight diagenetic reservoir facies with strong dissolution**
Rocks Types	medium-grained calcarenaceous sandstones	medium-grained feldspathic lithic sandstone, pebbled lithic quartz sandstone	medium-grained lithic sandstone	fine-grained calcarenaceous sandstone, fine-grained lithic sandstone
Sedimentary Facies	underwater distributary channels	underwater distributary channels	underwater distributary channels ,mouth bar	distal bar, sand sheets, inter-channels
The Primary Diagenetic Types	dissolution	dissolution	cementation/compaction	compaction
Compaction Ratio	26.21%~68.57%	56.89%~88.95%	27.57%~86.47%	20.79%~95.21%
Cementation Ratio	13.16%~50.00%	0.00%~21.95%	0.00%~57.89%	7.89%~76.32%
Reservoir Space	intergranular dissolved pores, residual intergranular pores, cuttings dissolved pores, fractures	Intergranular dissolved pores, fractures	dissolved pores, micro pores, fractures	micro pores
Porosity	(8~14) %	(5~8) %	(3~5) %	<3 %
Permeability	(0.05~10) $\times 10^{-3}$ μ m^2	(0.02~1) $\times 10^{-3}$ μ m^2	(0.01~0.05) $\times 10^{-3}$ μ m^2	<0.01 $\times 10^{-3}$ μ m^2

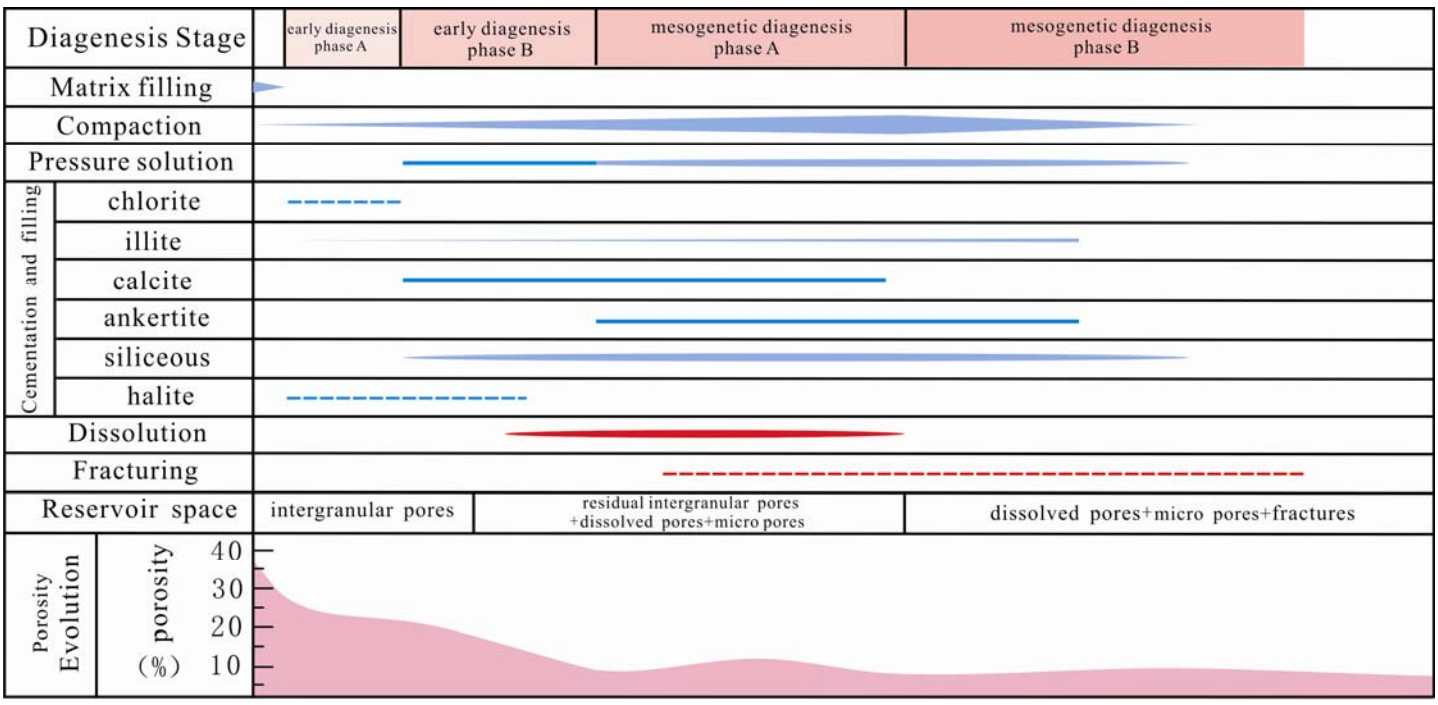
4.2 Diagenetic Evolutionary Sequences

Diagenetic processes happen in order but can company with each other simultaneously as well. The basic diagenetic evolutionary sequences are mechanical compaction, cementation of calcite, pressure solution, siliceous overgrowth, and transformation of clay minerals to illite-smectite mixed-layer minerals and illite, dissolution, crystallization of kaolinite, late-stage quartz overgrowth, cementation of ferric carbonate minerals. These diagenetic evolutionary sequences vary between different reservoir rock types.

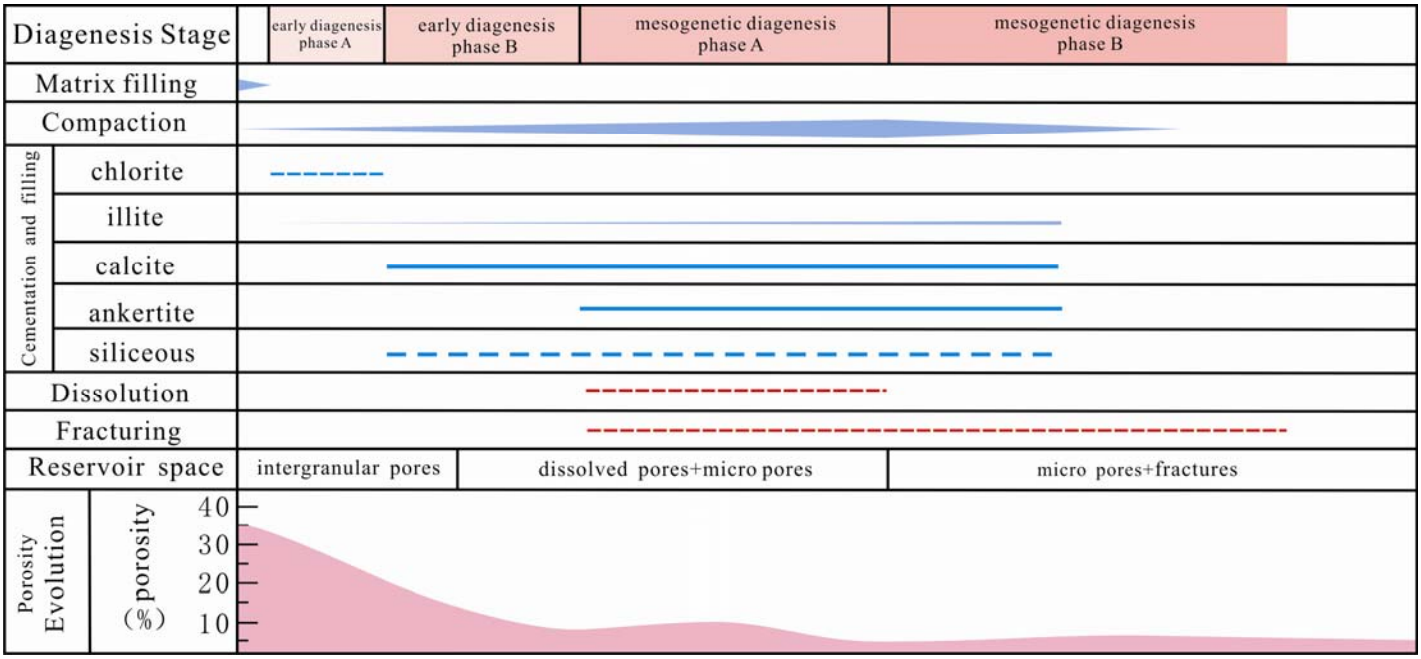
(1) Diagenetic evolutionary sequences of the residual intergranular pores-dissolved pores diagenetic reservoir facies with weak compaction and strong dissolution



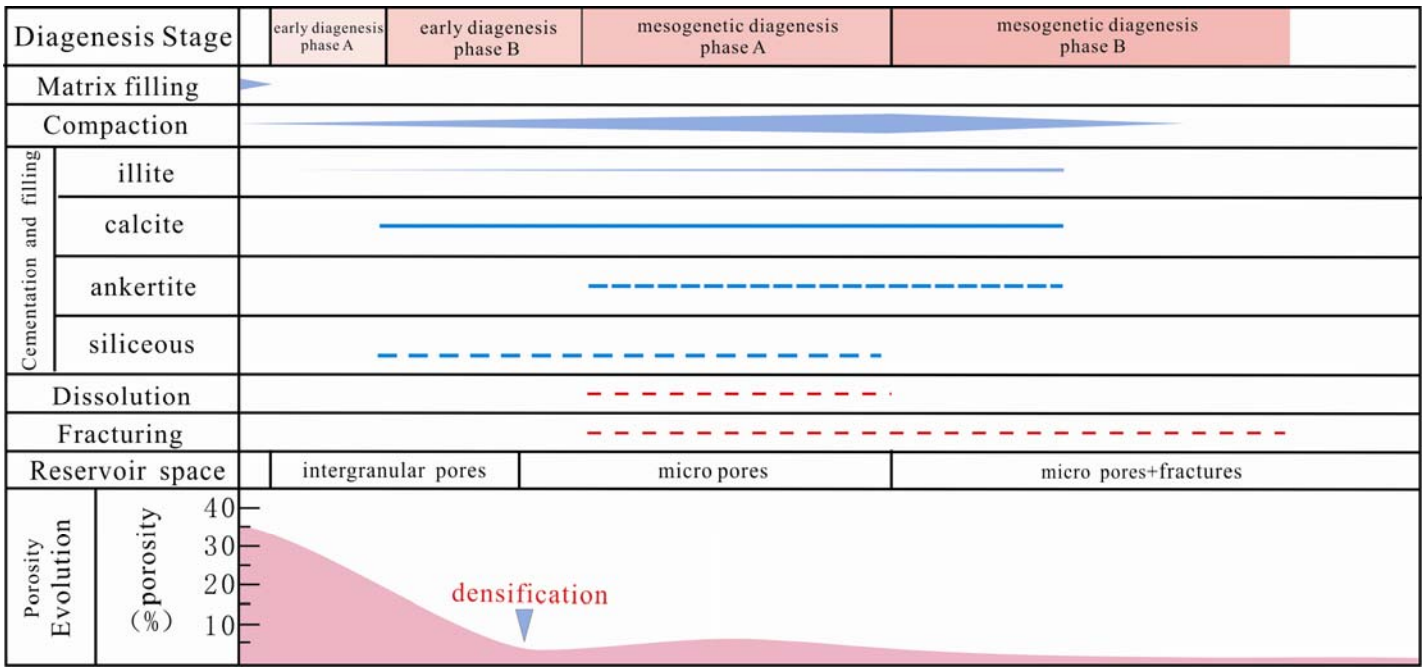
(2) Diagenetic evolutionary sequences of the dissolved pores diagenetic reservoir facies with compaction and dissolution



(3) Diagenetic evolutionary sequences of the dissolved pores- microporosity diagenetic reservoir facies with middle to strong compaction and weak dissolution



(4) Diagenetic evolutionary sequences of the tight diagenetic reservoir facies with strong dissolution



5 Conclusion

This study focuses on reservoir in the Upper Triassic Xujiahe Formation in Fenggu Structure of Western Sichuan Depression,China,which is classified as low porosity and extra-low permeability reservoir . After divided diagenesis stages, researched the diagenetic reservoir facies types and diagenetic evolutionary sequences based on the analysis of petrologic characteristic, sedimentary facies, diagenetic types, apparent compacting rate, apparent cementing rate, combination of reservoir spaces, porosity, permeability and some other parameters. The diagenetic reservoir facies are divided into 4 types.The development of the relic primary intergranular pores and secondary dissolution pores is mainly controlled by the rock components, compaction of pores, the filling of authigenic minerals and the multi-stages dissolution and the injection of acid fluid. The effective diagenetic reservoir facies of the 4 types are respectively the residual intergranular pores-dissolved pores diagenetic reservoir facies with weak compaction and strong dissolution and the dissolved pores diagenetic reservoir facies with compaction and dissolution. They play an important role in the formation of the high-quality reservoir of Xujiahe Formation.