PS Diagenesis and Origin of Porosity Formation of Upper Ordovician Carbonate Reservoir in Tazhong No.1 Slope Break, Tarim Basin*

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Abstract

A spectrum of condensate gas fields had been exploited from the reef carbonate reservoirs in Lianglitage Formation of Upper Ordovician in Tazhong No.1 Slope Break since 2005. Additionally, the early paradigm for porosity formation in this Fm. stressed subaerial exposure and attendant shallow meteoric diagenesis in syngenetic period. However, this theory above had been proved to be invalid during the exploration of oil and gas when it was applied to the northwestern No.1 Slope Break. Subsequently, numerous authors have interpreted deep-burial dissolution in carbonate reservoirs, and some have proposed that primary volumes of porosity were created in this manner. As many have argued, carbonate pore types are formed by depositional, diagenetic, or fracture processes such that the spatial distribution of porosity may or may not conform to depositional facies boundaries and pores may be formed or altered by diagenesis and brittle fracture. Therefore, a comprehensive origin of reservoir should be taken into consideration. Cores, thin sections, cathodoluminescence and geochemical analysis technique are utilized to understand the categories of porosity and cementation and analyze the origin of porosity formation from broader perspective. The result of this study demonstrates that pore network in northwestern Tazhong is mainly controlled by intracrystal microporosity, enlarged corrosion pores and fissures. Furthermore, five phases' differential cementation and five phases' dissolution of aragonitic skeletal allochems are identified in the diagenetic process. In contrast to the porosity mechanism of Lianglitage Fm. in central or southeastern Tazhong, tectonic movement and meteoric dissolution processes in second phase of Middle Caledonian are the origin of porosity formation.

Diagenesis and Origin of Porosity Formation of Upper Ordovician Carbonate Reservoir in Tazhong No.1 Slope Break, Tarim Basin

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Abstract

A spectrum of condensate gas fields had been exploited from the reef-shoals carbonate reservoirs in Lianglitage Formatin of Upper Ordovician in Tazhong No.1 Slope Break since 2005(Fig.1).

Additionally, the early paradigm for porosity formation in this Fm. stressed subaerial exposure and attendant shallow meteoric diagenesis in eogenetic diagenesis period (Xinyuan Zhou et al., 2006; Zhenyu Wang et al., 2007; Zhaoming Wang et al., 2007).

However, this theory above had been proved to be invalid during the exploration of oil and gas when it was applied to the northwestern No.1 Slope Break. Subsequently, numerous authors (Yixiong Qian et al., 2007; Yushan Sun et al., 2007; Hongqiang Ma, 2010 et al.; Bo Zhou et al., 2013) have interpreted deep-burial dissolution in carbonate reservoirs, and some have proposed that primary volumes of porosity were created in this manner.

As Wayne M. Ahr (2008) and other argued, carbonate pore types are formed by depositional, diagenetic, or fracture processes such that the spatial distribution of porosity may or may not conform to depositional facies boundaries and pores may be formed or altered by diagenesis and brittle fracture(Fig.2). Therefore, a comprehensive origin of reservoirs should be taken into consideration.

Cores, thin sections, cathodeluminescence and geochemical analysis technique are utilized to understand the categories of porosity and cementation and analyze the origin of porosity formation from broader perspectives. The result of this study demonstrates that pore network in northwestern Tazhong is mainly consist of moldic pores, intracrystal microporosity, enlarged corrosion pores and fissures. Furthermore, 5 phases' differential cementation and 5 phases' dissolution of aragonitic skeletal allochems or cements are identified in the diagenetic process.

In contrast to the porosity mechanism of Lianglitage Fm. in central or southeastern Tazhong, tectonic movement and meteoric dissolution processes in second phase of Middle Caledonian are the origin of porosity formation in northwestern Tazhong.

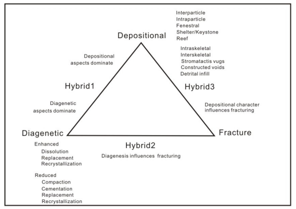


Fig.2. A genetic classification for porosity in carbonate rocks(W.M. Arh,2008)

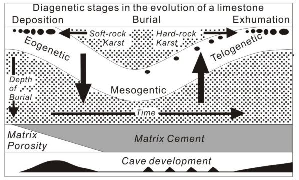


Fig.3. Diagenetic stages in the evolution of a limestone(Choquette and Pray,1970)

Introduction

Diagenesis refers to any physical or chemical changes in sediments or sedimentary rocks that occur after deposition. And it is highly essential to make clear the origin of porosity formation.

Choquette and Pray(1970) illustrated three diagenetic stages in the evolution of a limestone (Fig.3),that is eogenetic (begin at sea floor), mesogenetic (burial period) and telogenetic (uplift period) stage respectively.

Since then, meteoric dissolution during telogenetic stage was firstly got much attention due to oil and gas exploration breakthroughs of carbonate reservoirs in association with major unconformities(Harris P.M et al.,1984;Fritz R.D. et al.,1993 and Saller A.H. et al.,1994).

Late, subaerial exposure surfaces, encompassing not only at major unconformities but also capping shallow-upward carbonate cycles, were summarized to be a result of telogenetic and eogenetic diagenesis environment respectively(A. Foos,1996). Subaerial meteoric dissolution in eogenetic stage became a new focus of porosity genesis, especially for those reef-shoals gas fields and coastal flank margin caves(Vacher and Mylroie 2002).

Although restricted to the formation pressure and porosity preservation conditions, mesogenetic or burial dissolution was eventually proved to be a substantial path to create porosity (Mazzullo S.J. and Harris P.M.,1992;Klimchouk, 2009; Paul Wright and Paul Harris,2013; and William B.W.,2015)(Fig.4).

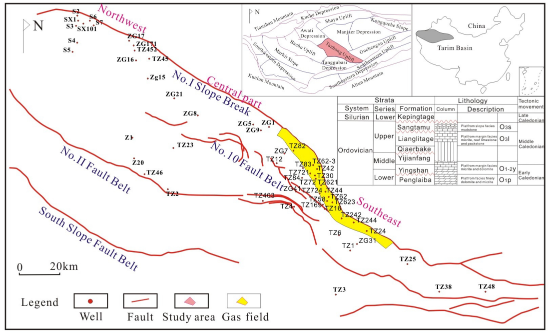


Fig.1. Sketch maps showing location of the Tazhong uplift, Tarim Basin, distribution of faults and locations of wells and simplified stratigraphic column.

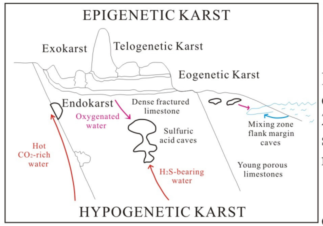


Fig.4. Sketch showing the various types of karst(modified after William B.W.,2015).

Methodology

About 62 core samples of O_3l limestone were collected from more than 20 wells along the No.1 slope break and were then made into doubly polished thin sections.

Then, around 40 calcite samples filled in vugs or fractures were crushed into very fine powder in an agate mortar for carbon and oxygen isotope analyses.

Results

1) 5 phases' cementation and dissolution were identified(Fig.6) in the diagenetic process in northwestern Tazhong, and tectonic movement and meteoric dissolution produced the existing porosity.

2)Integrating the previous study in Tazhong No.1 slope break, we hold that there are three categories of porosity genesis, that is mixing water karst, meteoric water karst and hypogenic karst.

3)Preserved porosity categories, porosity formation mechanism varied along Tazhong No.1 slope break.

Diagenesis

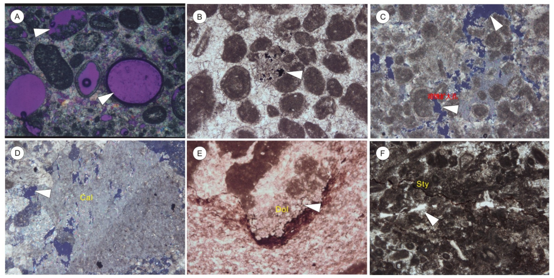


Fig.5. Porosity categories in Lianglitage Formation of northwestern Tazhong uplift

(A)Moldic pore, Plane-polarized light (PL), S2, 6879.5 m.(B)Intraparticle pore filled with bitumen,PL, S6, 6647.5 m.(C)Enlarged corrosion pore, Cross-polarized light (CL), S2, 6878.4m.(D)Intracrystal microporosity(corresponding to Phase 4 dissolution), CL,S2,6879.1m. (E)Intercrystal microporosity, PL,Z11,5332.3m.(F)Corrosion fracture, PL,S4,6567.2m.

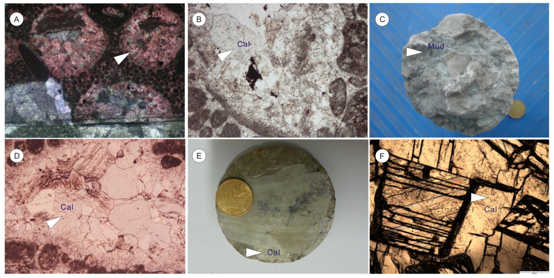


Fig.6. Dissolution in Lianglitage Formation of northwestern Tazhong uplift

(A)Fabric-selective dissolution(Phase 1), Plane-polarized light (PL), S3, 6442.3 m.(B)Non-fabric-selective dissolution filled with syntaxial calcite overgrowth cement(Phase 2),PL, S6, 6616.6 m.(C)Non-fabric- selective dissolution filled with gray green mud(Phase 2),S2, 6876.2m.(D)Non-fabric- selective dissolution filled with syntaxial or blocky calcite(Phase 3), S7, 6530.9m.(E)Vugs filled with coarse grain blocky calcite(correspongding to Phase 5 dissolution), S7,6568.0m.(F)Coarse grain blocky calcite,S7,6568.0m, a sample from calcite in E.

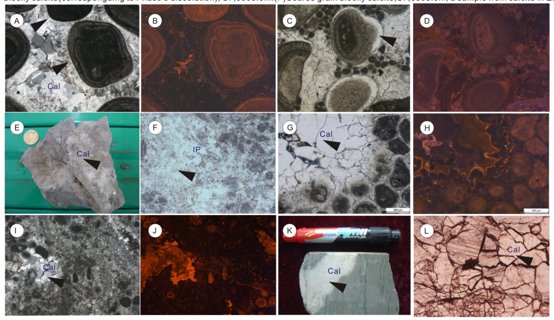


Fig.7. Cementation in Lianglitage Formation of northwestern Tazhong uplift

(A)Fibrous cements with isopachous crusts(Phase 1), Plane-polarized light (PL), S3, 6438.5 m.(B)Cathodeluminescence showed dim light of fibrous calcites,S3,6438.5m.(C)Micro-stalact cements(Phase 2),PL,S7,6531.9m.(D)Cathodeluminescence showed dim light of stalact calcites,S7,6531.9m.(E)Sparry calcite filled in a vug,S5,6500m.(F)Syntaxial calcite filled in non-fabric-selective porosity(Phase 3), PL, S5,6500m,a sample from calcite in E.(G)Blocky cements(Phase 4),PL,S7,6530.7m.(H)Cathodeluminescence showed dim light but with bright rim of blocky calcite,S7,6530.7m.(I)Blocky cements(Phase 5),PL,S2,6878.5m.(J)Cathodelumiscence showed bright light of blocky calcite,S2,6878.5m.(K)Sparry calcite filled in a fracture,S4,6427.4m.(L)Blocky calcite, S4,6427.4m,a sample from the calcite in K.

Diagenesis sequence

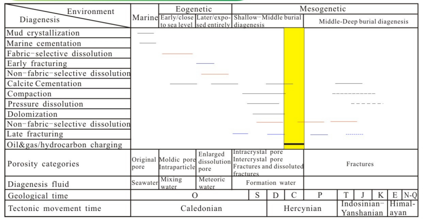


Fig.8. Diagenesis sequence in O_3l of northwestern Tazhong uplift

Porosity genesis

According to the existing porosity types and their genesis identification along Tazhong No.1 slope break, three different porosity genesis were illustrated. While meteoric water karst acted as a main process for porosity shaping in northwest area, mixing water karst generated primary porosity space in southeast part. And hypogenic karst distributed in almost the whole slope break, but performed to be destructive for porosity in northwestern and central part, while constructive in southeastern part.

Mixing water karst along TZ82-TZ44-TZ62-TZ24

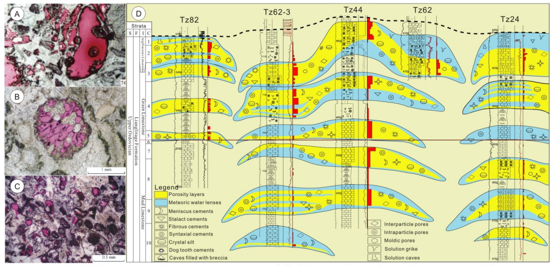


Fig.9. Mixing water karst evidences of O_3l in southeastern Tazhong uplift

(A)Moldic pore and intraparticle pore , intrasparite, Plane-polarized light (PL), TZ54, 5757.6m.(B)Intraparticle pore in bryozoan,biosparite, PL, TZ54,5757.83m.(C)Moldic pore and intraparticle pore, biosparite, PL, TZ722, 5013.54m.(D)Meteoric water lenses in southeastern Tazhong, well correlation displayed the porosity layers developed in early eogenetic diagenesis stage(Wang Zhenyu,2007).

Meteoric water karst and tectonic movement

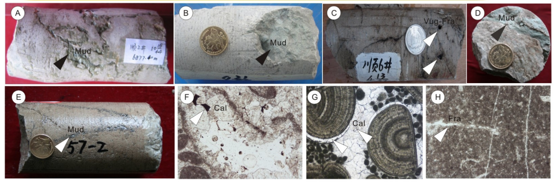


Fig.10. Meteoric water karst evidences of O_3l in northwestern Tazhong uplift

(A)High-angle fractures filled with gray green mud, S2, 6877.4m.(B)High-angle fractures filled with gray green mud, S2,6794.5m.(C)Vugs developed along fractures and both were filled with bitumen,S6,6701.4m.(D)Low-angle fratures filled with gray green mud, SX1,6532.8 m.(E) High-angle fractures filled with gray green mud, SX1,6538.8m.(F)Interparticle pores were filled by syntaxial calcite and some residual pores were filled by bitumen,S6,6616.8m.(G)Interparticle pores are filled with meniscus and sparry calcites, S7,6531.9m.(H) At least two phases of fractures and the late space preserved,S4,6565.0m.

Hypogenetic karst

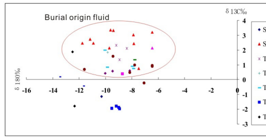


Fig.11. Burial origin fluids account for majority of calcite samples, filling in vugs and fractures in O_3l of Tazhong uplift(modified Zhou Bo,2013)

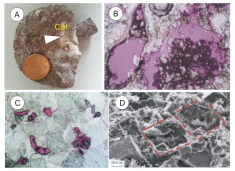
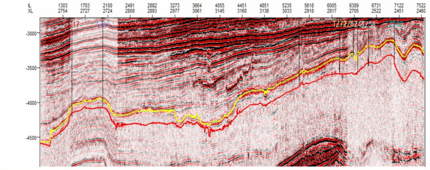


Fig.12. Burial filling and dissolution examples (Difference between the northwest and southeast)

(A)A vug filled with sparry calcite with burial origin fluild, S7,6570m.(B)Dolomites and biological body were dissoluted,TZ72,4966.5m.(C)Alga intraclast was dissoluted,TZ62,4752.54m.(D)Dolomites were dissoluted, TZ62,4742.26m(Sun Yushan,2007)

Discussion



No.1 slope break	Northwest	Central	Southeast
Deposition thickness	Thin		Thick
The degree of slope	Low		High
Strength of water	Small		Large
Modlic and intraparticle pores	Most were filled by calcite		Most were preserved
Porosity categories	Fractures,residual enlarged dissoved pores,intracrystal pores		Modlic and intraparticle pores, fractures, intracrystal and intercrystal pores
Main porosity genesis	Meteoric dissolution and tectonic movement		Mixing water and burial dissolution

Fig.13. Comparison of porosity genesis along No.1 slope break

Conclusion

(a)Digenesis sequence in Lianglitage Fm. displayed that porosity preservation varied a lot along No.1 slope break. (b)The difference of porosity origin between northwest and southeast areas is closely related to the deposition environment and tectonic differentiation.

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