Types and Properties of Dolomite Reservoirs in Carboniferous of East Margin of Caspian Basin

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Abstract: Taking the Carboniferous KT-I reservoirs in the NT Oilfield in the eastern margin of the Caspian Basin as a case, this paper studies the petrology and physical properties of carbonate reservoirs using core data. The carbonate reservoirs in the study area were deposited in the platform environment. The limestone deposited has experienced multiple stages of diagenetic alteration, among which the dolomitization played an important role in improving the reservoir quality. The dolomites in the study area are diverse in type and are characterized by the development of eight types of dolomites, including foraminifer dolomite, fuzulinid dolomite, bioclastic dolomite, micritic dolomite, micritic-powdery dolomite, powdery dolomite and lime dolomite, and karst breccia dolomite. Different types of dolomite have different characteristics observed on thin sections, and the physical properties vary too. Foraminifera, fuzulinid and bioclastic dolomites belong to grain dolomite with obvious biological characteristics, relatively high permeability and average permeability of more than 100mD. Micrite, micritic-powdery and powdery dolomites are crystalline dolomites which are composed of dolomite crystals arranged closely, and the average permeability is less than 35mD.

1 INTRODUCTION

The sedimentation and diagenesis of the carbonatite reservoir is extremely complex, making it very difficult to study the depositional environment, genesis, properties and distribution (Colin et al., 2004). The complexity of carbonate reservoir has great influence on oilfield development. Taking the Carboniferous KT-I carbonate reservoir in the NT Oilfield in the eastern margin of the Pre-Caspian Basin as a case, this paper evaluates the properties, distribution, storage and seepage of the dolomites.

2 GEOLOGICAL CONDITIONS

The NT Oilfield is located on the eastern margin of the Caspian Basin in the Republic of Kazakhstan in Central Asia(Figure 1). Under the oilfield, the Carboniferous to Quaternary formations were drilled in from bottom to top, in which the Carboniferous are carbonate reservoirs composed of KT-I and KT-II, and between which is a clastic interlayer about 300m thick. The KT-I carbonate reservoir experienced multiple stages of diagenesis, of which dolomitization is one of the major diagenetic processes, and played an important role in improving the storage capacity of the reservoir (López-Horgue et al., 2010). The dolomites account for 52.7% and limestones account for 47.3%, and dolomites are primary reservoirs in the KT-I carbonate section.

3 TYPES AND PROPERTIES OF DOLOMITES

The dolomites in the KT-I section in the NT Oilfield are dominated by crystalline dolomites, accounting for 74.26%, including micrite, micritic-powdery and powdery dolomites. They generally contain biological debris of different amounts, but without

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fine, medium and coarse dolomites. The content of grain dolomite is less, accounting for 15.44% (Table 1).

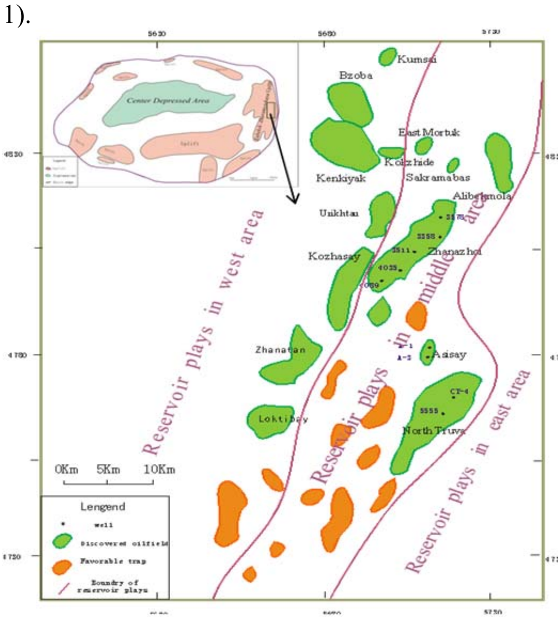


Figure 1: Location map of the study area.

Table 1: Rock type statistics of dolomite in KT-I Layer in NT Oilfield.

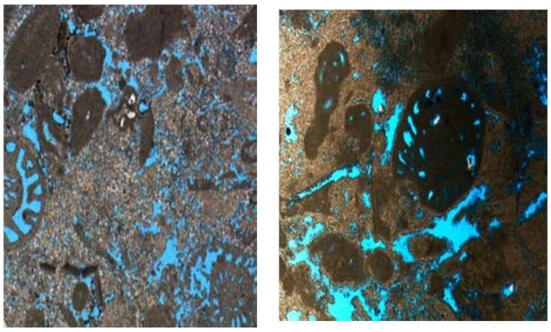
Lithology		Number of samples	Content (%)	Subtotal (%)
Grain dolomite	Foraminifera dolomite	3	2.21	15.44
	Fuzulinid dolomite	6	4.41	
	Bioclastic dolomite	12	8.82	
Crystalline dolomite	Micritic dolomite	45	33.09	74.26
	Mic-powdery dolomite	22	16.18	
	Powdery dolomite	34	25	
Other	Lime (lime-bearing) dolomite	10	7.35	10.29

3.1 Foraminifera Dolomite

The foraminifera dolomite is dominated by foraminifera (35% - 50%) and fuzulinid (2 - 10%), which all have been dissolved into residual debris. In addition, algae lumps and debris of chlorophyta were observed; cavities and granular cast pores were found common; and semi-euhedral dolomite with sparse contact is intergranular fillings (Figure 2).

3.2 Fuzulinid Dolomite

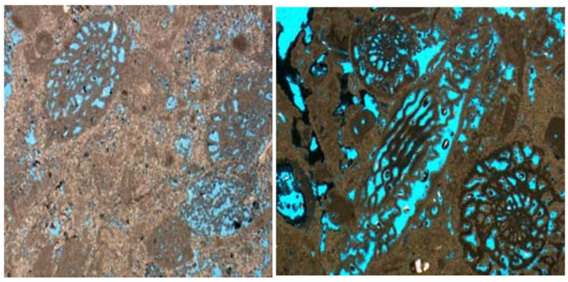
Fuzulinid dolomite contains a large amount of fuzulinid (30%-45%). Intense dissolution almost made the chambers empty, only leaving residual Schwarzkopf debris being identified



Powdery residual foraminifera dolomite . Residual micritic foraminifera dolomite.

Figure 2: Foraminifera dolomite.

in some ones. In addition, there found chlorella and rhodophyta fragments and foraminifera (5% - 15%), and echinoderm and bryozoan residues. The shells of all the creatures are composed of dolomicrite, which were often dissolved to form casted shell pores. The intergranular fillings are micritic-powdery dolomites accounting for 20% - 45% (Figure 3).

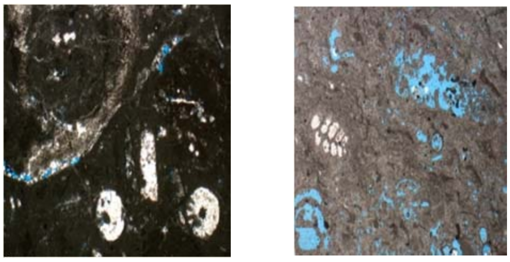


Micritic bioclastic fuzulinid dolomite Residual micritic fuzulinid dolomite

Figure 3: Fuzulinid dolomite.

3.3 Bioclastic Dolomite

Bioclastic dolomite is dominated by foraminifera (1%-30%) and fuzulinid (5%- 30%). The paleontological content is great with common observation of bryozoans, brachiopods, echinodermata, and relatively large amount of non-abrasive algal lump. More non-selective dolomitization formed coarse- powdery -level rhombohedron. Strong dolomitization and dissolution made the grain almost indistinguishable. Only the traces of species of fuzulinid and chlorophyta could be vaguely observed. Some biological debris came into being casted pores, and some became single and multiple crystal grains, but most of the bioclasts are micritic dolomite. The intergranular material is fine-powdery dolomite which is semi-euhedral. It contains a large number of residual bioclastic dolomite composed of micritic dolomite, partly forming grain casted pores and shell wall pores (Figure 4).

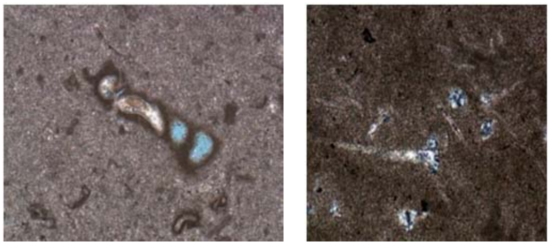


Micritic residual bioclastic dolomite   Micritic-powdery residual bioclastic dolomite

Figure 4: Bioclastic dolomite.

3.4 Micritic Dolomite

Micritic dolomite is dominated by micritic accounting for 56%-98%. With varying amounts of biological debris, it contains foraminifera of 2% - 25% and fuzulinid of 1% - 18%. The organism is less in its amount but miscellaneous in classes. There observed shallow benthic organisms, including sea urchin spine, sea lily stems, paleobraspora, small brachiopods individuals, sponge fragments, lamellibranch, and the likes. Deepwater phytoplankton could also be observed, including thin-shell bivalves, thin-shell brachiopods, and fibrous thin-shell organisms. In the dissolved pores, there found semi-filled, fine-coarse dolomite rhombohedra and kaolinite, and occasional occurrence of semi-filled casted pores with gypsum crystalline. Locally, it contains a small amount of terrigenous debris extremely fine to fine. It is dominated by quartz and a minor of quartzite debris. The biological shell wall consists of cryptocrystalline dolomite. The bioclastic represents residual structures, parts of which were completely dissolved to form biological molds, and foraminifera, fuzulinid individuals, ostracods, lamellibranch and the likes can be identified. A minor of bioclastic bodies were filled or semi-filled with fluorite, kaolinite and calcite. Locally there is the observation of casted molds of gypsum crystalline. Judged from the developmental characteristics of shallow benthic organisms such as spine and shellfish, the marlite should be formed in a subtidal environment. It is the marl deposited in restricted platform lagoon was dolomitized (Lucia, 2011), and such dolomitization was strong and complete (Figure 5).

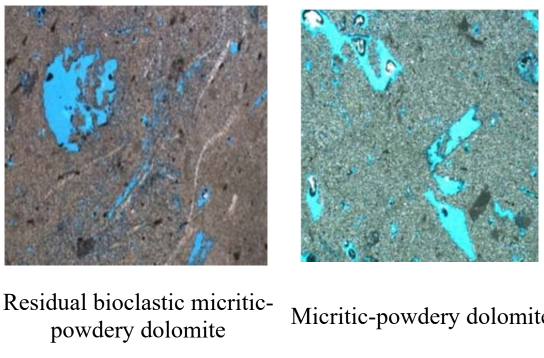


Micritic dolomite   Siliceous spine micritic dolomite

Figure 5: Micritic dolomite.

3.5 Micritic-Powdery Dolomite

Micritic-powdery dolomites are almost marlite-power crystalline dolomite accounting for 52% - 92%. They contain varying amount of bioclastic, including 2%-20% of foraminifera, 2%-35% of fuzulinid, and a minor of echinacea, ostracods, lamellibranch, gastropods, brachiopods, algae, and the likes. In summary, they are less in categories and amount, and in which intense and destructive dissolution created many molded holes and shell wall holes. The micrite-powdery crystalline was formed by strong and complete dolomization of marl deposited in the subtidal saline lagoon in a restricted platform (Figure 6).



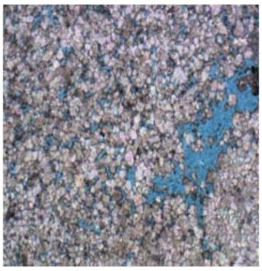
Residual bioclastic micritic-powdery dolomite   Micritic-powdery dolomite

Figure 6: Micritic-powdery dolomite.

3.6 Powdery Dolomite

Powdery dolomites are fine-medium- coarse powdery crystals, semi-euhedral and euhedral. They contain varying amounts of foraminifers, fuzulinid, ostracods, gastropods, lamellibranch, trilobite, echinoderms and algae, ranging from 12% to 70%, and mostly fragments and remnants often dissolved into casted mold pores. Shell walls of a small portion of gastropods,

echinoderms, ostracods are still calcite. Most foraminifera and fuzulinid species are remnants of debris due to dolomization and dissolution. Those well preserved are bradyid, paleobraspora and internal worms, and casted molds of chlorella, ostracods and lamellibranch, and occasional occurrence of echinacea fragments. Locally, there observed chlorophyta lumps filled with coarse calcite after dissolution, and large caves completely filled with deformed dolomite and lapis lazuli. In addition, a small amount of anhydrite was found from two origins: the anhydrite replacing biological debris, which shows wave absorption, and the single-crystal anhydrite filling into biological molded pores. Dissolved fractures semi-filled with anhydrite can also be observed. More gypsum molded pores were found, rectangular, cylindrical or like bar and other shapes (Figure 7).



Coarse podwery dolomite

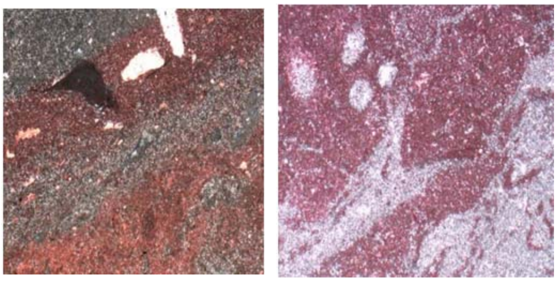
Residual foraminifer powdery dolomite

Figure 7: Powdery dolomite.

From the point of more shallow water organisms, the powdery crystalline should be subtidal deposits. The occurrence of a small amount of gypsum salt indicates that the sea water was salinized. That is, the powdery crystalline was formed by the dolomization of biological marl deposited in the subtidal saline lagoon in a restricted platform (Ma, 1999), and it was not formed in a supratidal Sabkha environment (Zhao et al., 2016).

3.7 Lime (lime-bearing) Dolomite

The lime (lime-bearing) dolomite is mainly of micritic structure, with sparse distribution of deepwater organisms, including monactines, thin-shell organisms, echinoderm fragments and phosphorus bioclastics. The distribution of calcite is more uniform, but that of echinacea and fuzulinid is not uniform, and a few echinacea have the phenomenon of coaxial growth. A few of fuzulinid were replaced by calcite. It shows strongly fragmented organism, less in amount, and more in kingdoms, with the observation of trilobite fragments and tail thorns, and bryozoans, brachiopods, echinoderms and the likes. What is extremely peculiar is that there are both the occurrence of tabular and columnar pseudo-crystals of gypsum, and that of monactines and thin-shell creatures. Also, there is the observation of normal shallow marine creatures. The dolomite is divided into two types, marlite and powdery crystalline, which are distributed disorderly. The biological burrow structure can be observed, representing ditch, stream, rooted and other shapes. All micrites are calcite, and powdery crystallines are semi-euhedral and euhedral. The content of dolomite is equivalent to that of lime, forming a transitional lithology. In the micrite, there are occasional occurrences of the remnants of echinoderm, fuzulinid and foraminifer. The replacement of chalcedony and gypsum (with wave absorption) can be observed locally. The breccia with a suspected genesis of biological burrowing or disturbance can also be observed and the dolomitization is not uniform. In the place where deformation is strong, found powdery dolomite and lime dolomite. In the place where replacement is weak, found dolomitic limestone, marlite, and sparsely distributed brachiopoda, porous bryozoans, echinoderms, fuzulinid, foraminifera fragments, and occasionally phosphorus bio-shaped barbed. The micritic structure contains coarser coral fragments, monactines and triactines. With normal shallow marine organisms, the lime (lime-bearing) dolomite should be formed by incomplete dolomization of deposits in restricted shallow sea (lagoon) (Figure 8).

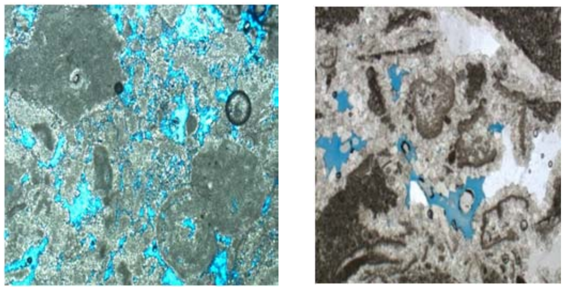


Powdery lime dolomite   Micritic breccia lime dolomite

Figure 8: Lime (lime-bearing) dolomization.

3.8 Karst Breccia Dolomite

The karst breccia dolomite, which contains karst breccia formed by rupture-dissolution, is mainly composed of marlite and pellets, mostly in angular, messy accumulation, but in relatively concentrated distribution. Among the breccia is filled with semi-euhedral powdery crystalline dolomite or coarse rhombohedral dolomite in the first generation, or semi-filled or fully-filled with coarse rhombohedral dolomite in the second generation. Among the grains is semi-filled with fine crystalline dolomite and coarse rhombohedral dolomite. The latest fillings are bitumen or kaolinite. Kaolinite fillings are more commonly observed in dissolved pores. Strong karstification created karst breccia dolomite, indicating the existence of ancient weathering crust. The dolomite was altered by dissolution and became the favorable reservoir in this area (Figure 9).



Micritic-powdery breccia dolomite   Karst breccia dolomite

Figure 9: Karst breccia dolomite.

Table 2: Statistics of physical properties of different types of dolomites.

Lithology	Number of samples	Porosity (%)			Permeability (mD)		
		Max.	Min.	Average	Max.	Min.	Average
Foraminifera / Fuzulinid dolomite	9	21.62	13.9	18.48	443	11.6	135.44
Bioclastic dolomite	12	16.5	5	11.09	611	0.0009	148.39
Micritic dolomite	45	39.2	4.9	15.6	400	0.0003	33.89
Micritic-powdery dolomite	23	30.72	7	14.93	179	0.0246	25.38
Powdery dolomite	31	18.46	3.62	13.8	126	0.0011	20.2
Lime/Breccia dolomite	15	26.54	1.56	12.49	1431.41	0.004	104.32

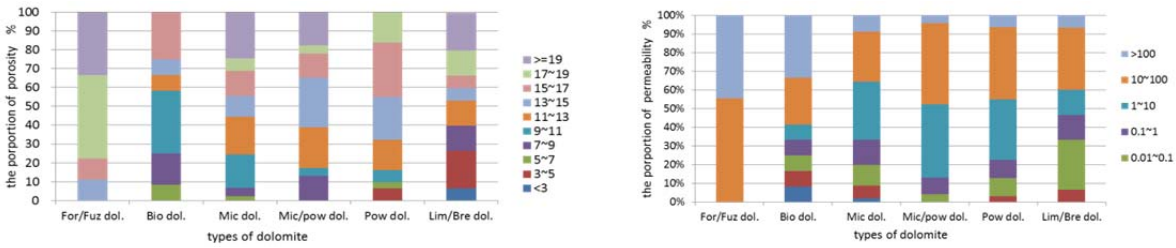


Figure 10: The porosity and permeability distribution of different types of dolomite.

4 PHYSICAL PROPERTIES OF DOLOMITES

Statistics of thin section observations and dolomite porosity and permeability indicates that different types of dolomites have different physical properties (Table 2, Figure 10). The average porosity of the dolomite reservoirs in different types ranges from 11.09% to 18.48%. The porosity is a little different, but the permeability is greatly different. The average permeability of foraminifer/fuzulinid,bioclastic dolomites and Lime/Breccia dolomite is more than 100mD, while that of micritic, micritic-powdery and powdery dolomites is below 35mD, because the latter three types are of grain structure with relatively homogenous grains. Although they have similar porosity, the distribution of the throat size is more extensive in grain dolomite; therefore grain dolomite shows obviously high permeability (Wang et al., 2010).

5 CONCLUSIONS

The Carboniferous KT-I carbonate reservoir in the NT Oilfield was deposited in a restricted platform. Early limestone experienced multiple stages of diagenesis, and the dolomitization played an important role in improving the reservoir quality. There found eight types of dolomites in the study area, including foraminifera, fuzulinid, bioclastic dolomite and micrite, micritic-crystalline, crystalline dolomite, lime dolomite, and karst breccia. Different types of dolomites have different appearances observed on thin sections, and their physical properties are different too. Foraminifer/fuzulinid, bioclastic dolomites and Lime/Breccia dolomite are granular, with obvious biological characteristics and relatively high permeability (more than 100mD on average). Micrite, micritic-powdery and powder dolomites are crystalline and composed of dolomite crystals. The crystal grains are relatively close, and the average permeability is less than 35mD.

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