Genetic research of fractures in carbonate reservoir: a case study of NT carbonate reservoir in the pre-Caspian basin

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Abstract. The degree of development and characteristics of fractures are key factors for the appraisal of carbonate reservoirs. In this paper, core data and well logging data from the NT oilfield in the Pre-Caspian Basin are used to study the formation mechanism and distribution characteristics of different genetic fractures, and analyze their influence on reservoir properties. Fractures in carbonate reservoirs can be divided into three categories according to their formation mechanism; these are tectonic fracture, dissolved fracture, and diagenetic fracture, which is further divided into interlayer fracture and stylolite. Fractures of different formation mechanism influence fluid seepage in different degree, tectonic fractures possessing strong connecting ability to pores, and dissolved fractures also improving reservoir properties effectively, however, diagenetic fractures contributing relatively little to fluid seepage.

1. Preface
At present, oil and gas reserves in carbonate reservoirs account for more than half of global reserves, and have become a major energy source. Thus, the study of carbonate reservoirs is also getting more and more attention. Fractures play an important role in improving the quality of carbonate reservoirs. The degree of development and characteristics of fractures are key factors for the appraisal of carbonate reservoirs. In recent years, more and more scholars have carried out relevant research in the aspect of prediction, characterization, features and genesis of fractures [1]. This paper carried out a genetic classification method for fractures in NT carbonate reservoir in the Pre-Caspian Basin, and summarized the distribution characteristics of different genetic fractures and their effects on reservoir properties based on the needs of oilfield development. The result lays the geological foundation for the oilfield development plan.

2. Oilfield overview
The NT oilfield is located on the slope belt of the eastern margin of the Pre-Caspian Basin which geotectonically belongs to the southeastern part of Eastern European Platform(Figure 1). To the east of the basin is the Ural-Hercynian folded mountain system[2]. The hydrocarbon bearing series are Carboniferous carbonate reservoirs, including two sets of carbonate reservoirs of platform facies which are formation KT-I and KT-II, with MKT, a high shale content classic formation, between them serving as a barrier.

In this paper, the characteristics of fractures in the NT carbonate reservoirs are mainly based on core data of seventeen wells. In the process of reservoir property analysis, comparison of core data
with well log data such as GR curve, porosity and permeability are made to calibrate the depth of core data correctly.

3. Fracture classification by genesis
Fractures are important storage spaces for carbonate reservoirs, and principal seepage channels as well. By their genesis, the fractures of the NT carbonate reservoir can mainly fall into three types, which are tectonic fracture, dissolution fracture and diagenetic fracture [3].

3.1. Tectonic fracture
Tectonic fractures are formed under circumstances of tensile or compressive stress when the stress subjected by the formation exceeds its elastic limit and breaks occur, and which are related to regional tectonic movements [4]. The concentration of tectonic fractures varies in different structural areas, that is, fractures of single strike principally develop and minor derived fractures of other strikes also form where a stress of single direction exists, and reticulate fractures develop where stresses of multiple directions converge. The tectonic fractures of the NT reservoir are characterised by straight edges, long extension length, and has directivity and group system. The tectonic fractures observed on cores are mainly low angle or oblique, with minor high angle or vertical fractures observed occasionally (Figure 2).
3.2. Dissolved fractures
Dissolved fractures develop from pre-existing tectonic fractures or where formation is brittle, which has irregular shapes, uneven plane and obvious dissolution phenomenon. The dissolution process is caused by unsaturated pore fluids and can proceed as long as pore fluids changes into unsaturated condition and flowage continues [5]. So dissolution process can occur at any diagenetic stages after sedimentation, even during sedimentary period, not only in weathered crust but also in deeply-buried formation, accordingly hypogene dissolved fractures and burial dissolved fractures are produced (Figure 3).

3.3. Diagenetic fracture
Diagenetic fractures form during or after diagenetic process being unrelated to tectonic movement or only having an indirect relationship to it, which is also called primitive non-tectonic fracture [6]. The primary features of diagenetic fractures comprise being bounded by bedding, stretching parallel to and within formation, and having irregular shapes.

The diagenetic fractures of NT carbonate reservoir fall into two types which are interlayer fractures and stylolites.

3.3.1. Interlayer Fractures
Interlayer fractures are surfaces or beddings of rock formation being a typical kind of diagenetic fractures and often described as parallel or low-angled fractures during core observation. Due to their contribution to fluids seepage and storage, interlayer fractures are considered as a kind of fractures in view of broad sense. Interlayer fractures extensively exist in micritic calcarenite, limestone with argillaceous ribbon, laminar algal limestone and muddy limestone, and are usually parallel to formation and filled by calcite, shale, etc., the space between which is 5 to 7 cm, with the minimum of 1 to 2 cm (Figure 4).
3.3.2. **Stylolite** Stylolite is a typical kind of diagenetic fractures, and widely spread in carbonate rocks. They form in telogenetic stage of deep burial under the burden of overlying sediments. Due to the effects of pressure and pore fluids, the mineral grains of carbonate rocks on stress concentration points are selectively dissolved and the products of which either precipitate on grain surfaces subjected to less stress or migrate out of the system, which form bay-shaped or denticulately embedded structure. Stylolites are caused by the common effects of compaction and pressure solution with their teeth indicating the stress direction subjected, and the amplitude reflecting the degree of compaction and pressure solution. Because the dissolved component is mostly of calcite, the residual, non-dissolved materials such as mud residual and carbonate are usually exist on the surfaces of stylolites. Most stylolites lie horizontally, and minor ones vertically or obliquely, and generally the former ones form earlier than the late ones (Figure 5).

4. **The distribution features of fractures**
   According to the classification criteria, fractures observed in cores of seventeen wells from the NT reservoir are classified into four kinds, that is, tectonic fracture, interlayer fracture, stylolite and dissolved fracture, by the result of which, diagenetic fracture accounts for the largest percentage being the principal fracture, and dissolved fracture and tectonic fracture follow behind it in turn.

   Diagenetic fracture account for 65.5% and 80.9% of the fractures in formation KT-I and KT-II separately, and the next one is dissolved fracture. Formation KT-I was exposed to the air due to late tectonic movement and subjected to strong weathering, erosion and karstification, so the percentage of dissolved fractures in formation KT-I is relatively large being 25%, much bigger than that of formation KT-II which is 12.8%. Tectonic fracture is the least one, accounting for 9.54% and 6.35% of the fractures in formation KT-I and KT-II separately (Table 1).
Table 1. Statistics of fractures by genesis.

| Formation | Tectonic fracture | Dissolved fracture | Interlayer fracture | Styolite | In all |
|-----------|------------------|--------------------|---------------------|---------|-------|
|           | count            | Percent-           | count               | Percent-| count |
|           |                  | age, %             |                     | age, %  |       |
| KT-I      | 265              | 9.5                | 696                 | 25.0    | 856   |
|           |                  |                    |                     | 30.8    | 963   |
|           |                  |                    |                     | 34.6    | 2780  |
| KT-II     | 288              | 6.4                | 578                 | 12.7    | 1555  |
|           |                  |                    |                     | 34.3    | 2114  |
|           |                  |                    |                     | 46.6    | 4535  |
| In all    | 553              | 7.6                | 1274                | 17.4    | 2411  |
|           |                  |                    |                     | 33.0    | 3077  |
|           |                  |                    |                     | 42.1    | 7315  |

According to the amount of fractures and the percentage of different kinds of fractures in seventeen cored wells these maps, fractures are richer in the middle and north than south area of the project, which is relative to tectonic movements and the topography during diagenetic process. Relatively more tectonic and diagenetic fractures develop in the north area where the formation subjects to higher uplift during tectonic movements and stronger stress and large amounts of dissolved fractures form during the late dissolution process, especially in formation KT-I, dissolved fractures account for obviously larger percentage in structurally high area than others.

5. The influence of fractures on reservoir properties

Fractures formed by different formation mechanisms influence fluid seepage to different degrees[7]. Most of high angle fractures are Tectonic fractures, and tectonic fractures are mostly of large aperture and possess strong connecting ability to pores, and dissolved fractures also improve reservoir properties effectively possessing irregular shapes, uneven plane and have a wide distribution, however, diagenetic fractures are mostly closed or of small aperture and contribute relatively little to fluid seepage. Tectonic and dissolved fractures account for relatively larger percentage of fractures in formation KT-I consisting of five subzones of A1, A2, A3, B1 and B2 than those in formation KT-II consisting of six subzones of G1 to G6, and accordingly larger porosity and permeability than those of KT-II. Reservoir porosity of each subzone of KT-I is 9.13% to 12.59% with an average of 11.82%, and permeability 1.18mD to 112.54mD with an average of 84.2mD, and reservoir porosity of each subzone of KT-II is 8.51% to 10.95% with an average of 9.9%, and permeability 4.96mD to 58.7mD with an average of 23.9mD (Figure 6).

Figure 6. Histogram of reservoir properties of each subzone of NT oilfield.

6. Conclusions

Fractures widely develop in carbonate reservoirs, and according to their formation mechanism fractures can be classified into three major types that are tectonic fracture, dissolved fracture and diagenetic fracture which comprises of interlayer fracture and styolite. The features of fractures and their influence to reservoir properties are different due to their different formation mechanism. In the NT oil field, Tectonic and dissolution fractures account for relatively larger percentage of fractures in formation KT-I then KT-II, so the Reservoir porosity and permeability of KT-I is larger than KT-II. The average porosity and permeability of KT-I are 11.82% and 84.2mD, and those of KT-II are 9.9% and 23.9mD.
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