The influence of diagenesis on the heterogeneity of sandstone reservoir

Ming Yan
No.3 Oil Production Plant of Daqing Oilfield Company Ltd., Daqing 163113, China
ym06879@sina.com

Abstract. Diagenesis plays an important role in controlling the quality and heterogeneity of clastic reservoirs. The variation of diagenesis is usually reflected in the variation of sedimentary porosity and permeability. The effects of the types and distribution of sedimentary rocks and clastic sedimentary evolution and sequence stratigraphic framework provide a powerful tool to predict the prediction effect on the distribution of rock mass and the heterogeneity of the control effect. The heterogeneity of sandstone reservoir, it determines the volume, velocity and hydrocarbon recovery, the sand body geometry and internal structure, grain size, sorting, bioturbation degree, origin, and diagenesis types, volume and distribution.

1. Introduction
Reservoir heterogeneity is the mean porosity and permeability or capillary phenomenon in the vertical and horizontal change. The heterogeneity of reservoir sand bodies, including different sections and scales, ranging from microns to hundreds of meters, is usually influenced by sedimentary facies, diagenesis and structural features. Reservoir heterogeneity affects reservoir performance by controlling fluid flow and recovery factors. The study of reservoir heterogeneity and prediction is the most important plan and strategy to improve oil and gas production.

The relationship between diagenesis and reservoir quality and heterogeneity is controlled by sedimentary facies and sandstone sequence. The sedimentary facies is usually controlled by: (1) the original porosity and permeability of sandstone; (2) the geometric characteristics of sand body, the ratio of sand to mud, the structural characteristics; (3) the chemical composition of pore water and the early diagenesis near the surface. The influence of deposition parameters (1) and (2) on the velocity and flow of the fluid will affect the degree and distribution of the early diagenesis of the sandstone reservoir. These changes promote the heterogeneity of the reservoir. For example, the cementation along the transgressive surface can be used to predict the upper and lower sequence stratigraphy. Early diagenesis is mainly buried diagenesis, diagenetic evolution of sandstone in the burial diagenetic fluid distribution of porosity by limiting and early effects, such as the product of diagenesis, conversion of clay minerals and quartz cements.

2. Type, particle size and its effect on Diagenetic Evolution and reservoir heterogeneity
The framework of the sandstone and the geological evolution of the source rocks (including the type and structure of the source rocks) are usually controlled by paleoclimate, sedimentary processes, relative sea-level changes and the control of sediment.

The mechanical and chemical stability of sandstone is related to its grain size composition. The clastic framework of sandstones can be divided into four groups: non carbonate in the basin, carbonate...
in the basin, non carbonate in the basin, carbonate particles in the basin. A mixture of different mixtures is called a mixed sand.

2.1. Non carbonate particles
In general, the chemical composition and mechanical composition of mature sandstones are stable. They have better potential for developing high-quality reservoirs in deep burial depth. The feldspar rich sandstone is stable in composition but contains unstable chemical components, such as the long-term interaction between unsaturated atmospheric water, which will promote the dissolution of particles and kaolinite. Sandstone with abundant lithic components usually contains unstable chemical components or mechanical components. With the increase of depth, the porosity and permeability of sandstone with abundant mechanical components will decrease rapidly due to mechanical compaction.

In the process of diagenesis, the chemical components of volcanic components are unstable and tend to be montmorillonite, chlorite clay mineral, zeolite, calcite and silica. However, not all sandstones are rich in lithic debris, but are chemically and mechanically unstable. Sandstone rich in igneous rock fragments or chert has a large degree of mechanical and chemical stability.

2.2. Carbonate reservoir
These particles are relatively rare in the sand, this is because the carbonate source rock depends on the chemical conditions rather than their own, especially in wet conditions. However, in the tectonic active period such as fold thrust faults and transition faults, carbonate rocks can provide a large number of carbonate particles, such as foreland basins in North America and Italy. These can provide a short time for the chemical weathering of subaerial exposed bedrock and the transient migration of particles accumulated prior to carbonates.

The carbonate particles in the basin, including limestone, dolomite fragments, single crystal calcite, dolomite particles, nucleation and the growth of the hydrochloride cement, resulting in reduced porosity and permeability. The reduction of porosity is caused by chemical compaction. In addition, these dissolved particles are sources of carbonate cements in pore closure.

2.3. Carbonate reservoir
These particles come from continental, shallow sea and deep sea sandstones. In marine sedimentary environments, these particles are mainly derived from the carbonate sediments of the continental shelf. The carbonate debris may also be derived from the erosion of carbonate cements, consolidating the vadose zone. In this way, the clastic rocks in the carbonate rocks are deposited in the river channel.

The carbonate particles are as follows: (1) the core of carbonate cement precipitation, such as the surface of the early diagenesis of the foreshore, turbidity, river detention sand. (2) carbonate cements are derived from their dissolved matter, which is typical of sandstone affected by active atmospheric water seepage. Therefore, the sediments rich in the basin hydrochloride particles generally have carbonate cements, which will greatly reduce the deposition porosity and permeability. In addition, the grain size of the carbonate particles is relatively ductile and the porosity is decreased by mechanical compaction.

2.4. Non carbonate particles
The argillaceous debris is defined as the erosion debris from the low energy deposition and the quasi syngenetic deposition in the high energy environment. The erosion of these debris from: (1) flood plain deposit, the corresponding soil common in fluvial deposits, usually in the river bottom conglomerate deposited; (2) muddy turbidite in turbidite bottom slope and redeposition; (3) is deposited in the continental shelf sedimentary transgression lag and in succession the shallow sea transgression. Because of the toughness of these clasts, pseudoplastic deformation occurs at a relatively shallow depth, with the formation of pseudo matrix. Rich in mud intraclasts strata may exist extensive carbonate cements in the early diagenetic stage, so without unloading rock and false matrix.
Table 1. Early diagenetic changes and their control parameters, common sedimentary facies and their potential impact on reservoir quality

| Process                                                                 | Main control parameters                                                                 | Sedimentary facies                      | Effect on reservoir quality                                      |
|------------------------------------------------------------------------|----------------------------------------------------------------------------------------|----------------------------------------|----------------------------------------------------------------|
| Mechanical compaction and formation of matrix                          | A large number of plastic debris particles, muddy debris                               | Turbidite, fluvial and deltaic sandstones| Rapid loss of porosity and permeability during burial            |
| Dissolution of feldspar and kaolinite                                   | A large amount of feldspar, effective atmospheric water                                | River, tidal, delta sandstone           | The formation of the inner hole and the mold hole                 |
| Cementation of K-feldspar                                              | A large amount of potash feldspar                                                     | River, tidal, delta sandstone           | Very little degradation of permeability                          |
| The formation of iron bearing clay with granular coating                | Sedimentation rate                                                                     | Delta and shallow sand                  | In the middle diagenetic stage                                   |
| The formation of micro quartz with granular coating                     | Abundant siliceous detritus                                                            | Shallow and deep sand                   | Overgrowth of quartz inhibits the production of cement           |
| Alteration of rock fragments of feldspar and mafic volcanicslastic rocks| The source of sediments, the volcanic activity at the same time, the structural styles of the basin | All sedimentary facies                  | Feldspar particles: porosity and permeability loss due to cementation of montmorillonite, zeolite, quartz and opal |
| Dissolution of carbonate particles                                      | The humid climate and the permeability of sandstone help to increase the flux of atmospheric water | Delta and shallow sand                  | Because of the formation of the inner hole and the mold hole, the porosity increases |
| Cementation of calcite, dolomite and siderite                          | The source of sediments, the volcanic activity at the same time, the structural styles of the basin | All sedimentary facies                  | Porosity and permeability                                       |
| Mechanical penetration of clay                                          | Mainly braided river and alluvial fan, followed by meandering river and Delta          | River and delta sandstone               | It is possible to inhibit the production of the colloid by the overgrowth of quartz to protect the porosity of the deep buried sandstone |

In a large number of authigenic glauconite condensed section enrichment related to marine flood events and transgressive system, because it can provide good conditions for authigenesis, settlement rate and the amount of organic matter in depth more than 100m on the platform of low. Quasi autochthonous glauconite, sandstone and quartz sandstone in the transgression related content rich, such as glauconite sand, in sedimentary and sequence boundary related lag. Modification of the shelf edge parautochthonous glauconite occur in turbidite deposition. Glauconite particles have toughness and rapidly after compaction deformation, lead to the decrease of porosity, but the chemical nature of rock stability in most of the burial environment.

Dissolve in the early diagenetic stage of elastic siliceous organisms. Release of dissolved silica can be precipitated in the vicinity of the framework of the particle microcrystalline quartz. At the stage of
deep burial diagenesis, the marginal product of the microcrystalline quartz can inhibit the generation of secondary enlargement of quartz and the solution of pressure. This situation exists in Sandy Rock, rich siliceous bioclastic contains abundant siliceous biogenic debris or adjacent, such as rocks, siliceous mudstone, radiolarian spiculite, diatomite and flint fine sediment. As a result of the appearance of the granular envelope, both the chlorite and the titanium mica are iron, and they are formed in the Delta and estuary. In the process of the burial depth, the chlorite and the titanium mica all developed into the chlorite. These soft particles are easy to be compacted, but usually have little effect on the porosity of sandy rocks.

3. Conclusion

The change of diagenetic distribution during the evolution of sandstone may aggravate the heterogeneity of reservoir. However, the linkage of diagenesis and sedimentary facies and the key sequence stratigraphic interfaces and system tracts provide a powerful tool to predict sandstone diagenetic changes, particularly offshore.

Early diagenesis is an iron-clay mineral with a granular coating, especially in the Delta and estuarine sandstones. In the middle diagenetic stage, the transition from the quartz cementation to the core reduces the surface and tends to oil wet to protect the reservoir quality.

The development of particle coated montmorillonite clay is an important factor for the evolution of reservoir quality and heterogeneity. In the middle diagenetic stage, transformation of smectite to illite, which has dual effects on the reservoir, including quartz particles, between pressolution enhancement and coaxial quartz has clean surface of the quartz grain deterioration of reservoir quality caused by overgrowth cementation; deep buried in the preservation of porosity and permeability in the sandstone reservoir. Inhibit or delay the quartz overgrowth cementation in sandstone, such as evolution, is rich in mineral particles.

Sequence boundary is related to diagenesis. Controlled by climatic conditions, the warm and humid climate caused considerable dissolution along the boundary of the sequence and the Gaoling petrochemical of the framework silicate. However, the semi-arid climate resulted in the formation of calcareous conglomerate or dolocrete cementation layer.

In the turbidite early carbonate cement rock is usually concentrated in the deep layer of cement or bathyal mudstone or carbonate mud and lime clay and the contact surface of carbonate bioclasts and intraclasts condensed layer. The cementation of turbidite sandstone with mixed carbonate, adjacent, coarse grained, large amounts of turbidity usually randomly dispersed spherical or ovoid conjugates.

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