Vol. 89 No. 3 pp. 1051–1052 ACTA GEOLOGICA SINICA (English Edition) June 2015

Research Advances

# Application of Pore Evolution and Fracture Development Coupled Models in the Prediction of Reservoir "Sweet Spots" in Tight Sandstones

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The Chang-$6^3$ reservoir in the Huaqing area has widely developed tight sandstone reservoirs characterized by "thick sand layers, but not rich in oil", and it is thus necessary to further study its oil and gas enrichment law. This study builds porosity and fracture development and evolution models in different deposition environments, through core observation, casting thin section, SEM, porosity and permeability analysis, burial history analysis, and "four-property-relationships" analysis. The present reservoir capacity and permeability and those at hydrocarbon accumulation critical period were dynamically analyzed from the aspect of "first compact and then accumulate" or "first accumulate and then compact" in combination with the oil and gas accumulation history. Furthermore, a map showing sedimentary-diagenetic facies and fracture development in the present and the critial period were made using the method of "overlay of three factors", and the hydrocarbon accumulation "sweet spot" in tight sandstone was determined. It is shown that the hydrocarbon enrichment "sweet spot" is significantly controlled by the porosity and fracture development. The sedimentary-diagenesis facies-fracture development map based on pore evolution and fracture development coupled models can accurately predict the "sweet spot" distribution areas in tight sandstones.

We analyzed the sedimentary facies by core observation and log facies analysis. It is indicated that the reservoir is dominated by underwater distributary channels of delta fronts distributed in four main oil sand bodies of the Yuan 284, Bai 209, Bai 156 and Shan 138 in NE-SW direction; the width of these sand bodies is about 4-6km, the thickness is about 5–25m, and the average thickness is about 18.5 m.

The development and evolution of reservoir pores and the formation and reconstruction of fractures is a dynamic process. Integrated casting thin section, ordinary thin section, SEM authigenic mineral observation, inclusion analysis with burial history suggest that the diagenetic evolution of Chang-$6^3$ sandstone is as follows: clay edge formed in early time→aluminum silicate and volcano glass hydration→formation of zeolite cements→rapid compaction in early time (porosity decreased sharply) →fractures developed in different degree (Yanshanian movement, 165Ma)→organic acid entered (low-mature oil and gas formed, 140Ma)→feldspar, debris particles and zeolite cements corrosion→authigenic kaolinite formed and the secondary enlargement of quartz→role of oil emplacement (a mature stage of oil and gas, Late Jurassic-Early Cretaceous)→mechanical compaction (porosity deceased steadily)→role of oil emplacement (a mature-high mature stage of oil, Late Cretaceous)→deep compaction (porosity decreased slowly)→the process of late iron carbonate precipitation.Different primary porosity, fracture development degree and pore throat decay rate of sandstones from different facies lead to their final different physical properties. Therefore, we divided it into the following three sedimentary-diagenetic facies:

(1) The underwater distributary channel-laumontite dissolution facies. They are distributed along the four stripped sand bodies. The pore space is primarily intergranular pores. The reservoirs have small pores with micro throats, with current porosity of 8%–14%. The main sand belts have the largest porosity and permeability, with their porosity ranging from 11% to 14%.

(2) The underwater distributary channel side-authigenic chlorite cementation facies. There is little chlorite clay film filling between sandstone clastic particles. The major reserving space is primarily intergranular pores and micro fractures. The current porosity lies between 7% and 12% and the porosity and permeability are inferior to the former.

(3) Interdistributary bay-clay filling facies. Current porosity is smaller than 8%. The sandstone pores are largely filled by massive clay at a synsedimentary stage under this environment. The pore throat decreases fast

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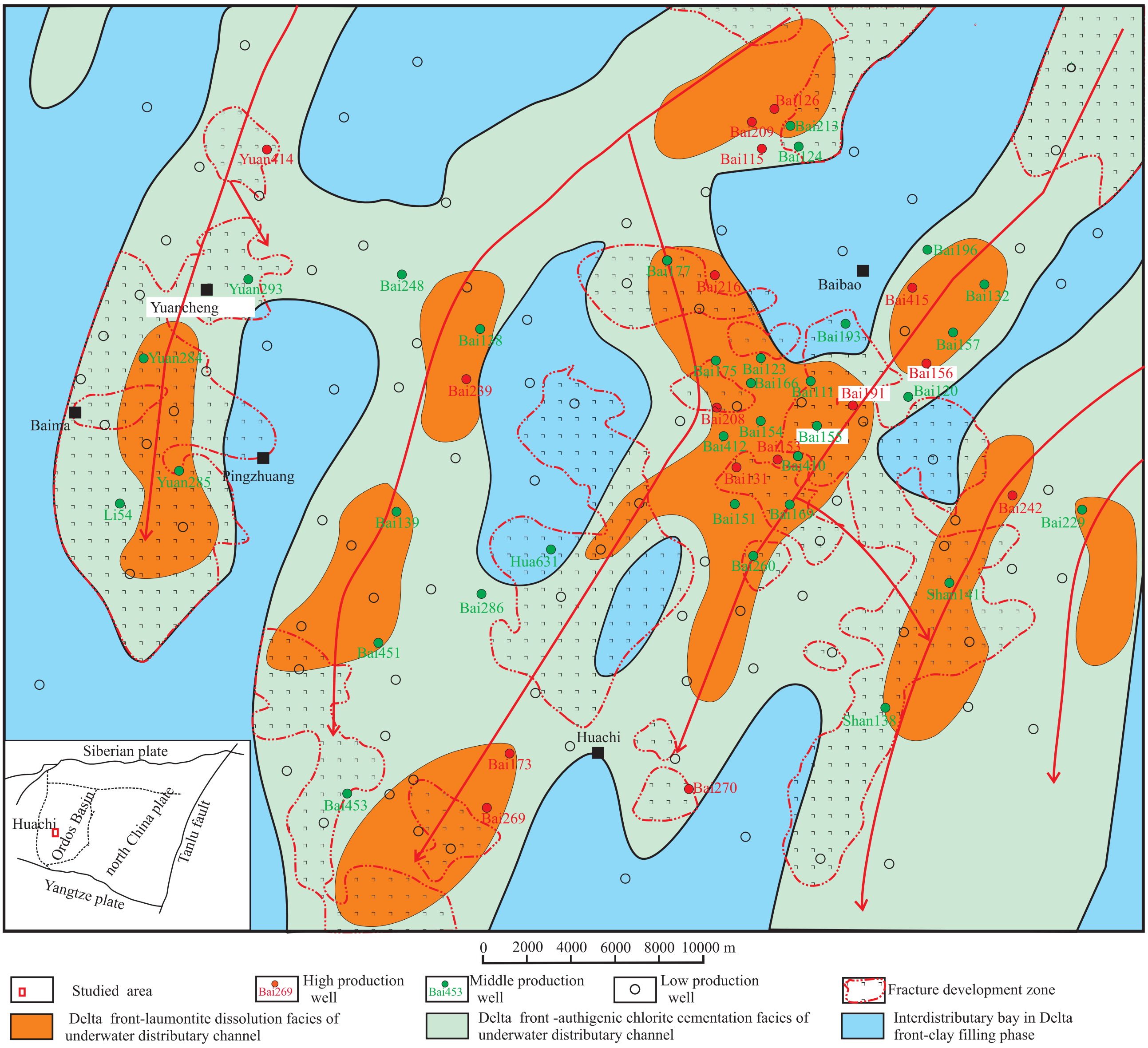


Fig. 1. Sedimentary-diagenetic facies and the prediction of fracture development degree in chang $6^3$ reservoir of Yanchang group in the Huaqing area.

during the compaction process. The ancient porosity is low during the critical reservoir forming period, and the reservoir is hard to be reconstructed by acidic fluid. It is hard for hydrocarbon to migrate into the reservoir, resulting in low hydrocarbon abundance.

Based on reservoir anisotropy stress field simulation, the planar fracture development degree was predicted integrated with core observation and the duality method.It is suggested that the fracture development areas are concentrated around the well blocks of Bai 155–Shan141, Bai169–Bai131, Hua 631 and Yuan 284–Yuan 285.

A comprehensive analysis of the three factors of sedimentary environment, diagenesis and pore evolution, and fracture development features was conducted to delineate dominant transporting sand body and high-quality reservoir areas during critical reservoir-forming period. Based on this, we have pointed out the hydrocarbon accumulation "sweet spot" in tight sandstone. It is suggested that underwater distributary channel laumontite dissolution facies in favorable well blocks of Bai 216–Bai 410, Bai 209, Yuan 284-Yuan 285 should deploy development wells (Fig. 1). The exploration and development practices indicate that oil production of the existed drilled wells from laumontite dissolution facies of underwater distributary channel is greater than 2 t/d, and that from side-authigenic chlorite cementation facies of underwater distributary channel is 1–2 t/d while that from interdistributary bay-clay filling phase exploration wells is 0–1 t/d.