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RESEARCH PAPER

Buried hill karst reservoirs and their controls on productivity

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Abstract: The concept model of ancient buried hill karst reservoirs was built taking the NWKK carbonate rock oilfield in the South Turgay Basin in Kazakhstan as an example, and the characteristics of karst reservoirs and their controls on productivity were analyzed in vertical and horizontal directions. Vertically, the karst reservoirs can be subdivided into, from top to bottom, weathering crust zone, epikarst zone, caves zone, vadose zone and phreatic zone, in which the development of fractures is strengthened gradually; Six reservoir types, breccia pore, cave, vug, fracture-vug, fracture-pore and pore, were developed; Each karst zone has high oil production and low water cut in the initial stage because of the developed fractures and karst caves, but the production declines rapidly and the water cut rises fast. Horizontally, the karst reservoir characteristics are controlled by structure altitude and ancient lithofacies: the ancient buried hill with high structure altitude and loose lithology suffers from stronger weathering and leaching, has much more solution caves and holes, the main reservoir types are breccia pore, cave, and vug, while the ancient buried hill with low structure altitude and compacted lithology has highly developed fractures and stronger communication with bottom water, the main reservoir types are fracture-vug and fracture-pore, and the reservoirs have better productivity effect but rapid production declines and water cut rising. Different areas in plane should adopt different development techniques and policies.

Key words: ancient buried hill; karst reservoir; reservoir characteristics; reservoir concept model; productivity characteristics; South Turgay Basin

Introduction

Carbonate ancient karst reservoirs belong to reformed reservoirs[1], with well-developed fractures and caves. Complex in origin and very strong in heterogeneity, this kind of reservoir is very difficult to predict[2]. The researchers have worked a lot on genetic mechanism[3–5], identification means of fractures and caves[6–8], 3D geologic modeling[9–12] and development modes[13–14] of ancient karst reservoirs, and their study results have been successfully applied in exploration and development of carbonate oil reservoirs at home and abroad. Taking the NWKK carbonate oil field in the South Turgay Basin in Kazakhstan as an example, based on core observation of 14 wells, as well as data of seismic survey, well logging, mud logging, well testing, production-absorption profile and development performance, a concept model of ancient buried hill karst reservoirs in this area has been built, to show the development characteristics of these reservoirs in vertical and plane directions, as well as their controls on productivity.

1. Geology

Located on the Aksay Bulge in the Aryskum Depression, in the south of the South Turgay Basin (Fig. 1a), the NWKK oil field is a carbonate oil reservoir in an ancient buried hill. On the plane, it has two ancient tectonic highs - NW high and SE high, the altitude of the NW high is higher than that of the SE high. Faults in the buried hill are mainly in NNE, NNW and SN directions (Fig. 1b). This reservoir is a massive dual-media oil accumulation with edge and bottom water (Fig. 2), and was put into production in 2010.

Influenced by intense tectonic movements in late stage, the carbonate rocks in ancient buried hill in this study area were uplifted to ground surface, subjecting to long-term weathering, erosion and leaching reconstruction by surface water, and finally forming karst reservoirs in the ancient buried hill with weathering crust at its top. With more than 20 types of lithologies, including limestone, meta-sandstone and weathering crust breccia, the karst reservoirs are diverse in types and different widely in spatial distribution. The major storage space includes dissolved pores, dissolved caves and pores. Fractures in the reservoir, moderately developed, are high-angle fractures (with dip angle of 50°–75°, which is basically consistent with fault striking directions). These frac-

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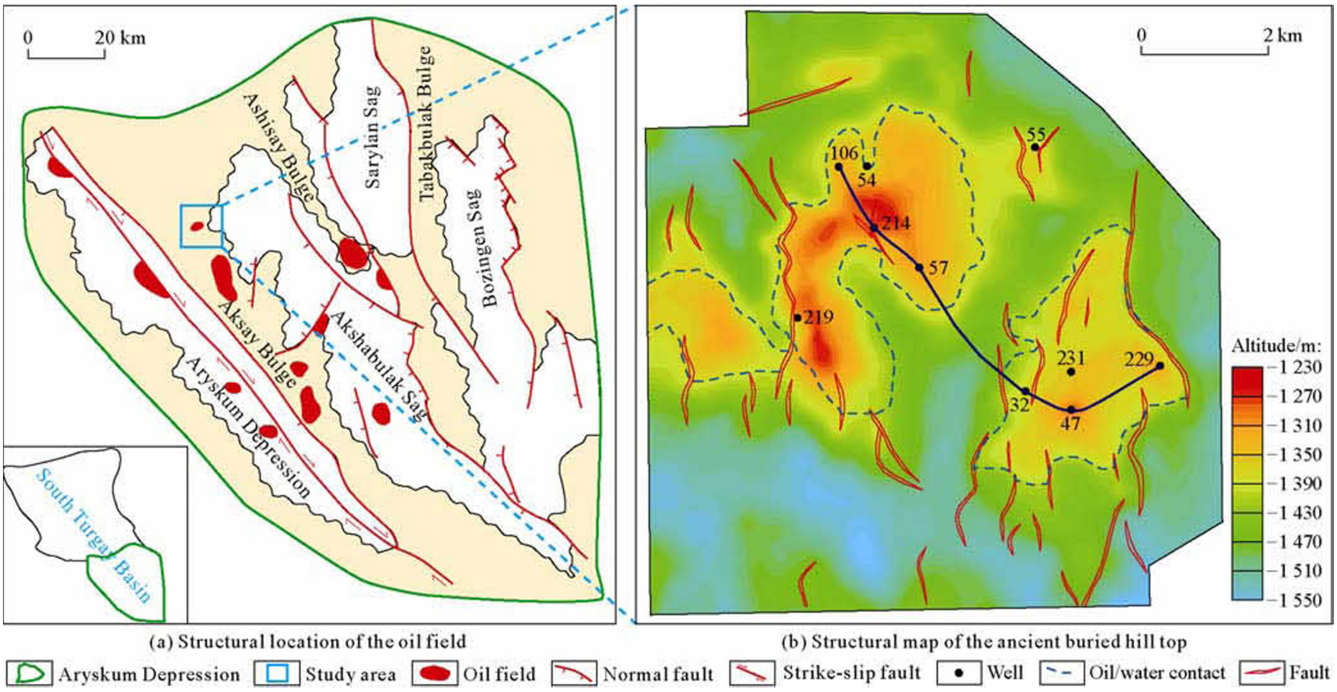

Fig. 1. General geology of the NWKK oil field.

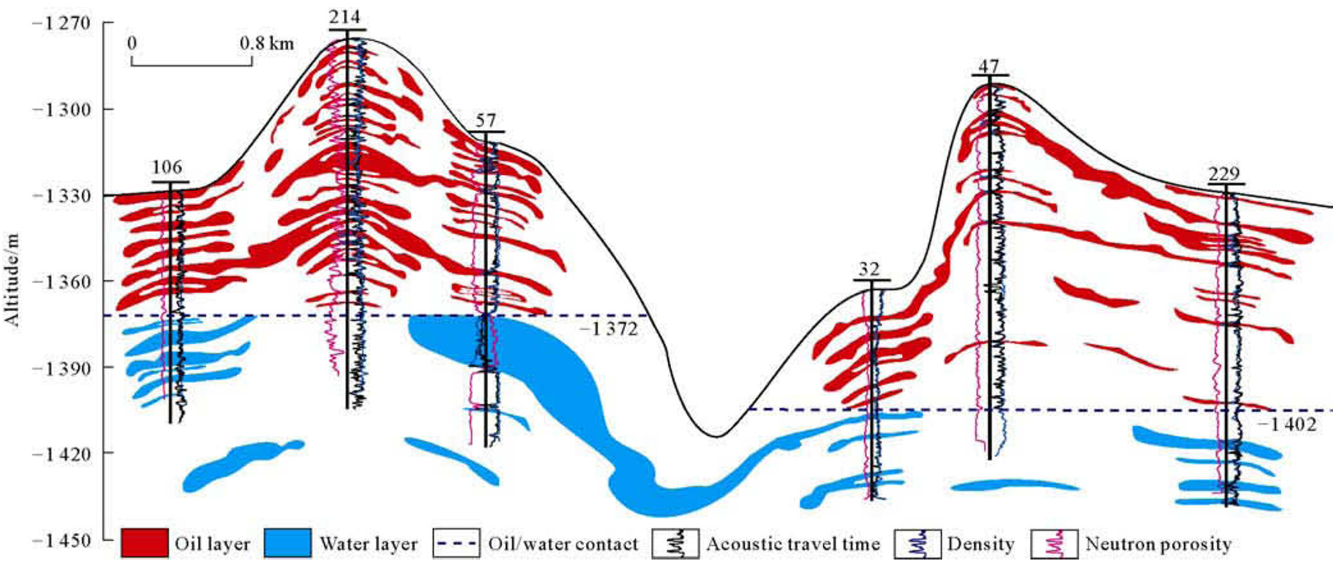

Fig. 2. Profile of ancient buried hill reservoir of the NWKK oil field (see Fig. 1b for the profile location).

tures connect pores and conduct hydrocarbons. Wide in physical property range, the karst reservoirs are 5.2%–40.0% in porosity (averagely 19.8%), (0.1–300.0)×10^{-3} μm^2 (averagely 8.4×10^{-3} μm^2) in permeability, and strong in heterogeneity.

2. The karst reservoirs

2.1. Concept model of karst reservoirs

Combining some static geology data (core, etc.) and development performance data (well testing, etc.), karst reservoirs in ancient buried hill (Pz) in this study area are divided into five types (i.e. weathering crust zone, epikarst zone, cave zone, vadose zone and phreatic zone) from upper to lower in vertical direction, and a concept model of the karst reservoirs is established (Fig. 3). Moreover, the reservoir heterogeneity of karst zones is analyzed.

The weathering crust zone is composed of breccia residual deposits formed by long-term weathering and leaching after the ancient carbonate rocks outcropped to surface, with loose cementation and apparent slumping. Its storage space includes mainly residual breccia pores after weathering and leaching, with features of sandstone pores. The weathering crust zone is averagely 12 m thick, and not stable in lateral direction. Located at the top of karst reservoir below ancient weathering erosion surface, the epikarst zone has the feature of vertical percolation of surface water, rich vertical dissolved caves to conduct surface water, and is 4 m thick on average and poor in lateral continuity. The cave zone, mainly characterized by