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RESEARCH PAPER

Reservoir architecture and remaining oil distribution of deltaic front underwater distributary channel

FENG Congjun[1, 2], BAO Zhidong[2, *], YANG Ling[3], SI Xiong[1], XU Guibin[1], HAN Xiong[1]

1. State Key Laboratory of Continental Dynamics, Department of Geology, Northwest University, Xi'an 710069, China;
2. State Key Laboratory of Petroleum Resource and Prospecting, College of Geosciences, China University of Petroleum, Beijing 102249, China;
3.Reservoir Evaluation Center, China Petroleum Logging CO. LTD., Xi'an 710077, China;

Abstract: Taking the J19 dense well network area in the Fuyu Oilfield as a case, combined with field outcrop and modern shallow water delta sedimentary model and using coring and logging data, this paper puts forward a comprehensive analysis method for reservoir architecture of deltaic front underwater distributary channel single sand body. The causes and sedimentary evolution mechanisms for foresets of retained type, destructive type and the mixed type and for foreset sandbodies of prograding type, retrograding type and aggrading type are summarized. The calibration of rock and logging, fitting formula, dense spacing wells and pair wells data are used to ascertain the foresets and foreset sandbodies. The models of three-dimensional reservoir architecture are set up. The analysis of remaining oil shows that foreset controls the vertical distribution of the remaining oil, while in the internal of foreset sandbodies, the remaining oil is enriched in the updip direction.

Key words: deltaic front; underwater distributary channel; single sand body; reservoir architecture; remaining oil

Introduction

In order to meet the demand of the remaining oil recovery during the later stage and tertiary recovery of mature oilfields, it is necessary to get a better picture of the oil reservoir [1–3], the internal structure of single sand body [4–10], delineate the internal structure of single sand body tens meters or only a few meters across between wells, and establish precise reservoir prediction models under the condition of dense well pattern development [11–17]. According to the actual situation of Fuyu oil field, the paper tries to find out the single sand body architecture and fine characterization methods of delta front underwater distributary channels.

1 Geological background

Located in the central depression area of southern Songliao Basin (Fig. 1), Fuyu Oilfield is a medium porosity and medium permeability structural sandstone reservoir. Fuyu reservoir of K_1q^4 at a burial depth of 310 to 450 meters is the major oil pay with a thickness of 70 to 120 meters. Mainly feldspar lithic sandstone and lithic feldspar sandstone, the rock is fine in grain size, medium in sorting and roundness. Heavy mineral analysis shows that the sediments have far source transportation features, the provenances mainly came from the southwest and south, detrital material was carried into the basin along the long axis of the basin, the depositional system was shallow water delta. J19 block is located in the central of Fuyu Oilfield, where five types of sedimentary microfacies developed, namely, underwater distributary channel, mouth bar, distal bar, underwater natural levee, and distributary bay.

The lithology of underwater distributary channel in the study area is mainly thick fine sandstone and siltstone, with thin interlayers of mudstone or calcareous siltstone. There developed cross bedding, parallel bedding, massive bedding, surface of scour, occasional lag deposits in the underwater distributary channel; the vertical sequence is positive rhythm or composite rhythm; the underwater distributary channel is flat on top and convex at bottom, the granularity of cumulative probability curve contains two stages; well logging curves are usually in box or bell shape. The fining of particle size and shale content increase gradually upward in the underwater distributary channel, together with strong water sweeping at the lower part of the underwater distributary channel, result in the fact that remaining oil is mainly distributed in the upper part of underwater distributary channel.

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*** Corresponding author.** E-mail: baozhd@cup.edu.cn
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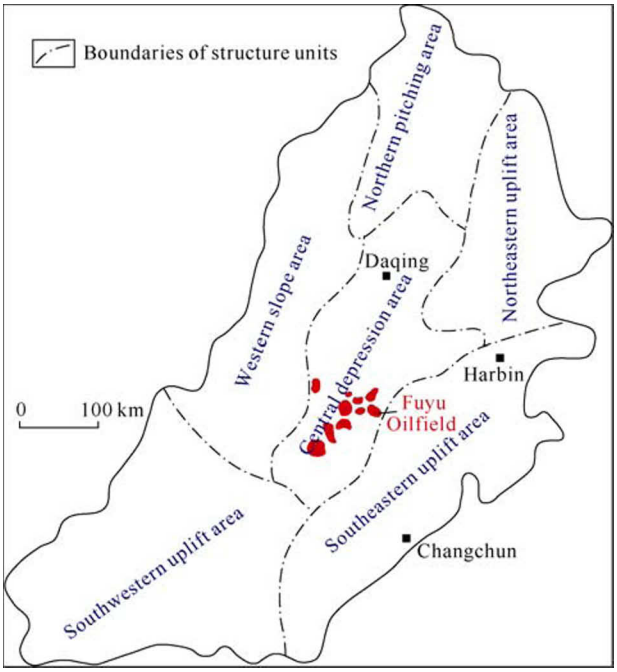

Fig. 1 Structure location of Fuyu Oilfield (From reference [18], modified)

2 Quantitative characterization of architectural elements

2.1 Type of architectural elements

Architectural elements are the architectural units of the reservoir [19–23], according to the interface classification of Miall [8] and the difference in the single sand body deposition mechanism, there are two kinds of architectural elements in underwater distributary channel single sand body, foreset sandbody and foreset. The foreset sandbody is the sandy sedimentary unit deposited in strong hydrodynamic condition, the foreset is the argillaceous sedimentary unit deposited in weak hydrodynamic condition.

2.2 Quantitative characterization of foreset

2.2.1 Type of foreset

A foreset is an argillaceous sedimentary unit deposited on the early foreset sandbody, meanwhile it can be destructed and reconstructed by the next foreset sandbody, so it is an important symbol to distinguish two foreset sandbodies. According to the damage degree of foresets perpendicular to the underwater distributary channel, the forset evolution in vertical direction can be divided into three types (Fig. 2).

(1) Remained form foreset. The remained form foreset refers to the foreset that is not completely destructed and remains a certain thickness, due to weaker local scouring by the later foreset sandbody. In flood period, sufficient provenance supply would result in sandy sediments, i.e. the foreset sandbody; after the flood, argillaceous sediments would deposit onto the foreset sandbody, forming a foreset; then in the next flood period, a new foreset sandbody would deposit onto the foreset. If the foreset was weakly destructed and could be preserved, many times after the flooding events, the remained form foreset would come into being which contains multiple foresets and foreset sand- bodies (Fig. 2a).

(2) Destructive foreset. The destructive foreset refers to the foreset which is destructed in the center of the channel, and left partially in only two wings of the channel due to strong local scouring of the next foreset sandbody. Many times after the flooding events, the destructive profile foreset would form which contains multiple destructed foresets and foreset sandbodies (Fig. 2b).

(3) Mixed foreset. The mixed foreset is a combination of remained form foreset and destructive profile foreset. Because different floods are different in hydraulic energy, so are their transportation and deposition, and their destruction to the foreset, many times after the flooding events, mixed foreset would form which contains multiple destructed foresets and foreset sandbodies (Fig. 2c).

2.2.2 Occurrence and scale of foresets

In the interior of underwater distributary channel, tendency of foreset is mainly referring to the direction of extension of underwater distributary channel. The dip of foreset is the angle between the progradation plane and the horizontal plane. Statistics show that the dip of prograding type and retrograding type foresets is larger, generally between 3° and 6°; the dip of aggrading type foresets is smaller, mostly in between 0 and 3 °. Perpendicular to the extension direction of the river, the width of remained form foresets approximately equals to the width of the channel; the width of destructive foresets, related to the extent of damage, is difficult to quantify.

2.2.3 Quantitative characterization of foreset thickness

The lithology of foresets in underwater distributary channel in the study area includes laminated mudstone or silty mudstone, generally 0.2 to 0.6 meter thick. The presence of foresets results in significant return *on* R_{05} (0.5 meters potential resistivity) and R_{25} (2.5 meters bottom of gradient resistivity) curves, natural gamma curves also show return. The return

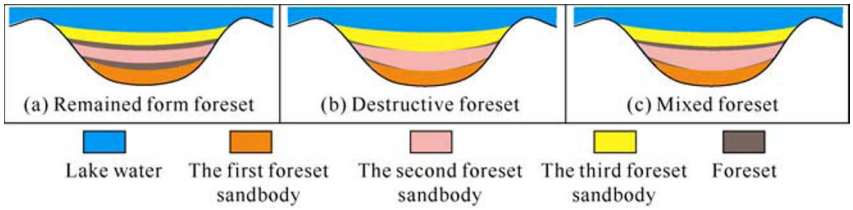

Fig. 2 Evolution type of foresets perpendicular to the underwater distributary channel