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RESEARCH PAPER

Big data paradox and modeling strategies in geological modeling based on horizontal wells data

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Abstract: Based on analysis of horizontal well data characteristics, the differences of data distribution and variogram between vertical and horizontal wells in MPE3 oil field of Orinoco heavy oil belt were compared, and modeling strategies were proposed to cope with the big data paradox when data of horizontal wells was used directly into geologic modeling. The study shows the horizontal wells in the study area contain a large quantity of information, strong directionality of well trajectories and high drilling ratio of sandstone, causing variogram analysis result unconformable to the geologic understanding, and in turn making errors in the modeling of sedimentary microfacies and reservoir physical properties and prediction of probabilistic reserves. Firstly, the distributary channel distribution variogram was analyzed with data of vertical wells, and then the lithofacies framework was established under the control of the sedimentary facies and seismic data. After that, the horizontal wells data revealing high heterogeneity accuracy of reservoir, was combined with the vertical wells data to analyze argillaceous interlayer variograms and the corresponding reservoir lithofacies models were constructed. Finally, reservoir physical property models were generated and the geological reserves were calculated by wellblocks. This reservoir modeling method does not only reflect the geologic features underground, but also improve the accuracy of inter-well sand body prediction, and enhance the reliability of reservoir geologic model ultimately.

Key words: horizontal well; geological modeling; big data paradox; big data analysis; variogram

Introduction

Horizontal wells are remarkably advantageous in old well productivity recovery, oil and gas well productivity enhancement and heavy oil reservoir development, and have been extensively applied to the development of old oilfields, low-permeability oil and gas fields and heavy oil reservoirs[1–4]. At present, horizontal well patterns for various kinds of oil and gas fields have been established. In these oil and gas fields, different from previous modeling based on vertical well data, the application of horizontal well data has a great effect on the geological modeling results of reservoirs[5–9]. The horizontal section of a horizontal well extends longer, so the sand bodies and the corresponding physical property parameters are characterized more accurately[10–11], and the uncertainty of inter-well prediction is reduced. Due to the particular well arrangement mode of horizontal wells, however, a large amount of data is collected in a specific direction, leading to greater effect on data statistical analysis and variogram calculation, and consequently, the paradox occurs in the subsequent sedimentary facies and physical property model. Modeling operators have proposed probability statistic method, Monte Carlo method etc. to reduce the modeling uncertainty, so as to reconstruct the actual underground situation as far as possible[12–15]. In this study, the characteristics of horizontal well data acquisition have been analyzed. Then, the paradoxes of sedimentary microfacies modeling, reservoir physical property modeling and probabilistic reserves calculation in the process of reservoir modeling with horizontal well data and the reasons for them are illustrated. And finally, the strategies to establish high-accuracy geological model by using horizontal well data rationally are proposed.

1. Regional profile

The MPE3 oil field in Orinoco heavy oil belt is located in the southern margin of the East Venezuela Basin, covering an area of 150 km^2. The Oficina Formation of Lower Miocene, Neogene is the principal oil bearing interval in the study area, with extensive sand bodies and large vertical thickness[16–19]. The reservoir of Orinoco heavy oil belt is a typical sedimentary system of sandy braided river-delta plain. The target layer in this paper is M Member, the lower stratigraphic unit of

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Oficina Formation. In MPE3 Block, the provenance is SW-NE trending, the sedimentary microfacies is mainly composed of braided distributary channel and interdistributary bay (Fig. 1), and is presented as a positive-cycle sedimentary rhythm in the log[20–24]. Mainly composed of moderate-fine quartz sandstone, the reservoirs are of high porosity (generally higher than 30%) and high permeability (average 4 000×10^{-3} μm^2). Cluster horizontal well mode is adopted for the development of the study area. In this mode, the average interwell distance is 300 m, wellbore trajectory is mostly EW oriented and single-well horizontal section is 800–1 200 m long. In this paper, the data of 31 vertical wells and 197 horizontal wells for the target layer was adopted for the study (Fig. 2).

2. Characteristics of horizontal well data acquisition

2.1. Data quantity

The horizontal sections of horizontal wells in the study area are long, so the information quantity of horizontal wells involved in the simulation is immense. When vertical wells and horizontal wells are used for modeling jointly, the data points of horizontal wells are superior to the data of vertical wells numerically. The target layer in the study area, M Member is 20 m thick on average, and the sampling interval of log data is 0.125 m. The number of log data sampling points of simple vertical well is about 160. The length of horizontal section is 800–1 200 m, and the number of log data sampling points of simple horizontal well is in the range of 6 400–9 600. When data sampling points of the two well types are shown in 3D grid (Fig. 3), the number of horizontal well data points is much more than that of vertical well, which will have a strong effect on modeling result. That is the big data effect of geostatistics[25].

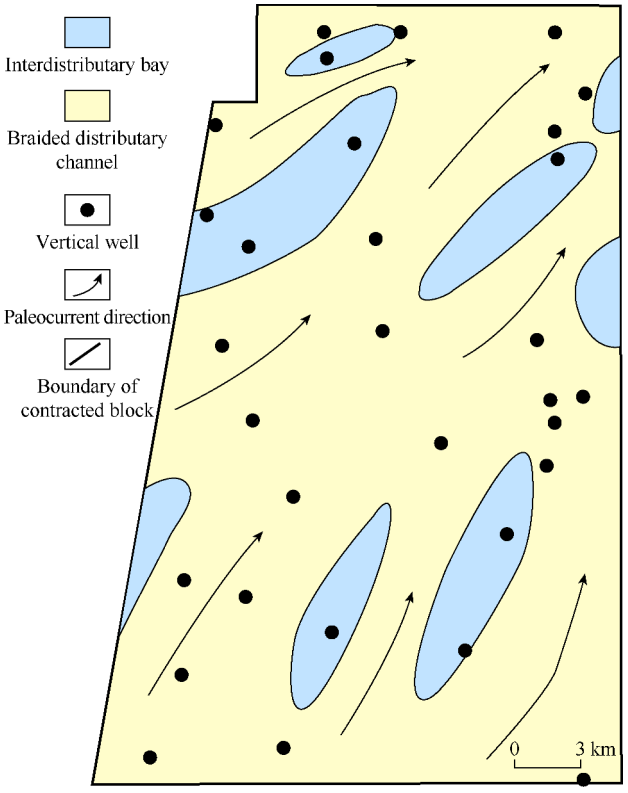

Fig. 1. Sedimentary microfacies in M Member of Block MPE3.

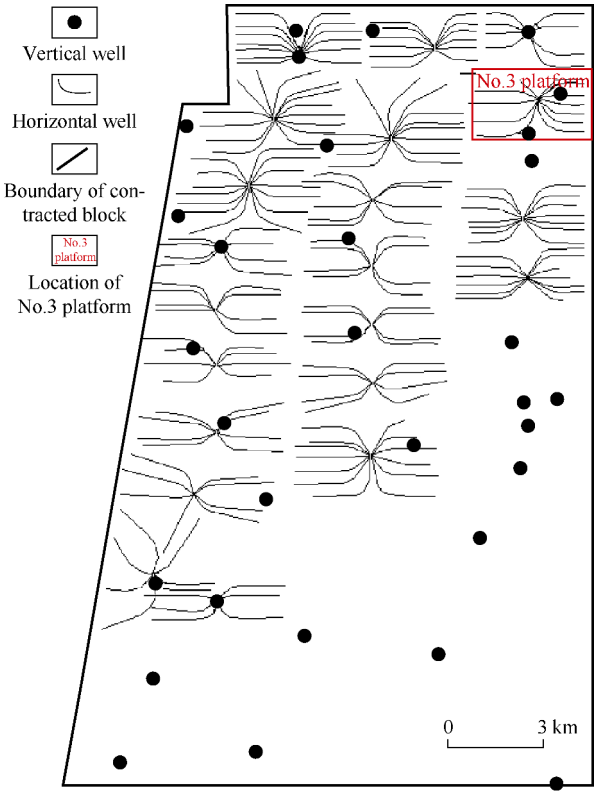

Fig. 2. Distribution of vertical wells and horizontal wells in Block MPE3.

2.2. Data distribution

Horizontal wells in the study area are mostly in centralized arrangement pattern based on the pad. At each development pad of 4 km^2, 8 horizontal wells are usually arranged at the horizontal section spacing of 300 m (Fig. 4). The number of horizontal well data points under the coverage of one pad is up to 76800. Large in quantity and centralized in distribution, these local data would have a great effect on the overall model in the process of modeling. The wellbore trajectory of horizontal wells at the same pad are EW and parallel to each other, but the sediment provenance in the study area is SW-NE oriented. Obviously, the direction of horizontal well data is nearly perpendicular to that of the provenance. As a result, the main range direction in the process of variogram analysis may be impacted by the trajectory of horizontal well, and is inconsistent with the actual provenance direction. Thus, the geostatistics would be inconsistent with the actual distribution of geo-bodies due to the non-uniform distribution of sampling points or the accumulation of numerous data in a specific direction, and consequently, big data paradox is brought about during the reservoir modeling data analysis (variogram analysis).

2.3. Sandstone drilling rate

In the process of drilling, the wellbore trajectory of hori-