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Mini Review

Study on Sedimentary Mechanism of Fan Delta Front and Quantitative Relationship of Sand Body

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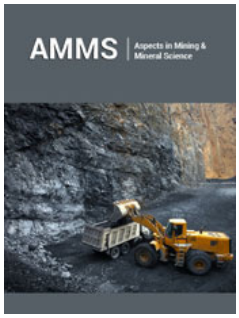

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Abstract

A fan delta sedimentation experiment was conducted through flume equipment, and based on different sedimentation bottom shapes, slopes, water depths, and supply conditions (supply flow rate, sediment concentration, and sediment particle size), the formation and evolution process of fan delta's delta front sedimentation were simulated. The superimposed pattern of the genesis unit of the front of fan delta was summarized, and the quantitative characteristics of the sand body scale of fan delta's distributary channel were established. Results indicated that the quantitative scale and relationship of distributary channel's width-thickness are related with its ability to erode downstream, thus they are also further influenced by several factors such as lake level fluctuation, distance from source, and particle size of sediments in distributary channels. When water depth in lake basin is shallow, the width of the distributary channel is 22-160m, the thickness of the main body is 5-28m, the ratio of width-thickness is 4-8, and the correlation coefficient reaches 0.9382. These research results have important guiding significance for fine description of sand bodies under the condition of few wells in China's offshore regions.

Keywords: Flume experiments; Fan delta; Genetic mechanism; Distributary channel; Quantitative relationship; Lake level

Introduction

The distribution of offshore oil field development well network is low, while the well spacing is large, and the data is relatively scarce, compared with onshore oil and gas fields. However, the understanding of geology below sea level, especially the accuracy of sand body distribution patterns prediction, requires high precision. Therefore, it is necessary to explore mechanisms that support the objective description of reservoirs. Previous researchers conducted extensive research on sedimentary environments, sedimentary microfacies, sand body distributions, and configuration features of fan deltas from perspectives such as outcrops, modern sedimentation and seismic information. And they even did lots of works on the characterization of quantitative relationships of microfacies in fan deltas [1-5]. A few researches have also been done in the study of flume experiments, but published results of systematic flume experiments are relatively few. Under the constraint condition of isochronous grid, limited works on the analysis of fan delta sedimentation and its evolution processes, sand body characteristics, and quantitative prediction systems, which are comprehensively controlled by horizontal plane and sediment grain size. Depends on measured parameters from X-section of fan delta, this article conducts systematic experiments on causes and main controlling factors of sand body distribution. It reveals the genesis mechanism of main sedimentary microfacies of fan delta and quantitatively predictions on distributary channels, thus supports reasonable predictions on sand body distribution under the condition of large well spacing in offshore oil and gas fields.

Design of the Flume Experiment

Main components of the setup of this experiment are shown as bellows: the main body of the flume consists of a sedimentary basin and a drainage pool, with a length of 2.85m (the length of sedimentary basin is 2.25m and the length of drainage pool is 0.6m), a width of 2.16m, and a depth of 30cm. In the front of the sedimentary basin, a channel with 0.8m in length and 0.05m in width, which serves as a supply channel for fluids and sediments to the sedimentary basin. Supply flow rate can be controlled by adjusting inflow rate. The front end of the supply channel is equipped with a sediment supply device, consisting of an input funnel and a vibrating plate. During the experiment, sediment supply rate can be adjusted by changing vibration frequency of the vibrating plate. Sediments and water flow are mixed at the forefront of the supply channel to ensure that the fluid enters the sedimentary basin in the form of stable jet. The drainage pool is located at the rear of the sedimentary basin, and the water pump can discharge water into the drainage pool to regulate changes in lake level in the flume. The boundary between the sedimentary basin and the drainage pool is an open boundary, which allows water to flow freely, while the rest of boundaries are closed boundaries.

In the experiment, the slope of sediment bottom was set according to the actual value of X-section. Supply flow rate, concentration of sediments, and particle size of sediments were set according to actual values of the study area (calculation was based on similarity criterion). The slope distribution range is 0.005-0.025m/m, the supply flow range is 7×10^{-5}-$1\times10^{-4}m^3/s$, the concentration of sediments distribution range is 1.786×10^{-2}-8.929×10^{-3}, and the particle size of sediments distribution range is 228-712μm. A total of 10 sets of flume simulation experiments were completed.

Result and Discussion

In the experiment, the formed sedimentary body integrally entered the lake basin in fan-shaped, and the sedimentary system contained gravity flow deposits. Under the condition of stable lake level, formation and evolution of sedimentation in the front edge sedimentation in fan delta mainly included the formation stage of initial tongue-shaped body, laminar flow sedimentation stage, small-scale distributary channel sedimentation stage and restrictive distributary channel sedimentation stage. The small-scale distributary channel sedimentation stage and the restrictive distributary channel sedimentation stage appeared alternately and cycle, and the fan delta grew continuously until overall forming a lobe-shaped, as shown in Figure 1.

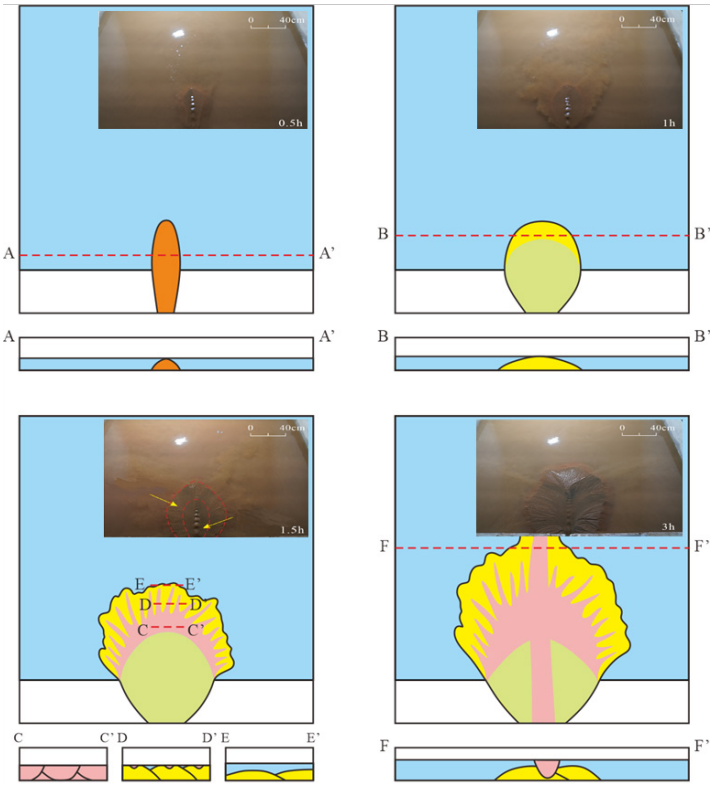

Figure 1: Sedimentary characteristics and spacial superimposed patterns of genesis unit in different sedimentary stages of fan delta.

There were significant differences in spacial superimposed patterns of genesis units in different sedimentary stages, also shown in Figure 1 as well. The formation stage of initial tongue-shaped body was characterized by isolated debris flow tongue-shaped bodies; and isolated estuary dams were mainly developed during the laminar flow sedimentation stage; the small-scale

distributary channel sedimentation stage was characterized by lateral-vertical shear stacking of distributary channels, lateral stacking of distributary channels and estuary dams with lateral stacking of estuary dams (appearing in sequence towards the lake basin); the restrictive distributary channel sedimentation stage was characterized by distributary channels' deep cut estuary dams. Due to the absence of lake wave's influences in this experiment, the estuary dam was not modified, so isolated sheet sand superimposed patterns did not appear.

Experiments indicate that the scale and width-thickness relationship of distributary channels are related with their ability to erode, which is influenced by several factors such as fluctuations in lake level, distance from sources and particle size of sediments within the distributary channel. When water depth in the lake basin is shallow, the width of distributary channels is 22-160m, the thickness of main bodies is 5-28m, the width-thickness ratio is 4-8, and the correlation coefficient is 0.9382. The width of distributary channels, which filled with conglomerate (thickness of medium conglomerate is greater than 50%) is 10-160m, the thickness of main bodies is 1.6-28m, and the width-thickness ratio is 4-8 (coarse gravel particles with diameters greater than 100mm can be observed in distributary channels with main body thickness greater than 10m); distributary channels filled with fine conglomerate (thickness of fine conglomerate is greater than 50%) have a width of 12-64m, thickness of main bodies is 1.5-7.8m, and the width-thickness ratio is 7-12; distributary channels filled with small-coarse gravel size sandstone (thickness of small-coarse gravel size sandstone is greater than 50%) have a width of 6-120m, thickness of main bodies is 0.6-2.2m, and the width-thickness ratio of 10-25.

Conclusion

Flume simulation experiments are able to effectively reflect the sedimentary and evolutionary characteristics of fan delta, with providing mechanistic supports for scientific characterizations of sand bodies under large well spacing conditions at offshore regions.

a. During the stable period, in terms of lake level, formation and evolution of front edge sedimentation in fan delta mainly include the formation stage of initial tongue-shaped body, laminar flow sedimentation stage, small-scale distributary channel sedimentation stage, and restrictive distributary channel sedimentation stage. The small-scale distributary channel sedimentation stage and the restrictive distributary channel sedimentation stage appear alternately and cycle, and the fan delta grows continuously, until overall forming a lobe-shaped body.

b. With increasing sediment supply flow rate, concentration of sediments, and particle size of sediments, the critical slope increases with increasing concentration of sediment, and it decreases with increasing supply flow rate and particle size of sediments.

c. The quantitative relationship between the width and thickness of distributary channels can be determined through simulations and experiments, while the correlation is controlled by lithology and varies with changes in grain size of sediments.

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