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Gravity flow channel character and reservoir prediction of the Miocene Congo fan basin, West Africa

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ABSTRACT

Determining the reservoir distribution of a gravity flow channel is a strongly researched topic that must be solved to address the difficulty of deep-water deposition. This paper takes the Miocene Congo Fan as an example for the analysis of lithological succession, seismic reflection feature and attribute map based on the core, logging, and 3D seismic data. Six primary reservoir depositions are identified: canyon, erosive channel, complex channel, migrated channel, isolated channel, and lobe. The seismic section geometric features and the seismic attributes are used to describe the different types of gravity flow channel structure characteristics and planar features. The GR analog acoustic impedance inversion clearly reveals the reservoir distribution and characteristics in different gravity flow channels; the results indicate that the sand-rich reservoir is at the upper part of the composite and isolated channel, levees and lobes. The reservoir types and distribution characteristics of a gravity flow channel in deep-water fan are important guides for identifying traps in exploration and production.

1. Introduction

In the past two decades, significant progress has been made on deep water deposition and reservoir prediction during the tremendous development of deep water exploration, with many large fields being found in the Gulf of Mexico, West Africa, Brail and the South China Sea (Pang et al., 2007).

The Congo deep-sea fan is one of the largest fans in the world that is still affected by presently active turbidity currents. The present activity of deep-sea sedimentary processes is linked to the existence of a direct connection between the Congo River estuary and the Congo canyon head, which enables a relatively continuous sediment feeding of the deep-sea environment. Since the Eocene to Miocene, the Congo fan basin developed multiple periods of typical gravity flow channels and lobe deposition, which gradually migrated north and seaward progradation upward (Zhang and Deng, 2009; Liu et al., 2012; Wang et al., 2013).

The focus of the Congo fan basin exploration gradually shifted from shallow to deep water areas with the gradual improvement of exploration technology. The many oil and gas discoveries in the Oligocene and Miocene gravity flow channel reservoir indicate the importance of the research of gravity flow channel character and reservoir prediction in the Congo Fan basin.

Based on the previous related research, the gravity flow channel of the Congo fan is formed in the complex erosion – bypass – filling process and in the complex of channel filling, such as debris flow, grain flow, liquefied flow, turbidity, slide, and other different types of gravity flow sediments (Mayall and Stewart, 2000; Peakall et al., 2000).

Guided by the deep water sedimentology and sequence stratigraphy, which is based on core, logging and 3D seismic data, we focus on the study of the gravity flow channel type, its internal structure, sand body morphology and distribution. The primary aim of this paper is to analyze the distribution of different types of gravity flow channel sand bodies through the sedimentary and fluid rheology characteristics and to establish a model of the sand body distribution of a gravity flow channel for reservoir prediction and exploration of oil and gas.

2. Materials and methods

2.1. Geological setting

The Lower Congo Basin is one of a series of related rift-drift West African basins that lie on the western flank of African continental margin resulting from the Early Cretaceous opening of the

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South Atlantic (ca. 130 Ma) (Jansen et al., 1984; Karner and Driscoll, 1998; Droz et al., 2003; Hodgson et al., 2006) (Fig. 2). From the Early Oligocene to the present, sedimentation in this area has been dominated by the progradation of a large terrigenous wedge fed by the Congo River, which drains the sizeable central African Congo Basin.

2.2. Data

The Congo fan is turbidite-dominated and deeply incised (Brice et al., 1982; Jansen et al., 1984; Karner and Driscoll, 1998; Droz et al., 2003; Hodgson et al., 2006); the Congo fan is characterized by a 800-km extension from east–west and covers an area of 30×10^4 km^2. The productive block Haute Mer A locates in the Congo fan basin on the west coast of the Congo River and, is approximately 488 km^2 in area and 350–1200 m in depth (Fig. 1). The regional geological map and core description are driven from HIS Energy Group and the well-logs and seismic data are provided by CNOOC, from previous holder TOTAL.

The Miocene Congo fan can be divided into three sequences, A, B, and C, and each of the sequences can be divided into internal phases (e.g., A1, A2, B1, B2, C1, and C2) of different thickness (Jiang et al., 2014) (Fig. 3).

2.3. Method and workflow

The primary aim of this paper is to analyze the different types and distribution of gravity flow channel sand bodies for reservoir prediction and exploration of oil and gas base on the collected data, the method and process is as follows: (1) analyse the gravity flow channel types in the stratigraphy framework drived by our partners; (2) depiciting the internal chanracteristic and planar features of gravity flow channel by seismic section geometric features and the seismic attributes maps; (3) Use GR analog acoustic impedance inversion to reveal the reservoir distribution and characteristics in different gravity flow channels; (5) summarized the characteristics of different gravity flow channel and the reservoir distribution for reservoir prediction and exploration of oil and gas.

2.4. Characteristic and type of gravity flow channel

A gravite is defined as sediment or rock deposited from a sediment gravity flow (Gani, 2004) and incorporates all sediment deposited by gravity flows, irrespective of their depositional environment.

Gravity flow moves downward along the inclined slope, and with a reduction in energy, fluid dilution, and velocity decreases. The flow properties (flow velocity, turbulence, and erosive power) of the currents depend directly on the characteristics of the sediment supply, such as the sand/mud ratio, grain-size distribution, concentration, and volume, and also depend on the slope gradient along the canyon. Due to the variation of velocity, concentration and viscosity, the gravity flow fluid mechanism changes from high density of debris flow to particle flow or liquid flow and gradually become turbid. These changes result in a different sequence and structure of gravity flow deposition, which changes the performance (as the gravity flow deposits change from the incised valley on shelf to the abyssal plain) as well as the inner stacking pattern of the gravity flow body and channel morphology, such as different types of channels, levees, and lobes (Reading and Richards, 1994; Gani, 2004; Zheng et al., 2012; Jiang et al., 2014).

Gravity flow channels exhibit obvious filling characteristics and fanning upwards, which consists of mass transport, slump, debris flow, turbid current deposits and deep water suspended muddy

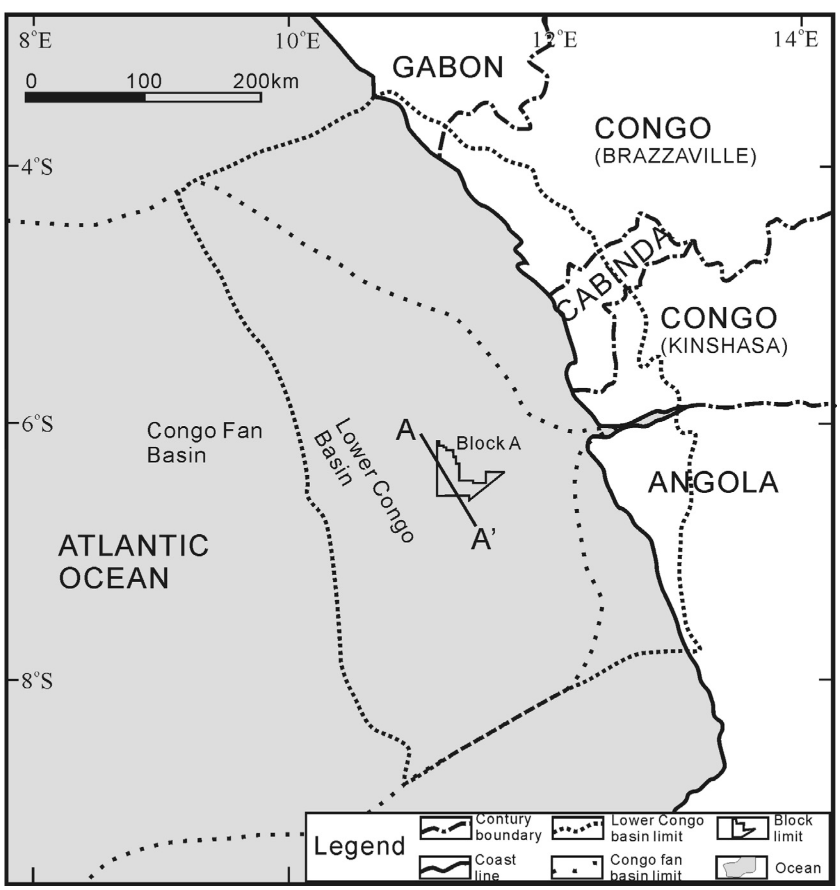

Fig. 1. Geographical location map of block Haute Mer A (IHS Energy Group, 2005).