

Bottom currents influenced deepwater canyons in the northern of Baiyun Sag slope, South China Sea

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Abstract: Most submarine canyons are documented as erosive features that deeply cut into the shelf margin, and are considered as important conduits for the transfer of sediment to the lower slope and abyssal plain. In this study we investigate a series of submarine canyons developed on the shelf margin in the Pearl River Mouth Basin. High-resolution 2D seismic and borehole data have been used to investigate the morphology and stacking pattern of these submarine canyons. Seventeen canyons oriented NNW-SSE, approximately perpendicular to the regional slope, have been distinguished. They evolve from V-shaped in the upslope part to U-shaped morphology downslope. Numerous buried channels can be distinguished below the modern canyons showing an auto-cyclic progression in the scouring-filling and vertical stacking, indicating that canyons experienced a cyclic evolution with several cutting and filling phases of varying magnitude. Infilling evolved from high to low energy deposits. The low energy deposits form asymmetric, eastward prograding bodies developed on the western flank of the buried channel. The remarkable asymmetry between the two flanks of canyons may result from the interaction between turbiditic current within canyons and along slope bottom currents that flow northeast-ward along the margin.

Key words: deepwater canyons, morphology controlling factors, turbidity, bottom currents.

INTRODUCTION

Submarine canyons represent long narrow strips of deep negative relief on the seabed, and are common types of sedimentary systems on the continental slopes. Down-slope gravity processes in submarine canyons have been widely documented (Huang et al., 2012).

The Pearl River Mouth Basin (PRMB) formed in the northwestern South China Sea and underwent a recent (i.e. from early Miocene) period of subsidence forming the present Baiyun Sag. Together with sea level variations, this led to a northward migration of the PRMB depocentre as well as canyon valley formation within the Baiyun Sag northern slope after 21Ma (Pang et al., 2005). However, the Baiyun Sag northern slope canyons exhibit buried laterally migrating channels suggesting a very strong along slope bottom currents influence over the entire turbiditic and canyon system (Cunningham et al., 2005).

This study investigates a series of submarine canyons that developed within the Baiyun Sag northern slope from late Miocene to present (Fig. 1). Based on 2D multi-channel seismic profiles and borehole data, we investigate the morphology, sedimentary architecture, and particularly the unidirectional migration features of the submarine canyons, in order to understand mechanisms dominating canyons dynamic.

DATA AND RESULTS

This study made use of a data set of over 15,500km of multi-channel 2D reflection seismic profiles covering an area of >72,000km². This data set

was provided by China National Offshore Oil Corporation (CNOOC) Shenzhen Branch in order to characterize seabed morphology. The seabed map has been obtained converting the seismic seabed reflector from two-way travel time to depth using a P-wave velocity of 1,500m.s⁻¹ for the water column.

The Baiyun Sag northern slope is affected by seventeen sub-parallel modern canyons, ranging water depth from ~500m to 1,700m (Fig. 1). Most of these canyons are oriented NNW-SSE. They are about 20-50km long for 1 to 7km wide. These deeply cut canyons are V-shaped at the canyon heads and widen to U-shaped downstream. They are asymmetrical with steep walls on their eastern flanks and stepped convex upward walls on the western sides.

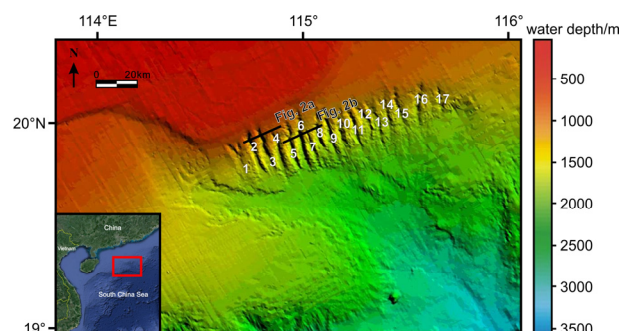


FIGURE 1. 2D multi-channel seismic derived seabed geomorphological map of the north slope of the Baiyun Sag canyons.

The crests between canyons are smooth and rounded in the shallower water near the shelf break to sharp downstream (Fig. 2a). Further to the south, these canyons are much wider and deeper (U-shaped), showing a combination of erosional and depositional characteristics (Fig. 2b).

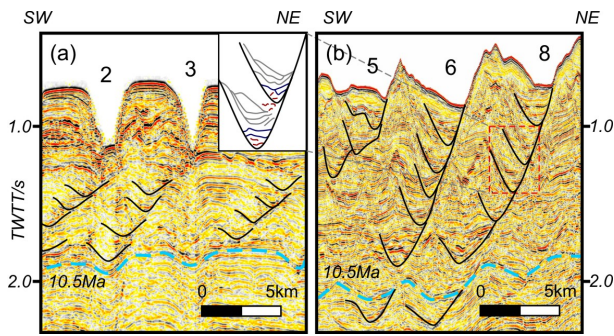


FIGURE 2. Seismic profiles from the north slope of Baiyun Sag near the shelf break (a), and further to the south (b). See Figure 1 for exact location. Both profiles show buried channels and their respective internal morphology.

Buried channels, with some of them even predating the 10.5Ma sequence boundary, are asymmetric with a rounded smooth western flank and a steeper eastern flank. Buried channels erosive bases are stacked and progressively offset toward the northeast, with more erosive eastern flanks. Infilling within these channels display a complex architecture suggesting an evolution of repeated erosion, infilling, offset, and subsequent re-excavation (Fig. 2). Three different seismic facies are distinguished in the channel infilling. The base is generally characterized by very low amplitude highly discontinuous reflectors. Medium- to very high-amplitude sub parallel reflectors are then recognized and form a relatively flattened channel bottom. They are overlain by a series of seismic reflectors dipping and prograding towards the east. These lateral accretionary packages are characterized by low to medium amplitudes, a high degree of continuity, and are parallel to sub parallel to each other.

DISCUSSION

The V-shaped segments close to the canyon heads are evidently erosional. To the south, both seabed and buried channels indicate cycles of erosive and depositional processes. Such erosive/depositional cycle within the canyons may reflect lateral migration of the sedimentary system, possibly induced by sea level variations. Within the subsequent fall in sea level, the study area would be erosion-dominated with newly developed erosive channels. Conversely, rising sea level may have induced progressive energy decrease, allowing deposition and filling of the channels. During periods of enhanced sediment input, perhaps during low stands of relative sea level, mass transport deposit may have occurred, forming the low amplitude, chaotic reflection at the channel base. Following this very high-energy MTD's, mass flow and channelized turbiditic flow would have been common, thereby favoring the formation of thick, continuous high amplitude reflectors, representing intermediate energy environment deposits.

Asymmetric eastward prograding muddy sediment packages on the western walls of the buried channels, as well as focused erosion toward the eastern walls suggest the influence of northeast-ward flowing

along slope bottom currents. The growth and preservation on these lateral inclined packages may have occurred during periods when turbidity currents along the canyon axes were diminished, perhaps during highstands of relative sea level, in low-energy environment. Such episodic sea level changes may have resulted in the interplay of downslope turbidity currents and bottom currents, which significantly contributed to the change between the vertical aggradation and lateral migration developed in the canyons. Such northeastward alongslope bottom currents in the study area are known since the Miocene within the intermediate-upper deep water (350-1,350m) (Shao et al., 2007).

CONCLUSION

The north slope of the Baiyun Sag features high slope gradients and a complex geomorphology, intensively crosscut by canyon valleys. Buried channel show cyclic alternation of erosive and depositional periods evolving from very high to relatively low energy environment.

The northeastward offset direction of the canyons and their asymmetry is attributed to bottom currents flowing from the southwest to the northeast. In effect, the lateral inclined packages are clinoforms formed as bottom currents sweep muddy sediments from the slope and outer shelf across the slope, over the canyon rims and into the canyons.

A persistent north-eastward traveling bottom current during highstands and increased turbidity currents during lowstands together shaped the unidirectional development of the buried channels in the north slope of the Baiyun Sag.

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