Introduction

The genesis of deep water sandstone has become the focus of sedimentology research and petroleum industry (Etienne et al., 2012), however, people still know little about these deep water sediments flows and depositional mechanisms (Tailing et al., 2012). Most of the deep water sandbodies were interpreted as turbidites in the past decades, until new theory of sandy debris flow challenged the classic theory of turbidity current (Shanmugam, 1996). What is more, new understanding of hyperpycnal flow fulfilled the theory of turbidity current (Mulder et al., 1995).

Although arguments still exist among sedimentologists on origination of some deep water sandstone, relationships among sandy debris flows, turbidity currents and hyperpycnal flows were unanimously agreed to be the key scientific issue of deep water gravity flows and deep water sedimentology. Complex transformations and inductions not only exist among sandy debris flows, turbidity currents and hyperpycnal flows, but also hyperpycnites, debrites and turbidites co-exists and co-exist in time and space usually. The variability and complexity of geological conditions in long geohistory determine the existence of multiple explanations of the same deposition products among sedimentologists.

2 Transformation among Gravity Flows

2.1 Sandy debris flows to turbidity currents

Sandy debris flows transforming to turbidity currents when the former mixed with water and diluted (Yang Renchao, 2014). During the down slope movement, erosion and dilution, the slumping liquefied sediment flow gradually turned into a sandy debris flow and distal remote turbidity currents. The transformations mostly take place at middle – upper part and tails of debris flows. Most of sandy debris flows rapidly deposited or froze at the foot of slopes because of higher density and viscosity than turbidity currents. On the other hand, sediments suspension supported by turbulence in turbidity currents can be transported to further regions contributing to their lower density and viscosity. But thick debrites are always covered by thin turbidites on spatial correlations (Fig. 1).

2.2 Turbidity currents to sandy debris flows

Concentration of sediments suspension increased continuously at the base of turbidity currents with settling of sediments suspension. With strengthening erosion of turbidity currents on sedimentary substrate and subaqueous...
levee, more and more mudstone intraclasts and fine-grained material may be present in re-involved in the channel systems (Sawyer et al., 2014). Figure 2 shows a three-dimensional sedimentary model of transformation from turbidity current to sandy debris flow. Figure 3 shows turbidite with classic Bouma sequence and sandy debris flow deposit with plant segments and mudstone intraclast in the upper Cretaceous in Lingshan island, Qingdao, China.

2.3 Hyperpycnal flows to sandy debris flows

Hyperpycnal flows are turbid river plumes that may form turbidity currents where they enter a water body of lower density (Lamb and Mohrig, 2009). Flood-generated hyperpycnal flows occur with a higher frequency than debris flows and turbidity currents since their accumulation needs neither a considerable volume of sediment nor trigger mechanisms such as earthquakes, volcanic eruptions, hurricanes or tsunamis to initiate slope failure (Yao et al., 2012; Clare et al., 2014). The hyperpycnites are characterized by couplets of upward coarsening and upward fining intervals, internal micro-scale erosion surfaces, fine-grained sediments and abundant plant fragments.

Hyperpycnal flow can transfer to debris flow or induce occurrence of debris flow as well as turbidity current. Handling mechanism of hyperpycnal flow mainly depends on the uplift of turbulent flow. As a result, hyperpycnal flow belongs to extensive turbidity current as the two share the same supporting mechanism, essentially, from fluid properties. Mulder et al. (1995) distinguished it from classic turbidity current generated from slope failure.

Steady hyperpycnal flows developed during floods in the distributary channels also may induce slumping of sedimentary masses on the basin’s slopes, so as to generate sandy debris flows and turbidity currents at the same time. The hyperpycnal deposits may also occur embedded between other gravity flow deposits. River load is deposited in a distributary estuary as mouth bars or in subaqueous channels when the density difference of the two water bodies is too small to form a hyperpycnite during fair weather, but hyperpycnal flows develop when sufficient suspension load is present and the other required conditions are met. Turbidites and debrites may originate when slope failure is triggered by earthquakes, volcanoes, storms or river floods.

3 Significances of Unconventional Petroleum

Thick massive sandbodies deposited from sandy debris flow are main reservoirs of tight oil and tight gas in deep
water sedimentary basins. Thin bedded sandstone, siltstone and shale generated from hyperpycnal flows and turbidity current are main reservoirs of shale oil and shale gas. What is more, hyperpycnal flows discharged from flood-rivers always contain a great amount of continental organic matters, which not only provide abundant nutrition for organisms, but also increase total organic matters in source rocks directly. On the other hand, a great deal of organic matters and debris materials input effect the ecosystem in the sedimentary basin to some extent, then to reproduction of organisms and accumulation of organic matters. The third, gravity flows are important transportation – deposition mechanisms to transport a great amount of materials from continental to deep water basin. Gravity flows depositions will fasten accumulation rate and burial of organic matters that it is proper to preservation of organic matters, so to unconventional petroleum.

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