Tidal and seasonal controls on the morphodynamics of macrotidal Sukmo Channel in Gyeonggi Bay, west coast of Korea – implication to the architectural development of inclined heterolithic stratification

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Summary

This study documents the occurrence of inclined heterolithic stratification (IHS) in the macrotidal Sukmo Channel, west coast of Korea. Facies architecture of IHS in the Sukmo Channel seems to be complicated by both tides and seasonal controls (waves and heavy rainfall). The former seems to determine the effectiveness of erosional processes and the locus of erosion, whereas the latter is responsible for the generation of erosional features such as scarps and rill channels. Channel bank morphology exhibits seasonal variation with summertime erosion followed by wintertime deposition. The climate-driven erosional processes result in the spatial heterogeneity in textural composition as well as the discontinuity of stratification within the intertidal portion of the channel bank. This study highlights the significance of the processes for the realistic characterization of IHS-bearing reservoirs such as Canadian Oil Sands.

Introduction

Inclined heterolithic stratification (IHS) constitutes a point bar facies of tidal channels that migrate laterally (Thomas et al., 1987). IHS occurs in tidal channels of various magnitude ranging from small tidal creek to large tidal channel in estuaries and deltas (Bridges and Leeder, 1976; De Mowbray, 1983; Choi et al., 2004). Architecture of IHS appears to be primarily governed by combination effects of tidal and seasonal controls (Hovikoski et al., 2008). In addition, waves and rainfalls are considered as main factors in forming erosional features on the channel bank (e.g. Lowler et al., 2001), which adds further complexity to the architecture of IHS.

Compared to waves whose impact on channel bank morphology has been well explored by many authors (e.g. Lowler et al., 2001; Choi et al., 2004), control of rainfall on the channel bank profile has been less well documented. It has been noted that heavy rainfall facilitates erosion by lowering erosion threshold of surface sediments (Tolhurst et al., 2006). Role of heavy rainfall as erosional agents has been recognized mainly in small tidal creeks associated with salt marsh environment (Mwamba and Torres, 2002; Novakowski et al., 2004; Voulgaris and Meyers, 2004; Murphy and Voulgaris, 2006; Tolhurst et al., 2006; Ralston and Stacey, 2007). To date, similar studies for large tidal channels are very scarce. Furthermore, little emphasis has been placed on the effect of heavy rainfall on the sedimentary structures constituting channel bank deposits.

5-m-thick IHS is developed in the channel bank at the Maeumri section of Sukmo Channel, which is much smaller than that is present at the Oepori section (Choi et al., 2004). Sedimentology and morphology of the bank are described in detail. This study presents a series of channel-bank profiles of Sukmo Channel at Maeumri section in an effort to understand the role of waves and rainfalls on the channel bank morphology. In addition, the effects of the two external controls on the discontinuity of stratification within the IHS architecture are discussed.

Sedimentology and morphology of channel bank

High-precision leveling of tidal channel bank at Maeumri tidal flat of Sukmo Channel was conducted 8 times over one and half year from July 2007 to February 2009 using a Total Station (model: SET 510K, Sokkia Co., Japan).

Sukmo Channel is one of distributary channels of Han River delta, which is flanked by narrow and steep channel bank. At the Maeum-ri section, the bank consists of tripartite morphologic subdivisions with gentle-sloped upper intertidal zone covered with salt marsh, steep middle intertidal zone, and gentle-sloped lower intertidal zone. A 5-m-thick inclined heterolithic stratification (IHS) is developed in the middle intertidal zone, where it consists of thinly interlaminated sand and mud with a dip angle reaching up to 10^o.

A concave-up, smooth-bank surface is often interrupted by intermittent occurrence of erosional scarps and rill channels. Occurring at several elevations mainly in the upper to middle intertidal zone, bank-parallel scarps are typically up to 0.5 m high and are generated by wind-induced waves during high tides (Figure 1). On the other hand, bank-normal rill channels are 1 to 3 m wide, up to 1.5 m deep, and 100 m long, which occupy the lower upper intertidal zone and entire middle intertidal zone (Figure 1). The rill channels resulted from heavy rainfall during low tides. Consequently, tide elevation determines the effectiveness of erosional processes and the locus of erosion.

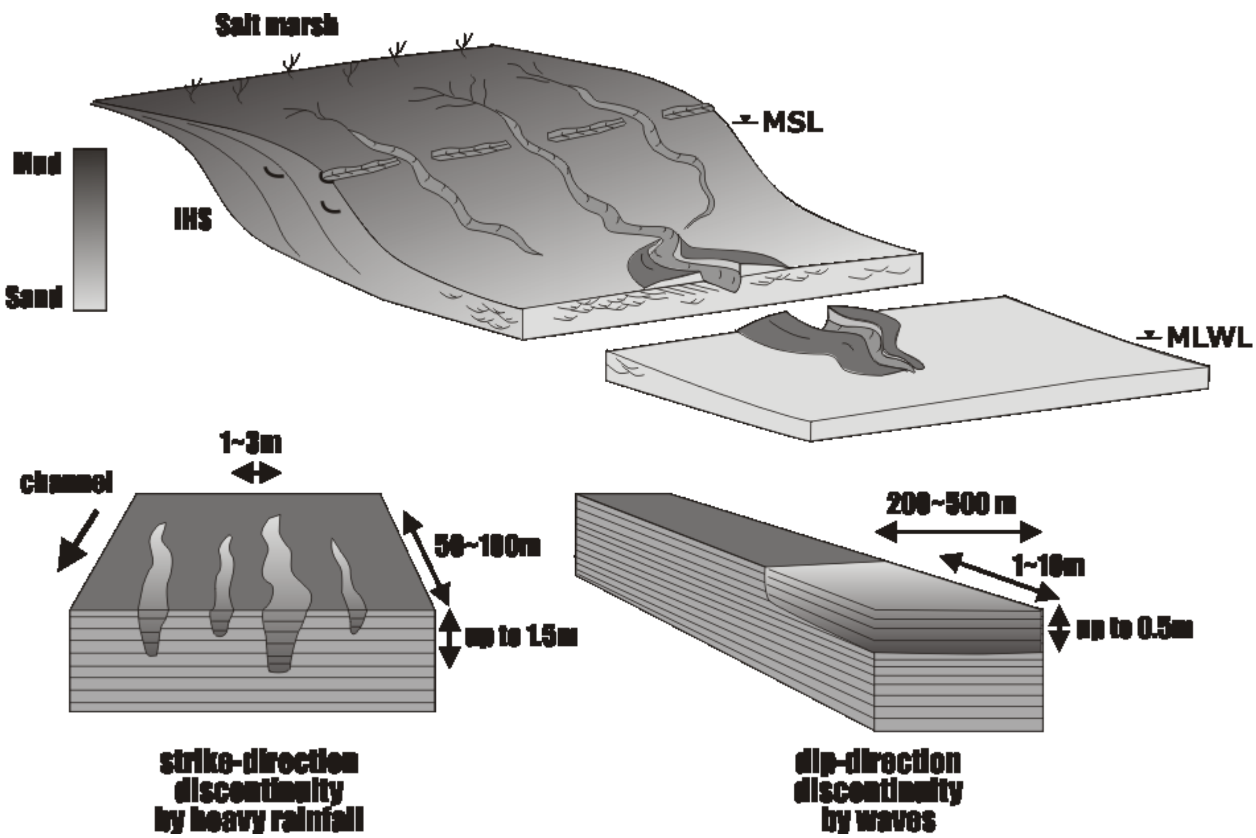

Figure 1: Conceptual diagram showing the location and dimension of erosional scarps and rill channels on the Sukmo tidal channel bank at Maeumri section.

Channel bank morphology exhibits seasonal variation with summertime erosion followed by wintertime deposition, which is most notable in the middle to lower intertidal zone. The bank surface maintained the smooth and convex-up profile during winter, which is moderately roughed up by wind-induced waves in spring when local winds were strongest. Remarkable bank erosions occurred during summer when numerous large-scale rill channels were formed by episodic heavy rainfall events. From fall to winter, a rugged bank surface was filled with newly deposited sediments that are texturally different with preexisting bank deposits. Through the sustained sedimentation with less erosional processes, the bank surface gradually regains a smooth, convex-up bank morphology.

Rainfall-triggered rill channel erosion is mainly responsible for the strike-direction discontinuity of IHS, whereas wind-induced waves coupled with tension cracks on the oversteepened bank surface to the dip-direction discontinuity of HIS (Figure 1). The climate-driven erosional processes (waves and rainfalls) result in the spatial heterogeneity in textural composition as well as the discontinuity of stratification within the intertidal portion of the channel bank. This study highlights the role of the processes that results in the complexity of facies architecture of IHS, which is crucial for the realistic characterization of IHS-bearing reservoirs such as Canadian Oil Sands.

Conclusions

Tidal channel bank deposits of Sukmo Channel consist of 5-m-thick IHS in the middle intertidal zone. Architecture of the IHS seems to be complicated by both tidal and seasonal controls such as heavy rainfalls and waves. Tide elevation determines the effectiveness of erosional processes and the locus of erosion. Heavy rainfall during summertime rainy season is responsible for the bank-normal rill channel erosion, while wind-induced waves resulted in along-bank scarps and terraces. The former result in a dip-direction discontinuity of IHS, whereas the latter a strike-direction discontinuity of IHS.

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