Erosional Remnants in Deep-Water Channel Systems: Outcrop and Subsurface Characterization*

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Introduction

Erosional remnants within deep-water environments have been identified in outcrop, ground penetrating radar (GPR) surveys, and conventional 3D seismic data sets. Two types of erosional remnants have been documented: within slope channels and canyons as well as between adjacent channels on basin floors. Within slope master channels or canyons, successive downcutting by individual channel threads can result in remnant terraces and knobs being preserved. On the basin floor, adjacent crosscutting channels that have incised into the substrate can result in erosional remnants being preserved between the channels. The observed plan-view geometries of the remnants are irregular, with pinches and swells along depositional dip due to the meandering of adjacent incising channels. Both types of erosional remnants suggest multiple episodes of incision into underlying strata.

3D Seismic Examples of Erosional Remnants

3D seismic imaging of Pleistocene slope strata, DeSoto Canyon area, northeast Gulf of Mexico documents erosional remnants that formed within a single leveed slope channel complex. These erosional remnants formed as a result of successive downcutting by small individual channel threads confined within the leveed master channel (Figure 1). In contrast, 3D seismic data from the Triassic-aged Montney Formation (western Canada) provides examples of erosional remnants between adjacent channels on the basin floor. The remnants are characterized by high amplitude and, based on available borehole data, are interpreted as being largely dissected frontal splays. Flanking the remnants are channels characterized by low-amplitude seismic reflections inferred as predominantly shale filled (Posamentier et al., 2003).

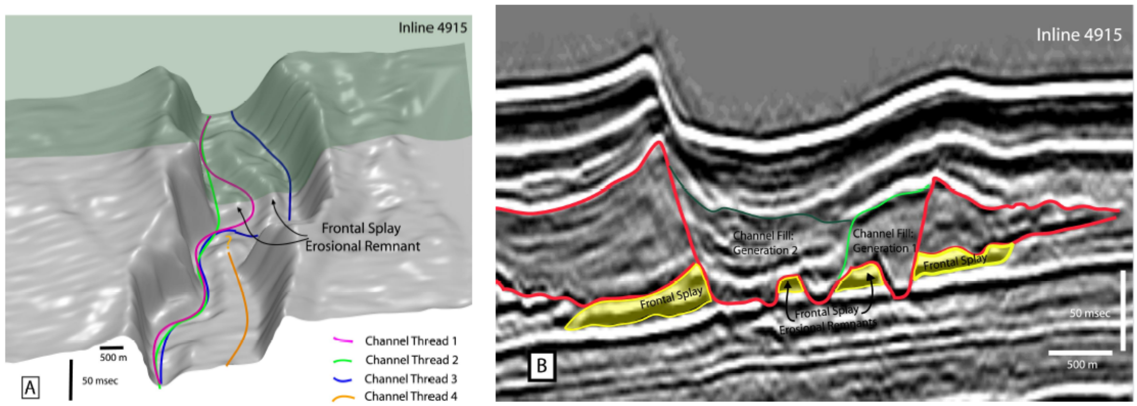

Figure 1. 3D seismic data from the Gulf of Mexico, showing two high amplitude frontal splay erosional remnants within a slope master channel complex. A) Spatial extent of the erosional remnants and the four incised channel threads, listed from youngest to oldest. A transparent plane indicates the position of Inline 4915. B) Inline 4915, showing the topographic relief, high amplitude nature of the erosional remnants within the master channel complex.

The Gulf of Mexico erosional remnants are found on the slope within a larger leveed master channel complex (Posamentier, 2003) (Figure 1). Successive deeply incised channel threads within the master channel are illustrated in Figure 1A. The first erosional remnant formed within a meander loop cut-off, between channel threads 2 and 3 (Figure 1A). The later high sinuosity channel thread 4 dissected the larger, earlier-formed meander-loop cut-off remnant, resulting in two smaller mounds. Figure 1B shows the topographic relief and the high seismic reflection amplitude of the preserved substrate, interpreted as remnants of an earlier deposited frontal splay. The larger of the two remnants pinches and swells along depositional dip, forming an elongate mound within the master channel complex. The smaller of the two remnants forms a small mound with no preferential elongation.

Erosional remnants from the Montney Formation are found between channels on the basin floor and are not confined to a master channel complex. Figure 2 shows four different channel orientations and their associated erosional remnants. The channels have incised into the underlying frontal splay at slightly differing times and orientations. Variation in the orientations of the channels resulted in the lens- and crescent-shaped erosional remnants (Figure 2). They are significantly larger than the Gulf of Mexico examples.

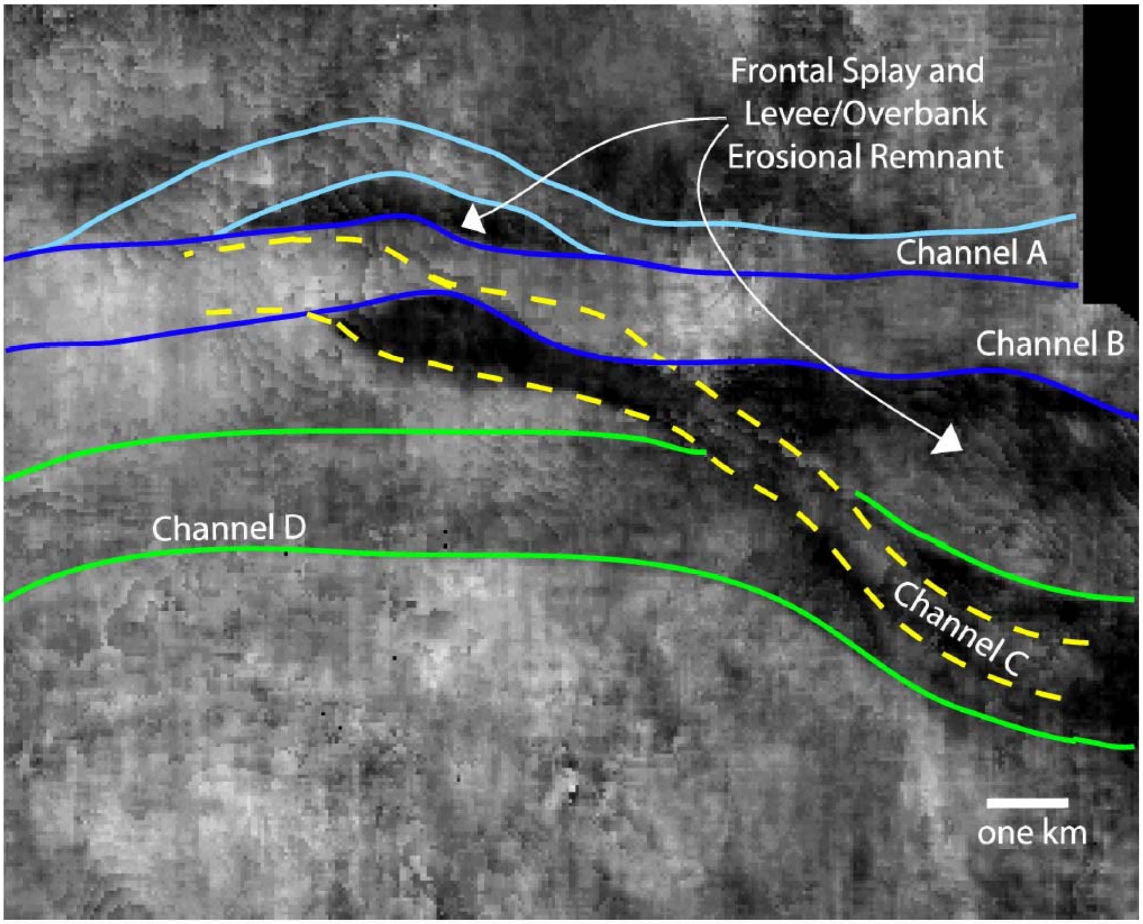

Figure 2. Horizon slice (50 msec above Belloy marker), of the Montney Formation showing two large, predominantly frontal splay erosional remnants and their associated channels.

Outcrop and GPR Examples of Erosional Remnants

The Dad Sandstone Member of the Lewis Shale in Wyoming exhibits erosional remnants on an outcrop and at GPR scale. These erosional remnants are similar to the Gulf of Mexico examples in that they are observed within an interpreted larger leveed master channel complex. Compositionally, the erosional remnants comprise levee/overbank deposits, and they are thought to differ in lithology from the high-amplitude Montney and Gulf of Mexico examples.

In outcrop (Figure 3), the erosional remnants are thinly bedded siltstones with rare interbedded thin sandstones. They are found in abrupt contact with the associated channel-fill. The uppermost sandy fill onlaps the remnant, indicating a hiatus between channel incision and fill. GPR lines, obtained from behind an outcrop (where the beds dip beneath the ground surface) at a different locality, confirm a similar relationship (Figure 4). On GPR lines, the erosional remnants are topographically high mounds within the channel complex. They are acoustically opaque zones as the result of rapid attenuation of the GPR waves due to the fine-grained nature of the remnant (Young et al., 2003). In contrast, the sand-prone channel fills contain numerous reflections representing bed boundaries. The spatial extent of these erosional remnants has proven problematic due to the two-dimensionality of the outcrop and limited GPR lines. However, initial evidence indicates they are a similar, to somewhat smaller, size than the Gulf of Mexico examples.

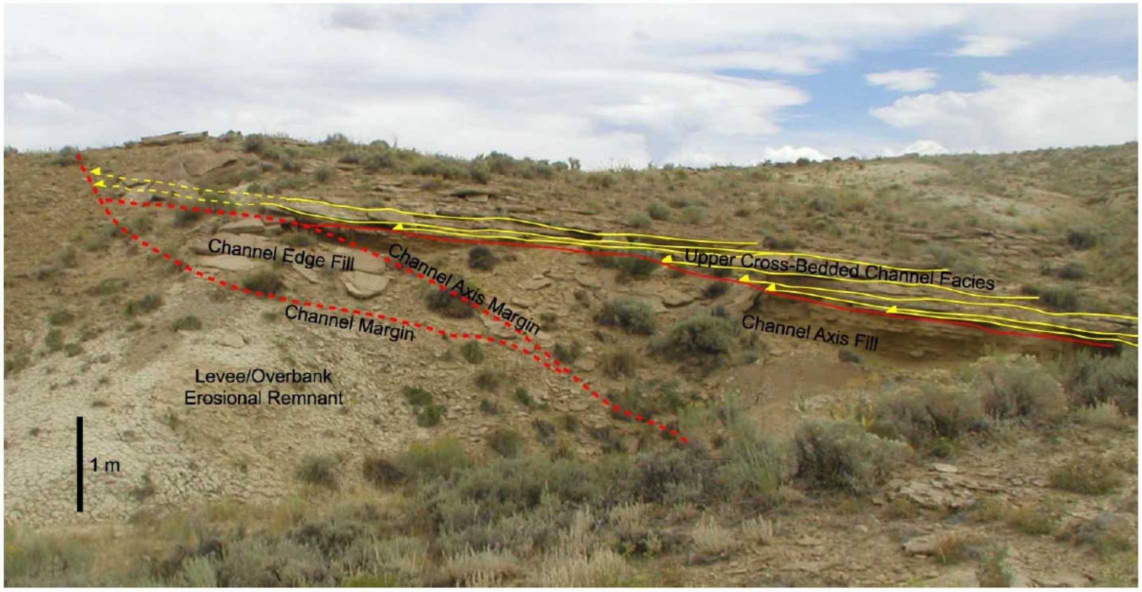

Figure 3. Outcrop example of an erosional remnant from the Lewis Shale. The remnant is composed of thin-bedded, fine-grained overbank/levee deposits. The upper channel cross-bedded facies onlaps the erosional remnant.

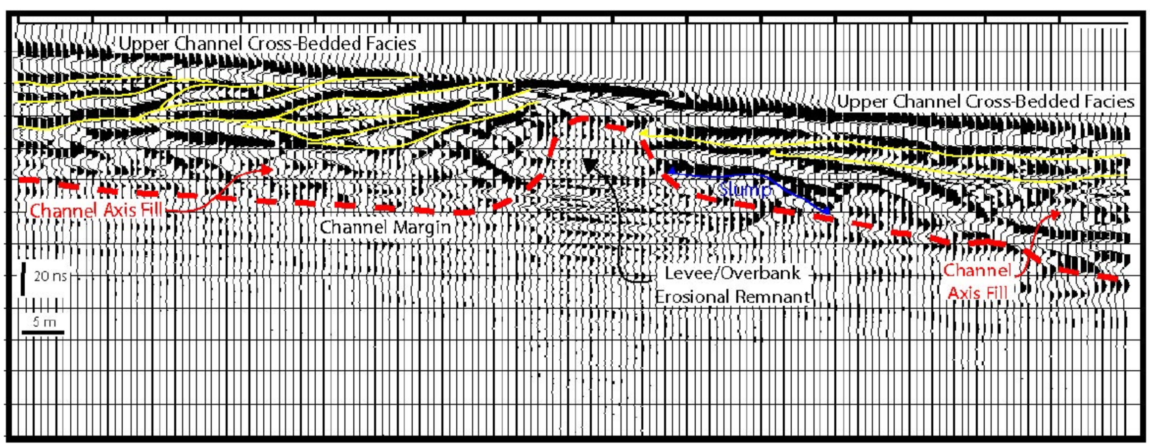

Figure 4. A GPR line oriented roughly along depositional dip across an erosional remnant, indicated by the GPR opaque zone.

Erosional Remnant Model

The formation of erosional remnants within a master leveed channel complex indicates several stages of incision within a confined setting. The combination of levee construction from bypassing flow and overall incision into the substrate provides the topographic relief necessary to confine the succession of channelized flows. The confining nature of this channel fairway creates a narrow conduit (thread) within which flows are concentrated. Concentration of the flows within this conduit causes erosion and incision into the underlying and laterally adjacent strata (Beaubouef, in press). Infilling of the relief created by the original thread results in lithofacies onlapping the channel margin. Erosion and re-incision from later bypassing flows will result in a new channel thread. If this new channel thread crosses the path of an earlier-formed channel thread in two places, an erosional remnant will be formed. The lithologic composition of the erosional remnant will be the same as the strata incised into by the channel threads. Repeated incision will result in the formation of numerous erosional remnants within the larger master slope channel complex.

Erosional remnants that form in an unconfined setting (e.g., the basin floor) are observed between neighboring crosscutting incising channels. These channels are not commonly active at the same time. Lithologically, these remnants also reflect the composition of the precursor substrate. Due to the lack of lateral constraints common in slope channels, erosional remnants on the basin floor can be significantly larger than those within slope channels.

Conclusions

Two different types of erosional remnants have been observed: within leveed slope channel complexes and between adjacent channels on the basin floor. The remnants forming within a leveed slope channel complex appear to be smaller than those observed between adjacent channels on the basin floor. Within a leveed slope channel complex, erosional remnants are formed as a result of channel thread migration or shifting in conjunction with progressive downcutting of successive channel threads. Repeated incision results in crosscutting channel threads, forming erosional remnants between the threads. In contrast, crosscutting of channels in an unconfined environment such as a basin floor can create erosional remnants between channels. The lithology of the erosional remnant is genetically distinct from that of the channel, but a function of the strata being eroded.

The examples shown document the internal complexity of erosional remnants, the geomorphology of such features, and the overall complexity that they add to deep-water environments. Within a channel-dominated reservoir section, erosional remnants can compartmentalize sands, giving rise to tortuous fluid flow paths. They can be an important element of the deep-water channel model and should be considered in reservoir modeling and management planning.

Acknowledgments

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