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The Stratigraphic Transition From Out-of-Grade to Graded Slope Margins Associated With the Filling of Deep-Water Foreland Basins

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Continental slopes, or slopes associated with other high-relief (> 400 m) basin margins, can be classified according to the relative balance between erosional and depositional processes (Ross et al., 1994). Out-of-grade slopes are dominated by extensive mass wasting and bypass of coarse-grained detritus to the basin floor. Graded slopes represent those formed under the influence of balanced degradational and depositional processes, which are characterized by smooth, high-relief clinoforms. The objective of this presentation is to document the transition of basin margin slopes from out-of-grade to graded, in two deep-water foreland basins, the Cretaceous Magallanes Basin of Chile, and the Oligocene-Miocene Molasse Basin of Austria. Controlling parameters on slope evolution, as well as the distribution of sandstone facies, is considered.

The foredeep troughs of the Magallanes and Molasse basins were narrow (tens of km) and deep (>1000 m of paleobathymetric relief) (Hubbard et al., 2009; Romans et al., 2011). Sediment transport was primarily focused along the basin axes, which paralleled the Andean and Alpine fold-thrust belts, respectively. Sediment entrained in large slumps and turbidity currents was also locally sourced from oversteepened lateral basin margins. Three main stages of depositional and stratigraphic evolution characterize both basins:

Stage 1: Both foreland basins were underfilled for a period of > 6-7 Ma, characterized by out-of-grade basin margin slopes. Large submarine canyons focused coarse-grained detritus onto to the basin floors, where immense channel belts (5-8 km wide) bound by substantial levees efficiently transported sediment for at least 80 km along each foredeep axis. The channel fills are dominated by clast-supported conglomerate and sandstone that was transported by bedload beneath thick turbidity currents, muddy mass-wasting deposits, and thick-bedded sandstone derived from collapsing high-density turbidity currents. Large terminal lobes have not been observed at the distal end of either channel belt, although in each case, data is limited beyond the first 80 km of the channel system. In the Austrian example, however, the channel belt narrows considerably, increases in sinuosity, and is associated with fine-grained fill that shares characteristics with distal lobe deposits from classical submarine fan systems (e.g., Talling et al., 2010). It is suspected that true, lobate fans do not exist and instead, elongate lobes confined to the narrow foredeeps record the terminal zones of deposition. During this evolutionary stage in basin history, accommodation was created at a greater rate than sediment accumulated and therefore the basin remained underfilled.

Stage 2: Coarse-grained sediment delivery was drastically reduced to each basin, leading to the demise of the basin axial channel-levee systems. This corresponded with widespread instability on basin margin slopes, and the accumulation of extensive mass-transport deposits. This stage represents an important period of slope reorganization, as it achieves grade. Effectively, oversteepened upper slopes fail,

with net accumulation at the toe of slope. Sand passing across the slope setting locally accumulates in topographic depressions, or intraslope minibasins. Overall, a shallower, more stable slope is the end result.

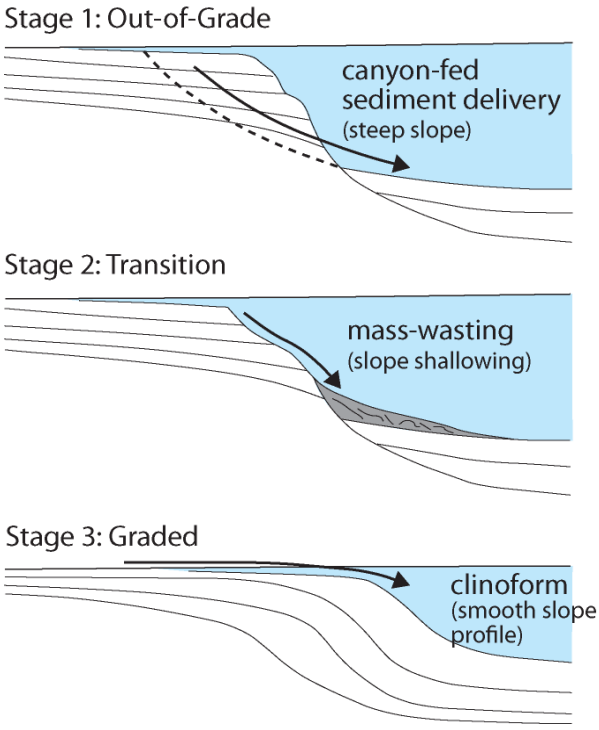

Figure 1: Stages of slope evolution documented from the Cretaceous Magallanes Basin of Chile and the Oligocene-Miocence Molasse Basin of Austria. Note that paleobathymetric relief is between 400 and 900 m for all stages. Diagram modified from Ross et al. (1994).

Stage 3: As basin margin slopes achieve grade they are characterized by smooth profiles (i.e., clinoforms). Fine sediment is more uniformly delivered across the slopes, with localized mass-wasting events common. Large shelf-edge delta systems characterize clinoform topsets, while relatively short-lived gullies and associated down-system channels transport coarse-grained detritus to basin floors. The systematic progradation of these slope clinoforms (400-900 m paleo-refief) effectively fills the deep-water basins; in this stage, sediment input is more substantial than accommodation generation.

The controls on the transition from out-of-grade to graded slope systems are likely numerous and difficult to isolate. With accommodation generation and sediment supply both fundamental controls in the ultimate filling of deep-water foreland basins, tectonic drivers are favored. Early, underfilled basin stages with immense canyon-fed axial channel belts correspond to times of active tectonism, manifest by uplift of the orogenic belt and elevated basin subsidence. As tectonism ceases, subsidence is greatly reduced and denudation of the mountain chain provides abundant detritus to the basin. This ultimately results in the transition to graded margin slopes, and subsequent basin filling as the large-scale clinoforms propagate along the basin axis.

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