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Failure Tracts in Deep-Water Settings Driven by Large-Scale Shelf Edge Failure

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Gravitational failure of sediment that gives rise to mass transport complexes composed of slide block, slump and debris flow deposits can play a key role in deep-water fold and thrust belts.

Failures sited on growth anticlines within the fold and thrust belt can initiate canyon-like breaches through the anticlines that induce down-dip sediment transport paths that complement or replace along strike transport paths confined to synclinal areas. Examples will be shown.

Of potentially greater importance are distantly sourced failure events that stem from large scale collapse of the shelf-slope break. Such events are commonplace where shelf-edge deltas exist at the shelf-slope break during lowstands in sea level. Failure is initiated by a combination of factors, usually non-seismic, of which the most important is the exceedance of a critical threshold angle forced by the delta oversteepening and overloading the upper slope. Failures occur at a range of scales including cases where the depth of detachment is at 100-150m and the area affected is 10's – 100's sq km. Many seismically resolvable mass transport complexes in deep-water settings result from large scale failures of the shelf edge and provide testimony to the commonplace nature of the events. Failures of this nature produce a suite of features that collectively define a distinctive failure tract that persists for some time after the failure event. From up-dip to down-dip the tract comprises : i) a failure scar from which material detached and the healing phase deposits that infill the scar; ii) a surface of detachment and erosion produced by shear and/or flow turbulence; iii) a mass transport complex; and, iv) a large volume debris flow and/or turbidity current. Mapping the scar determines the scale of the failure event and the nature of the healing phase stratigraphy determines the longevity and character of the failure tract post initiation. Smaller scale, more frequent failures and sediment gravity flow events are common during the healing phase. In cases where the mass transport complex evacuates from the scar and runs out downslope a new erosional seascape is created by shear at the base of the complex and turbulent erosion via any turbidity currents triggered by the event. This new seascape guides flows associated with healing phase failures along the pathway of the mass transport complex. The mass transport complex is a bathymetric high on the sea bed that initially deflects healing phase flows around the flanks of the complex. Deposition by these flows can onlap the margins of the complex and gradually obliterate its relief. If the healing phases continue beyond this stage the axis of the sediment pathway can then pass directly over mass transport complex, guided by unfilled erosional topography up-dip related to emplacement of the complex. The emplacement of a mass transport complex can also spawn large volume debris flows and/or turbidity currents that have the potential to outrun the complex and deposit in down-dip locations as a linked debrite/turbidite or turbidite megabed. Identifying large scale, seismically resolvable mass transport complexes in deep-water settings that stem from shelf-edge failures therefore has numerous implications for stratigraphy and sedimentation in the settings.

Deep-water settings influenced by large scale shelf-edge failures have a bimodality in the scale and frequency of sediment gravity flow events. Large magnitude, low frequency events relate to failure events and smaller magnitude, higher frequency events relate to the healing phase of the failure scar. The smaller magnitude, more frequent flows dominate sedimentation in the deep-water system. The large, less frequent flows are erosional throughout much of the deep water system and deposit only in very distal locations. In deep-water fold and thrust belts local, ponded accommodation is significantly less than in salt withdrawal minibasins (Steffens et al.,2003). Even so, the fills of strongly ponded salt withdrawal minibasins include widespread erosional surfaces that have been attributed to headward erosion of nick points from spill points that separate sub-basins but may equally be attributed to the erosional passage of exceptionally high volume flows through the minibasins. With lower levels of ponding in synclinal fold belt minibasins the potential for high volume flows to rip through a minbasin and erosionally re-define its bathymetry is far greater. The stratigraphic record of these basins may therefore be a combination of deposition by low magnitude sediment gravity flows directed either axially along the synclinal axis or transversely via a breach through the up-dip anticline, punctuated by significant erosional surfaces that are widespread within, and possibly between, minibasins. These surfaces will impart an event stratigraphy to the fill of the minibasin and will be associated with linked debrites/turbidites and or turbidite megabeds in downdip locations, or in areas where topography is sufficient to pond these events.