AAPG HEDBERG CONFERENCE
"DEEPWATER FOLD AND THRUST BELTS"
OCTOBER 4-9, 2009 – TIRRENIA, ITALY

Response of Submarine Channel Systems to Fold Growth: An Example from the Mississippi Fan Fold Belt, Deepwater NE Gulf of Mexico

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Introduction:

In response to the expansion of oil and gas exploration into the deep water slope and basin floor environments on passive margins and the associated increasing availability of 3D seismic data there has been much recent research done on the processes controlling submarine channel formation and on the transport of sediment from the shelf to the deep water. Along side this process-oriented sedimentological research there has also been significant structural work done on understanding the fold-belt system and related salt tectonics on the down-dip parts of the passive margin gravitational system. However less has been published on the detailed interaction between the evolution of structures and the syn-growth sedimentary systems in deepwater fold and thrust belts. The first order observations at the large scale have been made and documented: i.e. accommodation space, sediment supply, sea level changes, and climate are known to control the temporal and spatial variations of sedimentary systems at a large scale from shelf to deepwater. At a local scale in the fold and thrust belt part of the system, the principal controls on the depositional architecture is the interaction between the seabed topography and the sediment supply. So for example if folds or salt bodies generate seabed topography, channels might be expected to deflect around fold tips, before continuing down the regional slope. Where enclosed basins form behind folds, thrusts or salt bodies sands will pond until the basin fills to spill point (see Prather et al. 1998, Morgan 2004, Gee et al 2006, Saller et al. 2004, Mayall et al. 2008 for examples). We also know of examples where channels appear to cross active folds, and thus behave counter-intuitively. We suspect that this is a function of the ratio of sedimentation rate to the growth rate of the fold. Where sedimentation rate outstrips the fold growth the active structure gets blanketed and thus has little topographic relief allowing channels to flow over its crest. Conversely when the structure grows more rapidly than sedimentation rate, channels will get deflected and sand will pond. There is an intermediate case where channels with enough erosive power can keep pace with the growing structure, and continue to down-cut as the structure grows, and they may do this preferentially through structural 'lows' such as at linkage points between fold/fault segments. We investigate these ideas though the study of the geometry of a suite of evolving channels during the evolution of a growing fold in the Mississippi Fan fold belt, deepwater Gulf of Mexico, using 3D seismic reflection data.

Methodology:
The fold studied is the frontal-most fold in the Mississippi Fan Fold Belt, NE Gulf of Mexico, whose structural evolution was previously well documented by Rowan (1989). We have studied the interaction of Late Miocene -Pleistocene deepwater depositional systems with the growth of the fold by integrating simple structural reconstructions of fold growth with an analysis of the depositional systems by amplitude analysis of the seismic facies. We firstly established a framework correlation of pre-growth, syn-growth, post-growth and unconformity surfaces linking the mini-basins located between the folds. These interpretations were used to constrain amplitude extractions within the syn- and post-kinematic strata, from which channel pathways and other elements of the depositional system were mapped. Results were complied into a series of palaeogeographic maps.

Results:
- The fold studied has four segments and during the late syn-growth channel systems were focused through the bathymetric lows associated with the linkage points between the two fold segments with highest culminations.
- The basin directly behind the main fold is filled by a series of long-lived channel-levee systems that migrate both laterally and vertically-during the syn-growth period. The more confined parts of this basin are characterized by ponded infill, most probably consisting of sheet sands.
- The channels exit this basin at the linkage point between two fold segments. Over a substantial length of time the channel systems had enough erosive power to down-cut at a rate equal to the growth rate at a position along the fold where the structural growth rate was at its lowest.
- At one time during the fold evolution a channel is observed to cross the easternmost fold segment and is then deflected systematically sideways as the bathymetric relief associated with the fold increased. The onlap geometries during this time indicate that initially the sedimentation rate was outstripping the fold growth rate.
- The final tightening of the structure generated asymmetric sea bed topography with a significant scarp on the front limb of the fold. This scarp in the bathymetry persisted for a significant time interval (2-4 Million Years) when coarse-grained clastic sediment supply to this part of the Gulf of Mexico virtually shut down.
- Subsequent to the termination of fold growth in the Early Pliocene the pathways of the first large channel levee systems of the modern Mississippi Fan were still constrained by the palaeo-topography of the underlying fold belt, being deflected around the positive relief over the fold culminations on the seabed. Once this relict bathymetry was infilled the pathways of mid-late Pleistocene channels that continued to traverse the area were no longer affected by the underlying structure.

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