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Disentangling surface and deep crustal signals from the c. 20 Ma-old Burdigalian shallow marine Molasse sequences

Philippos Garefalakis and Fritz Schlunegger
University of Bern, Institute of Geological Sciences, Switzerland (philippos.garefalakis@geo.unibe.ch)

The 20 Ma-old transgression in the Swiss Molasse basin has been related to a reduction in sediment supply, to a rise in the global sea-level or to Alpine orogenic processes. Here, we disentangle these possible controls and establish a chronological framework through a compilation of published work. We examine the deposits of the Upper Marine Molasse (OMM) according to palaeo-bathymetrical conditions, sediment discharge directions and depositional settings. Flow directions are measured from ripple marks, parting-lineations, imbricated clasts and solmarks.

In the proximal east, OMM deposition started at c. 20 Ma within a wave-dominated environment with NE-directed discharge directions. At c. 19.3 Ma, the occurrence of m-thick offshore sandwaves mark a remarkable change to deeper bathymetrical conditions, which we interpret as the maximum flooding-surface (MFS). This deepening was associated with a widening of the basin, as shown by deposition of several m-thick offshore "Muschelsandstein" sandwaves in the distal eastern basin margin. During the MFS, the proximal sites record a W – E axial transport, while distal sites show a SW-oriented discharge direction. The depositional setting changed towards a tidal-dominated environment, and the sequence in the proximal east ends with c. 17.9 Ma-old palaeosoils. Discharge directions at the top of the suite show a NW-directed transport.
In the proximal west, OMM sedimentation started at c. 19.7 Ma within an estuarine-environment, where palaeoflow data indicates a NE-directed transport. Similar to the east, at c. 19.3 Ma, m-thick offshore sandwaves record a W – E oriented sediment transport and are interpreted as the onset of the MFS and thus as a deepening of the basin. Furthermore, the MFS is also recorded at the distal western sites with the occurrence of several m-high offshore sandwaves. There, palaeoflow-transport was oriented towards the NE. The sequence in the proximal west terminates with c. 17.7 Ma-old deltaic to fluvial sediments with a N – NW oriented transport. Finally, sedimentation was interrupted at 20 Ma, 18 Ma and 17 Ma.

A reduction of sediment fluxes at 20 Ma (Kuhlemann et al., 2001) paired with eustatic sea level changes most likely allowed the establishment of shallow marine conditions and the formation of multiple hiatus. However, the changes in the palaeo-depositional settings, the shifts to deeper bathymetrical conditions and the changes in discharge direction are possible recorders of the delamination and exhumation of the Aar-massif at c. 20 Ma and the associated fast period of roll-back subduction of the European slab (Herwegh et al., 2017). This is manifested by the deepening and widening of the basin towards the distal basin margin starting at c. 19.3 Ma during the times of the MFS. In addition, also at the distal sites, transport directions point towards a possible depocenter situated in front of the Aar-massif. This work thus shows that tectonic and surface signals can reliably be extracted from clastic records provided that a high-resolution sedimentological and chronological dataset is available.

Herwegh, M. et al., 2017. Scientific Reports, 7, 413.
Kuhlemann, J. et al., 2001. Tectonophysics, 330, 1 – 23.