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Relationship between nappe thrusting and coeval sedimentation: Cretaceous thrusting in the Northern Calcareous Alps

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In the western part of the Northern Calcareous Alps (NCA), all nappe units are exposed due to an overall eastward plunge of structures. The large nappe units are, from top to bottom, the Inntal, Lechtal and Allgäu nappes. The Allgäu and Inntal nappes are frontal and trailing imbricates of the Lechtal nappe, and the Cenomanrandschuppe (CRS) is a frontal imbricate of the Allgäu nappe. The thickness of the nappe units is in the range of 4km, and combined internal shortening and thrusting onto the footwall is in the range of 20km for the Inntal nappe and 40km for the Lechtal nappe (Eisbacher et al., 1990; Ecl. Geol. Helv. 83).

The switch from passive margin to synorogenic sedimentation in the western NCA took place under deep water conditions and is documented by the transition from marly or siliceous carbonates to marls, sandy marls and coarse clastic deposits. Synorogenic sedimentation develops gradually and conformably from passive margin sedimentation in the CRS, the Allgäu and southern Lechtal nappes. In contrast, synorogenic sediments on the northern Lechtal nappe and the Inntal nappe record surface uplift and subsequent erosion, followed by transgression and subsidence.

Assuming a ramp-flat geometry of the basal detachment of a nappe, thrusting in a deep marine environment has following consequences: As the frontal part of the thrust unit climbs up the ramp, water depth above the area of structural thickening decreases. If vertical growth is fast, shortlived carbonate buildups develop on top of the evolving structure, which shed biogenic detritus into the surrounding deep marine areas. At the foreland and hinterland dipping panels of the structure, angular unconformities within synorogenic sediments will record growth of the structure (e.g. Medwedeff, 1989;

AAPG Bull. 73). Continued growth will uplift the thrust unit above and behind the ramp above sea level. The thrust unit successively covers the upper footwall flat and ends sedimentation in the overthrust areas.

The synorogenic sedimentary successions of the western NCA were deposited at specific positions in such a model:

Upper Footwall sedimentation: On the upper footwall flat below the thrusted units, conformable onset of synorogenic sedimentation probably records distant onset of contraction related to orogeny, and deposition of shallow water biogenic detritus shows the approaching of the thrust unit. The youngest sediments below the thrust record the minimum age of thrusting at the point of observation. This situation is comparable to Aptian-Albian synorogenic sedimentation of the Tannheim and Losenstein Fms. on top of the Allgäu nappe, which are overlain by the Lechtal nappe, and to Albian-Cenomanian synorogenic sedimentation of the Lech Fm. on top of the southern Lechtal nappe, which is overlain by the Inntal nappe. The uppermost Lech Fm. locally contains shallow water detritus transported by gravity flows (Leiss, 1992; Geol. Rdsch. 81) and thereby records the destruction of carbonate buildups at the flanks of the approaching Inntal nappe.

Nappe-top sedimentation: On top of the thrust unit, where structural thickening has taken place, unconformable transgression of terrestric sediments on deeply eroded older rocks records surface uplift. The Branderfleck Fm. on top of the northern Lechtal nappe and of the Gosau Group on top of the Inntal nappe are found in this structural position.

In the foreland and the hinterland of the structure, undisturbed synorogenic sedimentation will continue. The CRS formed the northern continuation of the Allgäu nappe prior to the Campanian, when it was overthrust by the Lechtal nappe. The CRS has a conformable and continuous synorogenic sedimentary succession from the Aptian to the Campanian, overlapping both Upper Footwall sedimentation below and Nappe-top sedimentation on top of the Lechtal nappe. The CRS formed the foreland during thrusting of the northern Lechtal nappe. The hinterland in relation to the northern Lechtal nappe records conformable sedimentation up the Cenomanian, and was then overthrust by the Inntal nappe. It forms the upper footwall in relation to thrusting of the Inntal nappe.

Using such a model for synorogenic sedimentation and coeval thrusting has great predictive power, especially when working in poorly exposed areas, because it concentrates on simple geometric relationships between syntectonic sediments and their substratum.