Interacting folds, faults and thrusts – the conundrum of the Karwendel zone of slices ("Karwendelschuppenzone")

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The Karwendel mountains of the Tyrol have been considered a key area for the nappe tectonics within the Northern Calcareous Alps (NCA). On one hand, km scale outcrops expose one a major thrust, but on the other hand, minor thrusts and faults offset the major thrust. We have studied this zone in some detail, and present an attempt to unweave the kinematic evolution.

The oldest structure in the area is the (1) thrust, that superimposes Upper Permian to Lower Triassic evaporites of an upper thrust sheet with approximately 3 km of competent carbonates onto Lower Cretaceous marls of a lower thrust sheet. The geometry is that of the upper flat in a ramp-flat structure, and thus the hanging wall was not folded during Early Cretaceous emplacement. However, the thrust is folded in a NNE-verging km-scale Gamsjoch anticline. This fold, and the thrust, are offset by (2) WNW-striking sinistral transtensive strike-slip faults, and (3) low-angle long-limb thrusts that repeat the main thrust.

Sinistral strike-slip faulting (2) reactivated a preexisting, deep-reaching shear zone, which enabled the ascent of basanitic melts (Ehrwaldite dykes and sills), that occur in a 50 km long, roughly E-W-striking zone in the northern Karwendel and southern Wetterstein mountains. The shear zone has been related to Jurassic-Cretaceous intercontinental transform faulting. Beside the sinistral offset, the reactivation caused oblique normal offset of the southern block.

The long-limb thrust (3) truncates the strike-slip faults (2) and the main thrust (1). Locally, the incompetent Jurassic-Cretaceous succession is buttressed against the strike-slip fault in the footwall of a long-limb thrust. Orientation analysis of outcrop-scale structures in the Jurassic-Cretaceous sedimentary succession documents NW- to NE-verging folds, the first only preserved in more competent Upper Jurassic marly limestones, while structures in Cretaceous marls directly below the main thrust, and below the long-limb thrust are exclusively NE-verging. Folds in the hanging wall of the main thrust are N- to NNE-verging. Obviously, older structures could only be preserved in more competent rocks.

The following evolution of the Karwendel zone of slices is proposed:

• Intrusion of Ehrwaldite dykes and sills in the Lower Cretaceous along an E-W intercontinental transform

• Stacking of thrust sheets at the end of the Lower Cretaceous (1)

• Paleogene reactivation of the transported transform in the allochthon causing S-block down oblique sinistral normal faulting (2)

• Late Paleogene to Neogene reactivation of the main thrust (3) causing the long-limb thrust to climb the step created by preceding oblique normal faulting (2)

The observations and interpretations presented show how the localization of deformation is controlled by pre-existing structures. Folding is localized by the pre-existing transform, oblique slip normal faulting by the pre-existing fold, and long-limb thrusting is localized by pre-existing normal faults. As a consequence of the superposition of deformations and associated complexity, the Karwendel zone of slices has not been interpreted properly, and the boundary between thrust sheets has been placed at the long-limb thrust.