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A conceptual model for the development of pristine drainage systems during exhumation of metamorphic core complexes

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Metamorphic core complexes (MCCs) are defined as large scale geological features of domal shape. The essential characteristic comprises metamorphic rocks, which have been exhumed from lower crustal levels and now are exposed to the surface. The updoming process occurs at different tectonic settings of high strain zones initially exposing pristine gently dipping fault planes to Earth′s surface. Consequently, the dome shape highly influences the type of adaption of the drainage systems to the active landforms. However, drainage systems and their characteristic metrics in regions shaped by MCCs have only been sparsely investigated and were not examined regarding the distinction between different MCC-types (A-type, B-type, C-type).

In this study we investigate the drainage patterns of MCCs formed by different tectonic settings and build up a conceptual model for the development of the drainage systems under these conditions. We apply the χ-method to detect variations in uplift, as well as spatial unconformities in the drainage patterns. The χ-method is a mathematical approach to transform stream longitudinal profiles to the χ space where the slope of steady state profiles is solely dependent on uplift rate and bedrock erodibility. From this transformation we calculate color-coded χ-maps and χ-profiles of the main streams draining the MCCs. The applied method allows the interpretation of channel metrics in terms of (a) spatial gradients in uplift rate and (b) the time dependent evolution of drainage divides including drainage divide migration.

Our results show a high variation in the shape and greatest elevation of the χ-profiles. This indicates the migration of active uplift zones along the dome axes. Even though only MCCs younger than Miocene age are investigated, the shape of the χ-profiles clearly points to different development stages of these areas. -profiles plotted over the detachment underlying an active updoming process show concave shaped χ-profiles. In contrast, χ-profiles plotted over the detachments coined by long-term erosional processes tend to preserve prominent knick-points in linearly proceeding profiles. Additionally, the migration of the watersheds indicates lateral extension of the domes, potentially influenced by rolling hinges. MCCs subjected to active uplift show proceeding stream piracy of streams following tectonically induced lineaments. Drainage systems have systematically deflected streams at the edges of the dome structures. The deflections can be especially observed at A-type domes (dome axis oriented parallel to the direction of extension).

We conclude that our observations can be explained by the Rolling-Hinge model for MCC-formation. This model is applicable for all types of MCCs and gives the mechanical basis for the updoming process and such for the first stages of drainage development. Some of the observed features are dedicated to ongoing erosional processes and hence represent later phases of MCC development.