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The co-genetic evolution of metamorphic core complexes and drainage systems

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Metamorphic core complexes (MCCs) are large scale geological features that globally occur in high strain zones where rocks from lower crustal levels are rapidly exhumed along discrete fault zones, basically ductile-low-angle normal faults recognizable by a metamorphic break between the cool upper plate and hot lower plate. Standard methods, structural analysis and geochronology, are applied to reveal the geodynamic setting of MCCs and to constrain timing and rates of their exhumation. Exhumation is abundantly accompanied by spatially and temporally variable vertical (uplift) and horizontal motions (lateral advection) representing the tectonic driver of topography formation that forces drainage systems and related hillslopes to adjust. The drainage pattern commonly develops in the final stage of exhumation and contributes to the decay of the forming topography. Astonishingly, drainage systems and their characteristic metrics (e.g. normalized steepness index) in regions coined by MCCs have only been sparsely investigated to determine distinctions between different MCC-types (A- and B-type MCCs according to Le Pourhiet et al., 2012). They however, should significantly differ in their topographic expression that evolves by the interplay of tectonic forcing and erosional surface processes. A-type MCCs develop in an overall extensional regime and are bounded partly by strike-slip faults showing transtensional or transpressional components. B-type MCCs are influenced by extensional dynamics only. Here, we introduce C-type MCCs that are updoming along oversteps of crustal-scale, often orogen-parallel strike-slip shear zones.

In this study, we analyze drainage systems of several prominent MCCs, and compare their drainage patterns and channel metrics to constrain their geodynamic setting. The Naxos MCC represents an A-type MCC. The Dayman Dome located in Papua New Guinea a B-type MCC, whereas MCCs of the Red River Shear Zone, the Diancang, Ailao-Shan and Day Nui Con Voi complexes, show structural features of the C-type endmember. In the case of the Diancang complex, the MCC is even superimposed by late stage B-type dynamics. The Tauern window and Lepontine dome in the Alps are described as C-type MCCs. We extracted drainage systems and basins and calculated Strahler orders to explore asymmetries in the drainage pattern and to detect evidence for horizontal advection of rivers and catchments. We computed longitudinal river profiles and determined the normalized steepness indexes for channels to uncover regions of spatially variable uplift rates and to constrain the state of landscape adjustment at active MCCs. Furthermore, we analyzed the stability of watersheds by computing so called χ-maps.

A-type MCCs show a drainage pattern, which is partly parallel to the stretching and elongation direction, potentially developing from grooves of the detachment. The B-type MCCs show preferences for a radial oriented drainage pattern along lateral terminations. The radial morphology is overprinted by fault systems and neighboring uplifted domes beside the investigation site. A clear preferred direction for further capturing of catchments can be described along detachment zones. The results show an asymmetric alignment of the drainage networks of C-type MCCs, caused by tilting and lateral offset of the streams. One side of the valley shows short streams, whereas the other side is characterized by long, deeply incised streams with a clear tendency to capture adjacent catchments. In C-type MCCs, the drainage pattern develops perpendicular to the trunk streams, which are subparallel to confining faults. The tributaries of the trunk valleys show often dragging in shear direction of the confining fault. The drainage pattern along ductile low-angle normal faults seemingly develops parallel to these faults and shows an asymmetry due to tilting towards the hangingwall block. The analysis reveals that the three types of MCCs can be distinguished by their drainage pattern. All three types have a distinct central drainage divide in common, which is getting elongated in the stretching direction in C-type MCCs and remains small in B-type MCCs. Further early results of our analysis show the high potential of employing morphometric tools in combination with methods from structural geology and low temperature geochronology to determine the type of MCCs, to reveal timing and rates of uplift and horizontal advection, and to constrain the state of landscape adjustment at active MCCs.