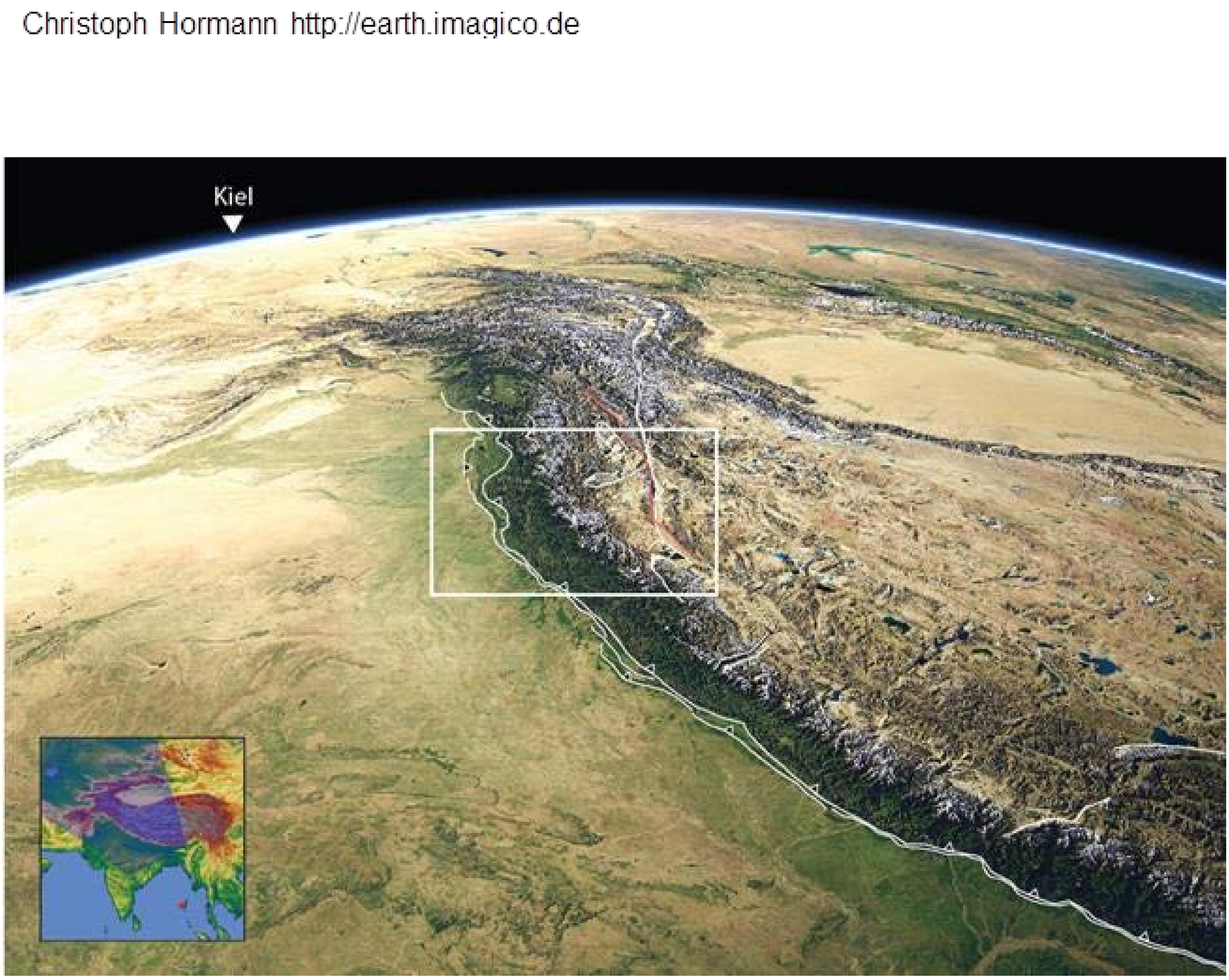
Orogenic processes on various time scales



The Uplift of the High Himalaya – the geologic evolution of main Indian-Tibetan orgraphic barrier (seen on the Photo from Pass at >5000 m asl. in Garhwal Himalaya)-

Photo: Dr. Rasmus Thiede

Abstract:

The shape of our Earth's surface is driven by plate tectonics, formed by tectonic processes and crustal uplift, and sculpted by erosion. Despite major advances in understanding how plate motion is accommodated, it is still both controversially debated and challenging to measure how the topography of orogenic fronts evolves through coupled shallow and deep crustal geodynamics as well as where/when exactly plate convergence is partitioned in space and time (Figure 1). As a result, on different time scales the measured short- and long-term derived orogenic growth and erosion often yield contradictory rates. The origin of these challenges may not only be intimately associated with temporal and spatial variations of deformation and erosional stripping of orogenic wedges, but also be related to rheological changes of the involved crustal and mantle lithosphere over geologic time. Unsolved questions are if disparate levels of fault activity are systematic or randomly triggered? Answering this question is fundamental for understanding the rheology, mechanisms, loci of wedge deformation, and its timing, which is ultimately necessary for hazard mitigation and risk reduction in tectonically active mountain ranges. To address these problems, I have studied various aspects of orogenic growth and deformation processes, using approaches from structural geology, thermochronology, climatology, tectonic geomorphology and surface processes. - My motivation has been to assess the deformation and uplift mechanisms on different timescales. More recently I started to try to better decipher earthquakes and their recurrence patterns. For this the ultimate goal has been to quantify and evaluate the spatial characteristics of mountain-front deformation in the context of orogenic wedge dynamics.

Based on the syntheses of my scientific results presented in this thesis, I have achieved the following milestones: (a) I hypothesize that tectonics along large plate boundaries may indeed follow patterns between two end-member deformation styles. Both deformation and crustal shortening is accommodated either solely along a basal décollement combined with a steep frontal fault system, or more broadly across several steep splay faults. One former accommodates crustal material by frontal accretion, the latter by under plating and/or duplex growth in the middle of the orogenic wedge (Chapters 2, 3, 4). I propose that in an orogenic setting, such as it exists along the southern Himalayan front (Fig. 1), both end-members of the orogenic evolution existed during various times of its evolution. The early Himalaya history lasting until the middle Miocene was dominated by frontal accretion. Since then, however, underplating and duplex growth is as important as frontal accretion and the establishment of basal décollement (Chapter 4). An additional characteristic is that orogenic fronts intersect with atmospheric circulation pattern resulting in strong precipitation and erosion gradients, such as it has been recognized with the Indian Summer Monsoon circulation along the southern Himalayan front (Chapters 2, 7, 11, 14). As a result various couplings between tectonic deformation and erosion processes have been established and are controlling the site and spatial extent of denudation within the orogenic wedge (Chapters 11, 14). This tight coupling between crustal geodynamics, surface processes, and climate has been recognized on various levels (Chapters 2, 3, 11, 14), but its exact relationships are still debated (Chapters 7, 11). Hereby this coupling enables to maintain the site of focused denudation within the orogen for many millions of years, and deformation does not propagate, as it

would do without erosion (Chapter 2). If similar couplings existed during the early Himalayan evolution is unknown, as the lack of preserved archives has prevented to measure these. I have quantified these couplings along several segments of the southern Himalayan front and discovered significant temporal and spatial variations along strike (Chapters 3, 4, 7). Thereby we have discovered that the northwest Himalaya is one of the best sites for this analysis.

(b) Further prominent crustal processes and feature in continental collision zones are syntectonic extension and growth of gneiss domes (Chapters 6, 10, 12). Gneiss domes are large crustal syn-orogenic culminations; the way they deform is an ideal measure for the overall crustal stress field during formation – recognized both in the Himalaya and Pamir Mountains (Chapter 6). In contrast to earlier assumptions that the evolution of syntectonic extension and gneiss domes are a late to post collisional orogenic phenomenon, recent studies document that extension and gneiss dome develop syn-collisional during convergence. For instance, both in the northern Himalaya and across the Pamir prograde metamorphic mid crustal rocks were exhumed just ~30 Myr after onset of Indian-Eurasian collision. Thereby we found out that gneiss dome can initiate and exhume middle crustral rocks from >20 km crustal depth to the surface within <5Myr after peak metamorphism and the entire exhumation process can terminate just after ~10 Myr – possible related to rheological and/or stress field changes within the crust.

(c) Surface processes, erosion and sediment flux are not continuous, but rather subject to strong climate variations controlling changes in erosion and sediment flux rates on various timescales (Chapters 5, 8, 9). We discovered strong fluctuation in sediment aggradation and incision within intra-mountain basins exposed within the deformed Sub-Himalaya on time scales of 10 ka and 100 ka. One represents fluctuations related provisionally driven variations of monsoonal strength, the latter one is possibly related to glacial and interglacial cycles.

Despite all advances in our understanding of the Himalayan evolution, we recognize several tectonic events and changes in structural style of the orogen deformation – which are not related to processes described above and the triggers for these events are still to be proven and quantified. For instance several recent studies propose that Greater Indian slab breakoff at 20 to 25 Ma triggered a rebound of the Greater Himalaya that caused the establishment of a new basal detachment system, the Main Central Thrust System (MCT), fostering the extrusion of the Greater Himalaya Crystalline. Recent advances demonstrate that we are just at the beginning to understand crustal deformation pattern of large orogens in space and time such as the Himalaya and further research is strongly needed.