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# Long-term stability of present rotation patterns - GPS measurements and paleomagnetic directions

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The thermodynamic evolution of an orogen can be subdivided into three stages depending on the relative rates of energy accumulation and dissipation. After a first phase of energy accumulation, interplay of accumulative and dissipative processes dominates the second stage. During the third stage the dominance of energy dissipation leads to the degradation of the orogen. The second stage of orogeny is dominated by lateral mass transfer. For both, continuum deformations or discrete shear zones, lateral mass transfer is characterised by rotations about vertical axes. The Quaternary to present vertical axes rotations have been deduced from a joint inversion of Quaternary strain rates and over 700 GPS velocities for a self-consistent velocity field. For equidimensional crustal blocks rotation rates can be calculated. Paleo-rotations have been determined from 20 paleomagnetic studies (71.7 to 91.8°E) with remanence acquisition ages between 47 and 13 Ma. The striking consistency of rotation directions in the short- and long-term rotation pattern points to a longer-term stability of the present rotation pattern over geological time. Oroclinal bending around the western syntaxis can be considered as lateral mass transfer without influence on the potential energy budget of the collision zone. Since no vertical thickening is involved, oroclinal bending is attributed to the second stage of orogeny. In order to investigate the transition between the first and second stage in the compressional part of the collision zone, we present a compilation of present rotation rates deduced from GPS measurements and the late-orogenic rotation pattern since 40-50Ma deduced from paleomagnetic results. The evaluation of different correlations between both provides new constraints on the stability and the onset of oroclinal bending. The Quaternary to present rotation pattern is characterized by counterclockwise and clockwise rotation rates of up

to 10-16rad/sec west and east of the Nanga Parbat Haramosh syntaxis, respectively. The paleo-rotation pattern (40-50 Ma) in the Tethyan Himalayas in respect to the Eurasian plate is dominated by clockwise rotations W of the Nanga Parbat-Haramosh syntaxis. To the E, the counterclockwise rotation of NW Kashmir is supported by the Pliocence rotations in the Peshwar basin. This rotation pattern in conjunction with the rotations south of the Tethyan Himalayas pinpoints oroclinal bending around the western syntaxis. The remanence acquisition age provides the maximum age of rotations due to oroclinal bending. Linear extrapolation of the rotation rates from Quaternary strain rates and GPS measurements to the remanence acquisition time describe a linear correlation with the observed paleomagnetic rotations with a coefficient of determination of R2=0.60. Since the age of remanence acquisition represents a maximum age for oroclinal bending, the rotation patterns of paleomagnetic results and GPS measurements have been calculated for different ages in 5 to 10 Ma steps between the remanence acquisition age and 5 Ma. At 20 Ma the correlation between the expected rotations from GPS measurements and the paleomagnetic rotations reveal a linear fit with a gradient a=1. Assuming a stable rotation velocity, this gradient indicates that the oroclinal bending related rotations initiated 20 Ma ago. The fact that the linear fit runs approximately through the origin minimizes the influence of earlier rotation processes on the absolute rotational motion. This implies that the onset of lateral mass displacement occurred at about 20 Ma, which can be considered the transition age from the first to the second stage of orogeny in the compressional part of the collision zone. The timing of onset of oroclinal bending is consistent with the right-lateral motion at the southern end of the Karakoram fault since about 23Ma and the onset of doming in the Nanga Parbat-Haramosh massif in the Miocene.