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Velocity Fields and Strain Patterns as a Tool to determine driving Factors of an Orogen?

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Observation of finite strain patterns, seismicity, or of active surface deformation in orogens merely provides a snapshot of the structural evolution of an orogenic system. Changes over time are not readily captured with these approaches. Yet, they are instrumental to identify the role of various factors both from internal system properties or of external causes.

Analogue models are an important tool yielding complete time-series of deformation accumulation including their patterns and transients, thereby allowing to test the influence of various factors on such processes. Our analogue set-up models the upper crust down to the asthenosphere and includes a weak lithospheric unit that is compressed between two stronger blocks. We model single parameters and combinations thereof to examine their importance for the development of a certain orogenic type and its associated pattern, and evaluate their stability against changes. In other words, we test the sensitivity of various orogenic deformation styles to changes in starting conditions.

Surface deformation in the experiments is monitored by a digital stereoscopic camera system using particle imaging velocimetry (PIV). PIV data do not only show the ‘snapshot’ or incremental velocity field during evolution of an orogenic system - which would be analogous to GPS data -, but a complete time series of velocity fields during the development of the orogen. Hence, we are able to detect changes in velocities and direction both in space and in time, e.g. due to strain localization and formation of faults. Thus we observe velocity fields, the strain evolution, and the development of topographic relief in a high spatial and temporal resolution. This also allows us to compare deformation on different scales, namely long-term deformation (or cumulative strain) with instantaneous vector fields.

We focus on the experiments which yield a plateau-style setting, of which there are only two in nature (the Central Andean Altiplano and Himalaya-Tibet). They are characterized by a number of Cordilleras bounding highly elevated flat surfaces, where strain does not accumulate in a systematic way. Due to the scarcity of such orogens, there must be a special combination of parameters that cause an initial system to form a plateau rather than a classic fold-and-thrust belt.

We show that only a special parameter combination supports development of a plateau orogen: lateral strength contrasts and intralithospheric decoupling horizons are the most crucial factors. This is similar to the Andean example. Although our models are not as complex as nature itself, our analogue plateau reproduces both the spatial and the temporal pattern of orogen-scale strain accumulation that we find for the Altiplano. Furthermore, a hierarchy of parameters responsible for deformation accumulation styles is observed. In addition, our experiments indicate that inferences drawn from velocity fields based on GPS or seismicity data may be misleading due to the role of various processes causing transient changes in the velocity fields thereby explaining the often observed discrepancy between the above data and geological long-term strains.