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Links between long-term and short-term rheology of the lithosphere: insights from strike-slip fault modelling

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The study of geodetic data across strike-slip fault zones is believed to play a key role in our understanding of the lithosphere mechanical behaviour. InSAR and GPS measurements permits to determine more and more accurately both large and rapid co-seismic displacements and the slower deformation associated with the inter-seismic and post-seismic phases of the earthquake cycle on continents. However, no modern geodetic observation spans a complete earthquake cycle for any single fault in the world. Understanding this time variability through modelling is therefore crucial to reconstruct a global pattern.

It is non trivial to compare the effective parameters retrieved from the different simple models are used to extract effective parameters from the geodetic data. Using the popular visco-elastic relaxation model reaches two paradoxes:

- the lower crust must be very strong in order to fit the data long after the earthquake and very weak to fit the data during the early post-seismic period.
- the retrieved a mantle lithosphere viscosity is as weak as 10^{17} - 10^{20} Pa.s and differ significantly from those deduced from post glacial rebound models and long term geodynamic models requirements in order to generate self consistent plate tectonics.

Rather than assuming that the rheology of the lithosphere changes with time scale, it would be preferable to go on quest for an Earth's lithosphere rheological model based on some simple physics, which would be equally valid at all time scale from inter-seismic to orogeny.

3D models of long term strain localisation in wrenching context show that localisation of strain across strike slip faults modifies locally the rheological architecture of the lithosphere and lead to some sort of structural weakening. That weakening occurs because as strain localises the "jelly sandwich" type lithosphere evolves self-consistently into a "banana split" type rheological structure. This strain localisation process is very efficient when the lower crust has a very low viscosity (10^{19} Pa.s) compatible with post seismic relaxation while the secular strain localisation across the fault is steeper when the lithosphere surrounding the fault is the strongest.

Within that frame, long time after the earthquake, the steep velocity gradients reported by GPS data would reflect the secular/long term localisation of strain in a strong lithosphere rather than transient processes related to the last earthquake.