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Determining sub-seismic strain in the hanging-walls of seismically-visible faults using 3-D kinematic retro-deformation

David C. Tanner (1), Jennifer Ziesch (1,2), Charlotte M. Krawczyk (1,3,4)

(1) Leibniz Institute for Applied Geophysics, Stilleweg 2, D-30655 Hannover, Germany (davidcolin.tanner@liag-hannover.de), (2) State Authority for Mining, Energy and Geology, Stilleweg 2, D-30655 Hannover, Germany, (3) GFZ German Research Centre for Geosciences, Telegrafenberg, D-14473 Potsdam, Germany, (4) Institute for Applied Geosciences, Technical University Berlin, Ernst-Reuter-Platz 1, D-10587 Berlin, Germany

It is of utmost importance to determine the smaller-scale deformation caused by the movement on a large fault, especially if the fault in question is only visible in, for instance, seismic, and no other method is available to determine the former. Sub-seismic deformation improves or decreases the permeability of a fault, and it is therefore invaluable to geothermal prospecting, safety issues of radioactive waste depositories and CO_2 sequestration, to name a few applications. This is where 3-D kinematic restoration plays a key role, because restoring a structure to its original pre-fault geometry in three dimensions (3-D retro-deformation), can also allow the illumination of the sub-seismic deformation in the surrounding volume. Nevertheless, care must applied to choose the right algorithm for retro-deformation, use the correct kinematic parameters for the modelling and understand the meaning of the results.
We show an example of determining the areal distribution and magnitude of strain during the retro-deformation of faults within 3-D seismic volumes from the Otway passive margin in Australia and the Alpine Molasse basin in Germany. In both cases, we use the inclined-shear algorithm —widely used in research and industry, but poorly investigated— to restore the seismic-scale faults. By kinematically restoring the tetrahedral volumes between the seismic horizons, we are able to determine orientation and magnitude of the strain tensor at every node point defined by tetrahedral volume. The magnitudes of strain during forward and retro-deformation are identical, and therefore directly related to the density of sub-seismic structures such as fractures. We show graphically the effect of the incline shear angle, as the main parameter, on the strain magnitude and discuss its relevance for such modelling.