Experimental data on scaled analogue experiments modelling GPS velocity field variations and kinematic partitioning in the Southern Andes (34°S to 42°S)
(http://doi.org/10.5880/fidgeo.2021.023)

Jan Oliver Eisermann, Paul Leon Göllner, Ulrich Riller*

Universität Hamburg, Bundesstrasse 55, 20146 Hamburg, Germany
* Corresponding author: ulrich.riller@uni-hamburg.de

1. License

2. Citation

When using the data please cite:
Eisermann et al. (2021): Experimental data on scaled analogue experiments modelling GPS velocity field variations and kinematic partitioning in the Southern Andes (34°S to 42°S). GFZ Data Services. http://doi.org/10.5880/fidgeo. 2021.023

The data are supplementary material to:
Eisermann et al. (2021): GPS velocity field and kinematic partitioning in the Southern Andes (34°S to 42°S) revisited. DOI to be added

Table of contents

3. Data Description

The southern Andes are regarded as a typical subduction orogen formed by oblique plate convergence. Despite decades of studies, there is considerable uncertainty as to how deformation is kinematically partitioned in the upper plate. Using scaled analogue experiments modelling, we test the concept of dextral transpression for this orogen. We advocate that the GPS velocity field portrays interseismic deformation related to deformation of strong crust north, and weak crust south, of 37°S. Contrary to the popular hypotheses that the Liquiñe-Ofqui Fault Zone, a prominent intra-arc deformation zone, takes up most of the plate boundary-parallel dextral strike-slip, we find that dextral transpression affects the entire model orogen through tectonic segmentation of crust.

Moreover, prominent, regularly spaced sinistral oblique-slip thrust faults, interpreted as antithetic Riedel shears, developed spontaneously in all of our experiments and call into question the general believe that their NW-striking natural equivalents formed from pre-Andean discontinuities. Our experiments prompt us to reconsider the apparently well-established geodynamic concept that strain and margin-parallel displacement is localized on a few margin-parallel faults in the southern Andes.

3.1. Experimental Setup

The *MultiBox* consists of two halves, each of which contains a piston. One half is mobile and moves relative to the fixed one parallel to the box midline. Computer-controlled stepper motors driving all mobile parts of the *MultiBox* ensure precise reproducibility of experiments. Each piston of the *MultiBox* is fitted with a 100 cm x 21 cm wooden base plate amounting to L-shapes of the pistons. An initially 27 cm wide gap between the frontal edges of both piston base plates is filled with a 0.5 cm thick layer of low-friction micro glass beads covered by plastic wrap to avoid mixing of polydimethylsiloxane (PDMS) and micro glass beads. The base plates and space between the plates are covered by a 3 cm thick layer of a mixture of PDMS and fine-grained corundum, simulating the viscous lower crust. A 0.5 cm thick layer of quartz sand with Mohr-Coulomb rheology models the brittle upper crust. The variation in crustal strength in the experiments is simulated by thickness changes of model upper crust.

The analogue materials are detached from the base of the *MultiBox* and deform freely above the gap between the pistons. During shortening, a small portion of the micro glass beads escapes below the L-shaped pistons. Therefore, the micro glass-bead layer remains constant in thickness and, thus, has no influence on the overlying analogue materials. As the mobile half of the *MultiBox* moves left-lateral with respect to the fixed half, the graphical modelling results are mirrored to be comparable to the deformation kinematics in the Southern Andes.

The combined movements of the pistons and the moving box half mimic upper-crustal kinematics as inferred from the GPS velocities in the forearc between 35°S and 37°S, in which material is displaced at a rate of 30.35 mm/a toward an azimuth of 75.64°. Given the overall trend of the trench of N5°E between 34°S and 41°S, the convergence vector in the experiments amounts to 70°. GPS data from the back arc between 37°S and 39°S indicate displacement rates of about 4.11 mm/a towards 207.76°. Thus, the displacements in the back arc are 7.4 times slower than in the forearc.

The experiments test different orogen-parallel model crustal strength gradients by varying the thickness of the quartz sand layer of the "northern" portion of the experiment, pertaining to the region north of the slab tear. The sand thickness in the "southern" portion, modelling the region south of the slab tear, is kept constant in all experiments, i.e., 0.5 cm, and corresponds to the average upper-crustal thickness of 10 km in the Southern Andes. A 15 cm wide transition zone between both portions amounts to 300 km in nature.

Three different model crustal strength setups were tested: Setup 1 is characterized by a uniform thickness of the sand layer of 0.5 cm. Setup 2 is made up by a 0.2 cm thick sand layer in the northern portion, amounting to a weaker crust there than in the southern portion. With a sand layer thickness of 0.9 cm, setup 3 models a mechanically stronger crust in the northern than in the southern portion. To assess the reproducibility of results, each experimental setup was run several times, in addition to conducting eight pilot and verification experiments. The results of repeated experiments proved to be similar in terms of orientation, kinematics and overall zonation of visible faults. Differences among identical experimental setups are apparent by slight variations in fault spacing.

3.2. Monitoring of experiments

The experiments were recorded with a 3-D Stereo Digital Image Correlation (DIC) StrainMaster system manufactured by LaVision GmbH (Germany). Two monochrome Imager M-lite 12M CMOS cameras with a 12-bit sensor (12-megapixel, 4112 x 3008 pixels, 4096 values of grey) where mounted on a frame above the model surface.

The images were recorded and synchronized with a Device Control Unit X (DCU X) running DaVis 10.0.4 by LaVision GmbH (Germany). A set of high-quality Nikon lenses with 24 mm and 35 mm focal lengths were used. The focal length of 35 mm allowed us to capture a large area within the *MultiBox*, whereas using a focal length of 24 mm resulted in cropped images of the experiment surface. The experiments shown here have been recorded with a focal length of 24mm.

3.3. Digital image correlation

Stereo DIC permits the computation of 3-D surface displacement fields by cross-correlation of sequentially recorded stereo image pairs. Simultaneous application of stereo image reconstruction generates a highly accurate 3-D model of the surface topography. This allows for quantifying the spatio-temporal evolution of the monitored experiment. The quartz sand used for the brittle layer included black dyed quartz grains serving as markers for DIC cross-correlation. The mixing ratio of 1:12 with regard to non-dyed sand has been optimised for the cameras used, camera distance to the surface and sizes of experimental setups. The black marker grains have the same physical properties as the non-dyed sand grains. Sieving the sand created a random particle pattern, which is conducive for improved tracking and reconstruction of displacement vectors.

Calibration of the cameras prior to each experiment identified and corrected lens distortions, calculated the camera position relative to each other for stereo reconstruction and sets the correct length scale to ensure for a high-precision vector field calculation. By utilising a calibrated and perfectly flat calibration chart with known marker size and spacing, 30 images with varying calibration chart positions were captured. Using the automatic calibration option of DaVis 10.0.4, an average residual fit error of 0.0406 pixel was achieved for the experiments.

Careful removal of the sand layer immediately after completion of each experiment revealed the deformed PDMS surface and allowed us to record this surface in 3-D. By combining the 3-D model of the final sand surface and the underlying PDMS surface allowed the generation of digital cross-sections at selected locations.

The image recording time interval of 1 minute between images is sufficient to monitor model deformation. The software DaVis 10.0.4 was also used for displacement vector field calculations. This allowed us to precisely monitor the morphological evolution of the surface by calculating the incremental and cumulative displacement vector fields for each experiment. The sum of all incremental vector fields resulted in a cumulative vector field. From the computed vector field, the software allowed us to display and output a number of different derivates of surface deformation. Based on these derivates, the deformation history up to the resolution of a few grain diameters can be displayed. The deformation derivates are: surface displacement in X-, Y- and Z-directions; divergence describing convergence as a negative value and divergent motion of surface displacement vectors as a positive values defined as $div = \frac{du}{dx} + \frac{dv}{dy}$; shear strain showing direction-independent shear, where sinistral is represented as a positive and dextral as a negative value $\varepsilon = \frac{1}{2}\left(\frac{du}{dy} + \frac{dv}{dx}\right)$, and rotation around the Z-axes were positive is clockwise an negative counter-clockwise rotation.

4. File description

For three of the six setups (Setup 1, Setup 2 and Setup 3), there are the following file types:

(i) **2021-023_Eisermann-et-al_Movies.zip**: Movies of surface deformation (mov format)

(ii) **2021-023_Eisermann-et-al_Images.zip**: Images of the final surface deformation (bmp format)

(iii) **2021-023_Eisermann-et-al_Images.zip** Supplementary experimental parameters (xlxs format)

For additional three setups (Setup 3a, Setup 4, Setup 5), there are the following file types:

(iv) Images of the final surface deformation (bmp format, included in **2021-023_Eisermann-et-al_Images.zip**)

(v) Supplementary experimental parameters (xlxs format, included in **2021-023_Eisermann-et-al_Data.zip**)

An overview of all data files is given in the **List of Files.** For the three main setups (Setup 1, Setup 2 and Setup 3), individual movies show cumulative divergence, differential strain, rotation, shear, displacement vectors and topography of the experimental surface. For all six setups, individual images show cumulative divergence, deformation grid color-coded topography of the experimental surface of the final experimental stage. Davis raw data (.Vc7 format) available on reasonable request. The supplementary tables list details of the physical boundary conditions of each experiment and the recording paraments used for DIC.