Images and videos of analogue centrifuge models exploring marginal flexure during rifting in Afar, East Africa (https://doi.org/10.5880/fidgeo.2020.020)

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1. Licence

2. Citation

When using the data please cite:

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Related datasets:

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Zwaan, F.; Rudolf, M.; Corti, G.; Keir, D.; Sani, F. (2020): Rheology of viscous materials from the CNR-IGG Tectonic Modelling Laboratory at the University of Florence (Italy). GFZ Data Services. https://doi.org/10.5880/fidgeo.2020.018

Zwaan, F.; Rudolf, M.; Pohlenz, A.; Corti, G.; Keir, D.; Sani, F. (2020): Ring-shear test data of feldspar sand from the CNR-IGG Tectonic Modelling Laboratory at the University of Florence (Italy). GFZ Data Services. https://doi.org/10.5880/fidgeo.2020.019

Table of contents

1. Licence 1
2. Citation 1
3. Data Description 2
   3.1. Monitoring of experiments 3
   3.2. Data presentation 4
   3.2.1. Top view images 4
   3.2.2. Side view images 5
   3.2.3. Digital elevation models (DEMs), topo maps and subsidence curves 5
   3.2.4. Final cross-sections 7
   3.2.5. Top view videos 8
   3.2.6. Side view videos 8
   3.2.7. Topography (DEM) videos 9
4. File description 9
4. Acknowledgements 10
5. References 10

3. Data Description

This data set includes images and videos depicting the evolution of deformation and topography of 17 analogue experiments c passive margin development, to better understand the ongoing tectonics along the western margin of Afar, East Africa. The tectonic background that forms the basis for the experimental design is found in Zwaan et al. 2020a-c, and references therein. The experiments, in an enhanced gravity field in a large-capacity centrifuge, examined the influence of brittle layer thickness, strength contrast, syn-rift sedimentation and oblique extension on a brittle-viscous system with a strong and weak viscous domain.

All experiments were performed at the Tectonic Modelling Laboratory of of the Istituto di Geoscience e Georisorse - Consiglio Nazionale delle Ricerche (CNR-IGG) and of the Earth Sciences Department of the University of Florence (CNR/UF). The brittle layer (sand) thickness ranged between 6 and 20 mm, the underlying viscous layer, split in a competent and weak domain (both viscous mixtures), was always 10 mm thick. Asymmetric extension was applied by removing a 1.5 mm thick spacer at the side of the model at every time step, allowing the analogue materials to spread when enhanced gravity was applied during a centrifuge run.

Differential stretching of the viscous material creates flexure and faulting in the overlying brittle layer. Total extension amounted to 10.5 mm over 7 intervals for Series 1 models that aimed at understanding generic passive margin development in a generic orthogonal extension setting, whereas up to 16.5 mm of extension was applied for the additional Series 2 models aiming to reproduce the tectonic phases in Afar. In models involving sedimentation, sand was filled in at time steps 2, 4 and 6 (i.e. after 3, 6 and 9 mm of extension). Detailed descriptions of the experiments, monitoring techniques and tectonic interpretation of the model results are presented in Zwaan et al. (2020d).

3.1. Monitoring of experiments

All experiments (Table 1) were monitored with top view and side view photographs (Canon EOS 1300D 18 Mpx or Canon IXUS 500 HS 10 Mpx), with different lighting directions to highlight deformation at the model surface. The photographs were generally taken at every modelling time step (i.e. 1.5 mm), although some intervals are missing in certain cases (Table 2). Next to top and side view pictures, also 3D photographs were taken from various directions during most intervals, allowing for 3D photogrammetry and model topography reconstruction (digital elevation models or DEMs) over time using using Agisoft Photoscan software. These DEMS were further processed using Global Mapper and QGIS software to create subsidence curves throughout the central axis of the models. Finished models were furthermore wetted with soapy water, frozen and hand-cut to allow analysis of internal structures. The naming conventions of the various files are provided in Table 3.

Table 1: Overview of experimental parameters and monitoring details.

	Experiment name in Zwaan et al. (2020d)	Lab code (CNR/UF)	IC layer	Sand layer thickness	Sedim.	Total extension (intervals)	Top view photo intervals	Side view photo intervals	3D photogrammetry intervals available
Series 1 models	A	WAM_02	X	6 mm	-	10.5 mm (7)	t0-7	t0, 7	t0, 3, 7
	A_2	WAM_20	X	6 mm	-	10.5 mm (7)	t0-7	t0-7	t0, 5, 7
	B	WAM_03	X	10 mm	-	10.5 mm (7)	t0-7	t3-7	t0, 1, 3, 5, 7
	C	WAM_01	X	15 mm	-	10.5 mm (7)	t0-7	t7	t0, 1, 3, 5, 7
	C_2	WAM_17	X	15 mm	-	10.5 mm (7)	t0-7	t0-7	t0, 1, 3, 5, 7
	C_3	WAM_18	X	15 mm	-	10.5 mm (7)	t0-7	t0-7	t0, 1, 3, 5, 7
	C_4	WAM_19	X	15 mm	-	10.5 mm (7)	t0-7	t0-7	t0, 1, 3, 5, 7
	D	WAM_04	X	20 mm	-	10.5 mm (7)	t0-7	t0-7	t0, 1, 3, 5, 7
	E	WAM_12	X	6 mm	t2, 4, 6	10.5 mm (7)	t0-7	t0-7	t0-7
	F	WAM_09	X	15 mm	t2, 4, 6	10.5 mm (7)	t0-7	t0-7	t0-7
	G	WAM_06	-	6 mm	-	10.5 mm (7)	t0-7	t0-7	t0, 1, 3, 5, 7
	H	WAM_07	-	15 mm	-	10.5 mm (7)	t0-7	t0-7	t0, 1, 3, 5, 7
	I	WAM_11	-	6 mm	t2, 4, 6	10.5 mm (7)	t0-7	t0-7	t0-7
	J	WAM_10	-	15 mm	t2, 4, 6	10.5 mm (7)	t0-7	t0-7	t0-7
Series 2 models	K	WAM_14*	X	15 mm	-	15.0 mm (10)	t0-9	t0-8	t0, 2, 4, 6, 8
	K_2	WAM_13*	X	15 mm	-	16.5 mm (11)	t0-11	t0-11	-
	L	WAM_15**	X	15 mm	-	12.0 mm (8)	t0-8	t0-8	t0, 2, 4, 6, 8

*IC: intra-crustal, * 35˚ oblique extension, ** 5˚ oblique extension + steps (See Zwaan et al. 2020d for details)*

Table 3: Name convention of images and videos. *See List of Files for the total overview of videos and images as well as the data publication folder structure.*

Data	**Number**	**Name elements**	**Format**
Model overview images	12	Type_model group*	.jpeg
Top view videos	17	ExperimentName_LabCode_topview	.mov
Side view videos	17**	ExperimentName_LabCode_sideview	.mov/.jpeg **
Digital elevation models (DEMs)	101	ExperimentName_LabCode_interval	.tiff
DEM videos (top view)	16	ExperimentName_LabCode_DEM	.mov

** Type: Top view, side view, topography (Topo), subsidence curves or final cross-sections, **of Model C only a final side view exists*

3.2. Data presentation

3.2.1. Top view images

The top view overview images are produced by means of surface view photographs taken at every deformation interval (i.e. at every 1.5 mm of extension, Fig. 1). Pictures were taken with different light sources (i.e. either light from both the left and right). In general, these with lighting from the left were used (with the moving sidewall to the right) as they best reveal surface structures in these particular models. Yet in some cases these images are missing, so that an image with lighting from the right had to be inserted instead (e.g. t4 of model A2/WAM_20 in Fig. 1). Two top view overviews of the Series 1 models (experiments with sedimentation and without sedimentation) are provided, as well as an overview of the Series 2 models.

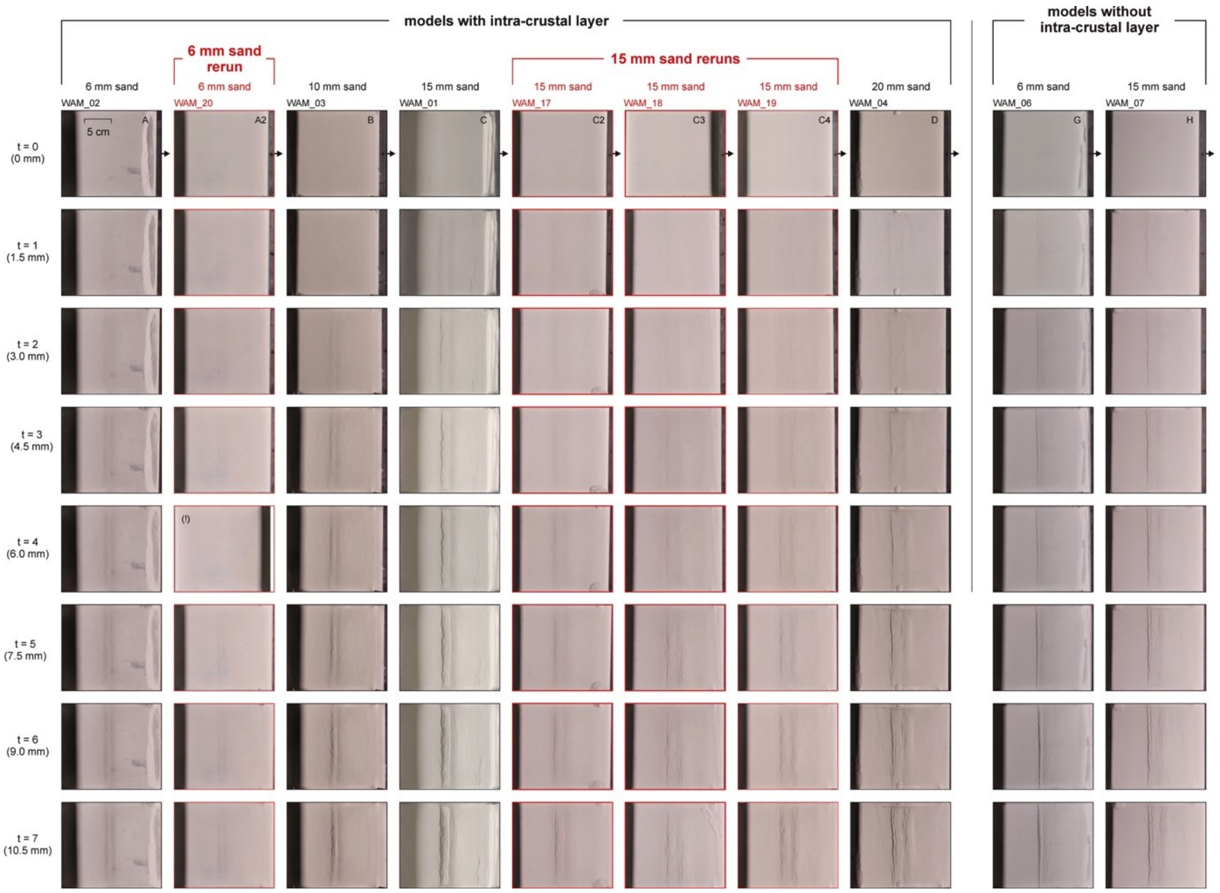

Figure 1: Example of surface view overview image depicting the evolution of Series 1 models without sedimentation. *Both the experiment name and Lab code are shown. Reruns are highlighted in red.*

3.2.2. Side view images

The side view overview images are produced by means of surface view photographs taken at every deformation interval (i.e. at every 1.5 mm of extension, Fig. 2). In some cases these images are missing (e.g t1-6 of Model A/WAM_02 in Fig. 2). Two side view overviews of the Series 1 models (experiments with sedimentation and without sedimentation) are provided, as well as an overview of the Series 2 models.

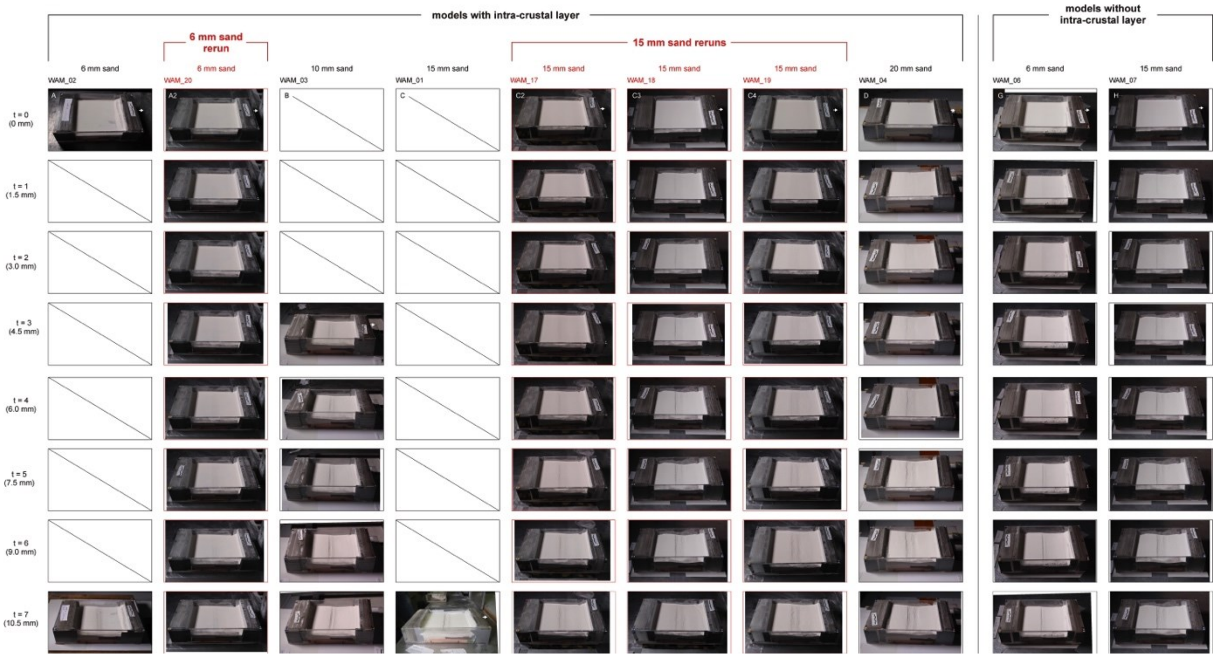

Figure 2: Example of side view overview image depicting the evolution of Series 1 models without sedimentation. *Both the experiment name and Lab code are shown. Reruns are highlighted in red.*

3.2.3. Digital elevation models (DEMs), topo maps and subsidence curves

Taking pictures from different positions allows for photogrammetry and reconstruction of model topography by means of Agisoft Photoscan software. The resulting digital elevation models (DEMs) were further processed using Global Mapper and QGIS software. Such 3D pictures were taken for most time steps, but for standard models, DEMs were only produces for time steps t0, 1, 3, 5 and 7 (Fig. 3). For standard models with sedimentation, all time steps were used, in order to extract the subsidence history. This was done by summation of subsidence per time step, as the sedimentation intervals "reset" the topography to the initial level. The DEM overview image of these models shows the true topography for every time step. Yet the subsidence curves (Fig. 4) plot the summed subsidence along the central axis of the model (always for time steps t0, 1, 3, 5 and 7, if available). Note that subsidence curves were only created for the Series 1 models, since the different parameters of the Series 2 models would not allow for a proper systematic comparison.

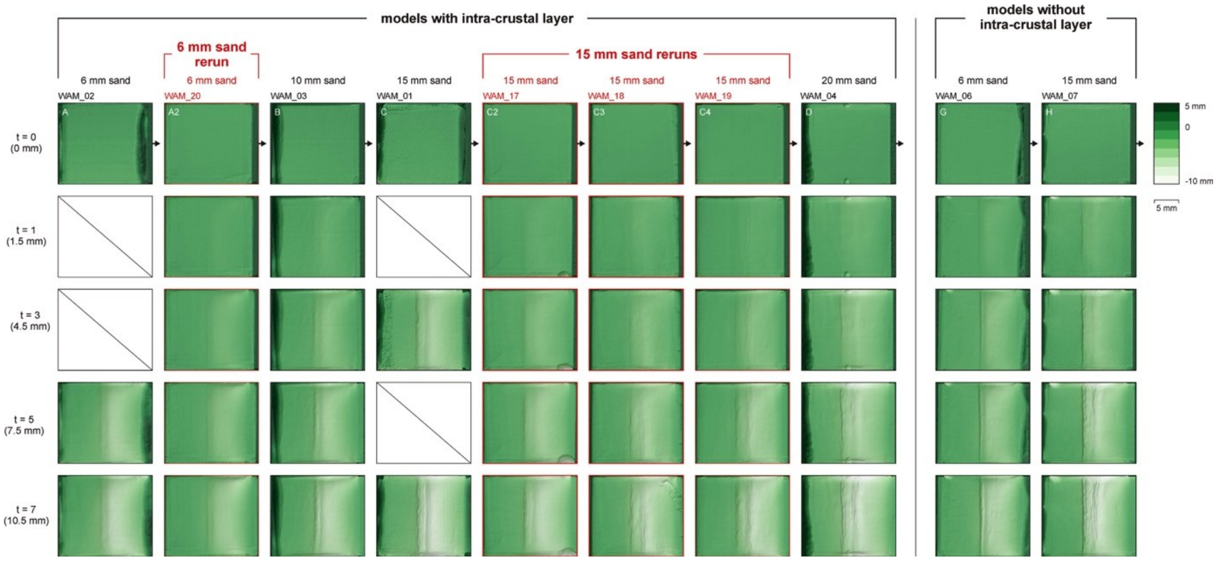

Figure 3: Example of DEM overview image depicting the evolution of Series 1 models without sedimentation. *Both the experiment name and Lab code are shown. Reruns are highlighted in red.*

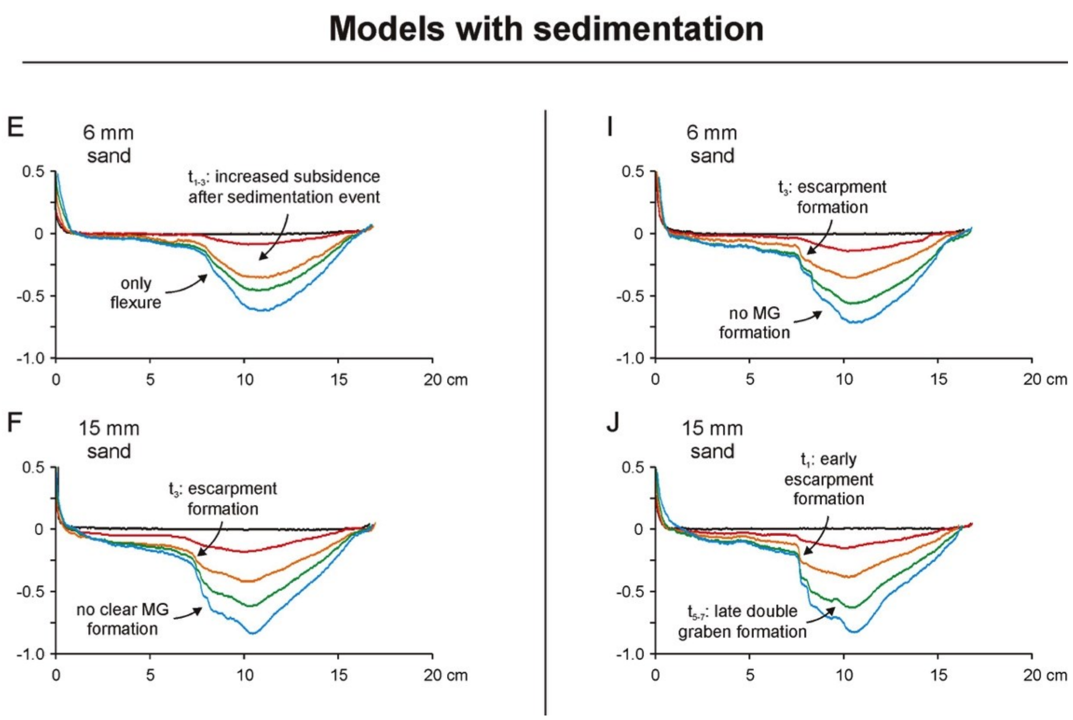

Figure 4: Example of subsidence curves for Series 1 models with sedimentation. The subsidence is given for intervals t0, 1, 3, 5 and 7, as is also done for the models without sedimentation. Note that these subsidence plots are cumulative and do not reflect the actual topography of the model, which is “reset” to the intial level at every sedimentation interval.

3.2.4. Final cross-sections

At the end of the model runs, the model was wetted, frozen and cut along its axis to create cross-sections, allowing examination of the models' internal structures. In general, 3 to 4 sections were taken, at every 3-4 cm over the 16 cm width of the model. Some sections were affected by the growth of ice crystals and are not representative of the model's internal structures. Therefore a selection had to be made (Fig. 5).

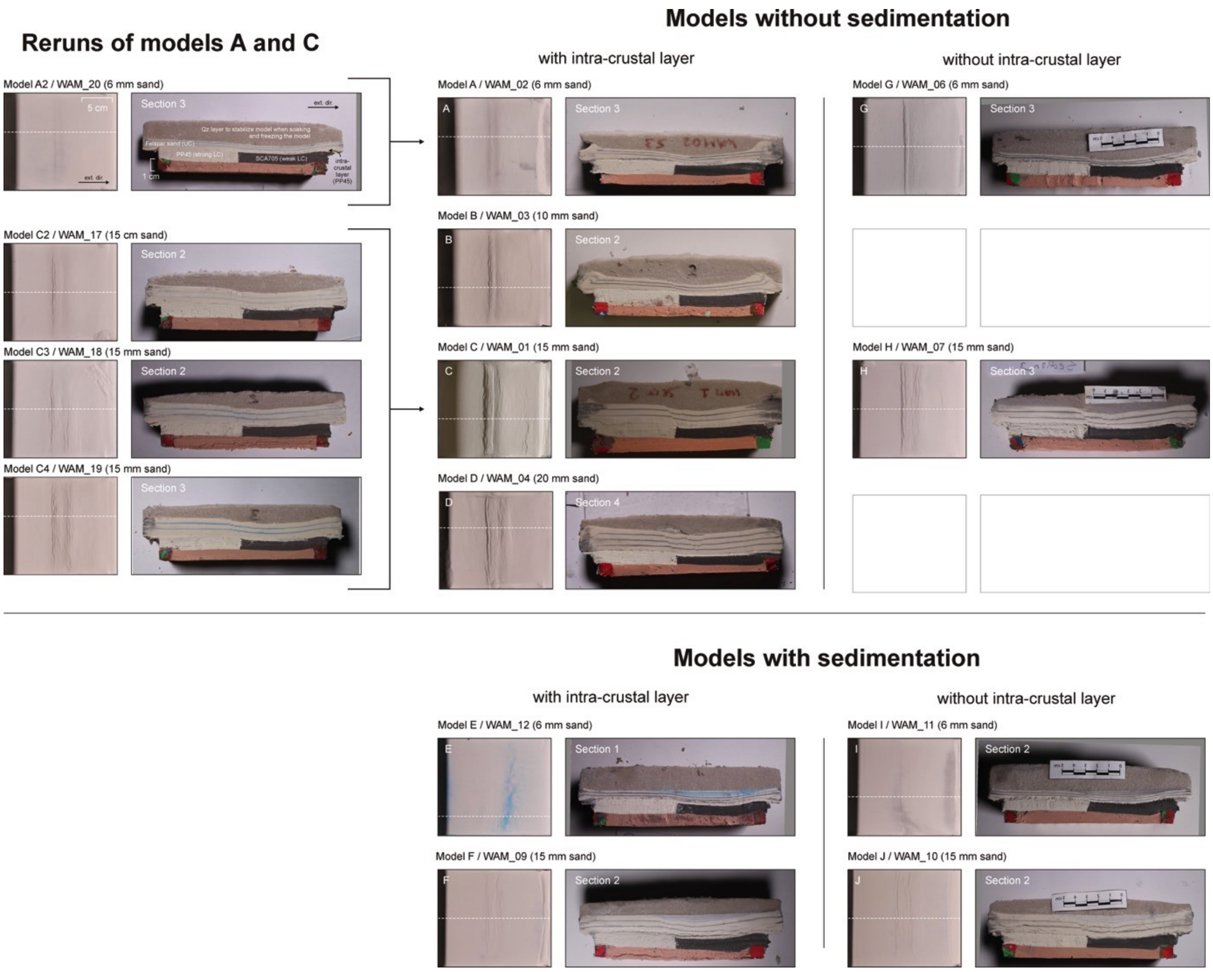

Figure 5: Example of final cross-sections for Series 1 models. *Left: Section location on top view image, right: cross-section.*

3.2.5. Top view videos

The top view images taken for the overview image (section 3.2.1) are also used to create videos (Fig. 6). Frame rates were set at 1.5 fps.

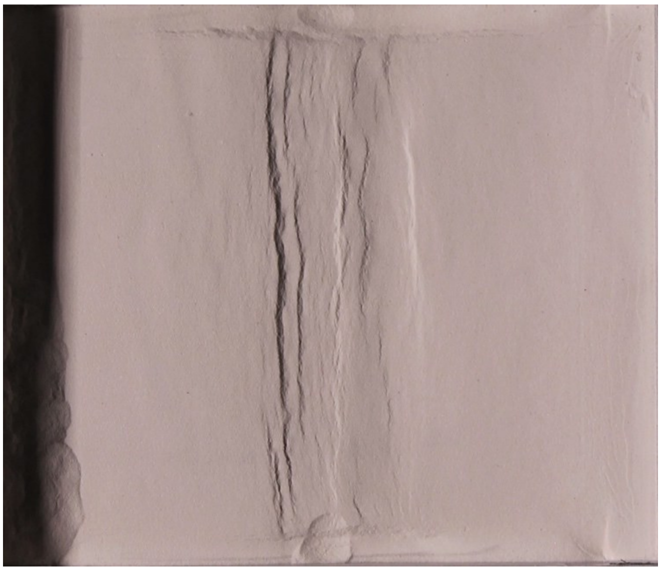

Figure 6: Example of surface view video still (Model D/WAM_04 at the end of the experiment).

3.2.6. Side view videos

The side view images used for the overview images (section 3.2.2) are also used to create videos (Fig. 7). Frame rates were set at 1.5 fps. Note that for Model C/WAM_02 only a final side view is available (Table 1).

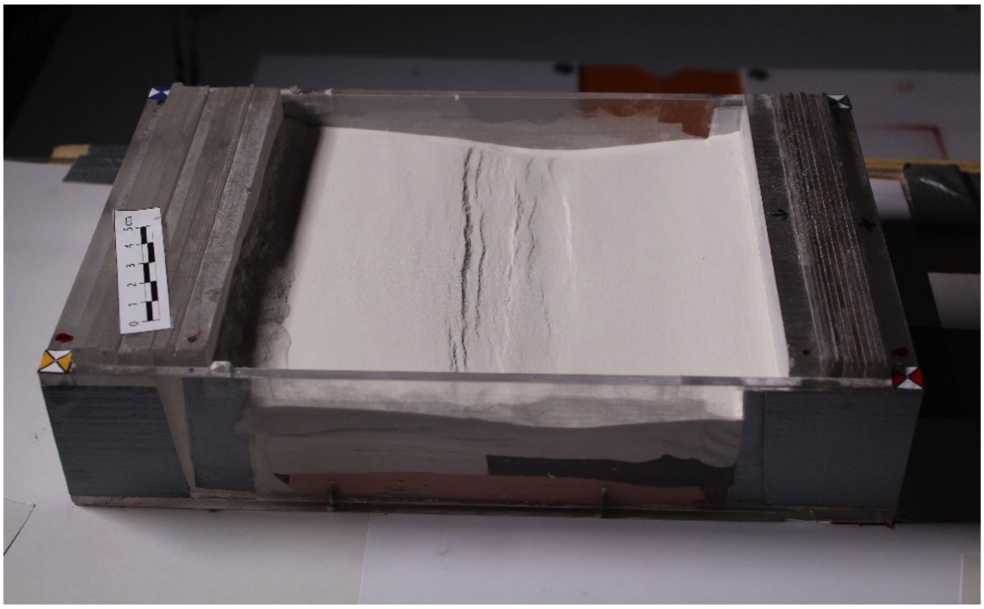

Figure 7: Example of side view video still (Model D/WAM_04 at the end of the experiment).

3.2.7. Topography (DEM) videos

The topography maps taken for the overview images (section 3.2.3) are also used to create videos (Fig. 8). Frame rates were set at 1.5 fps. Note that for Models A/WAM_01 and C/WAM_02 only a partial sequence is available (Table 1).

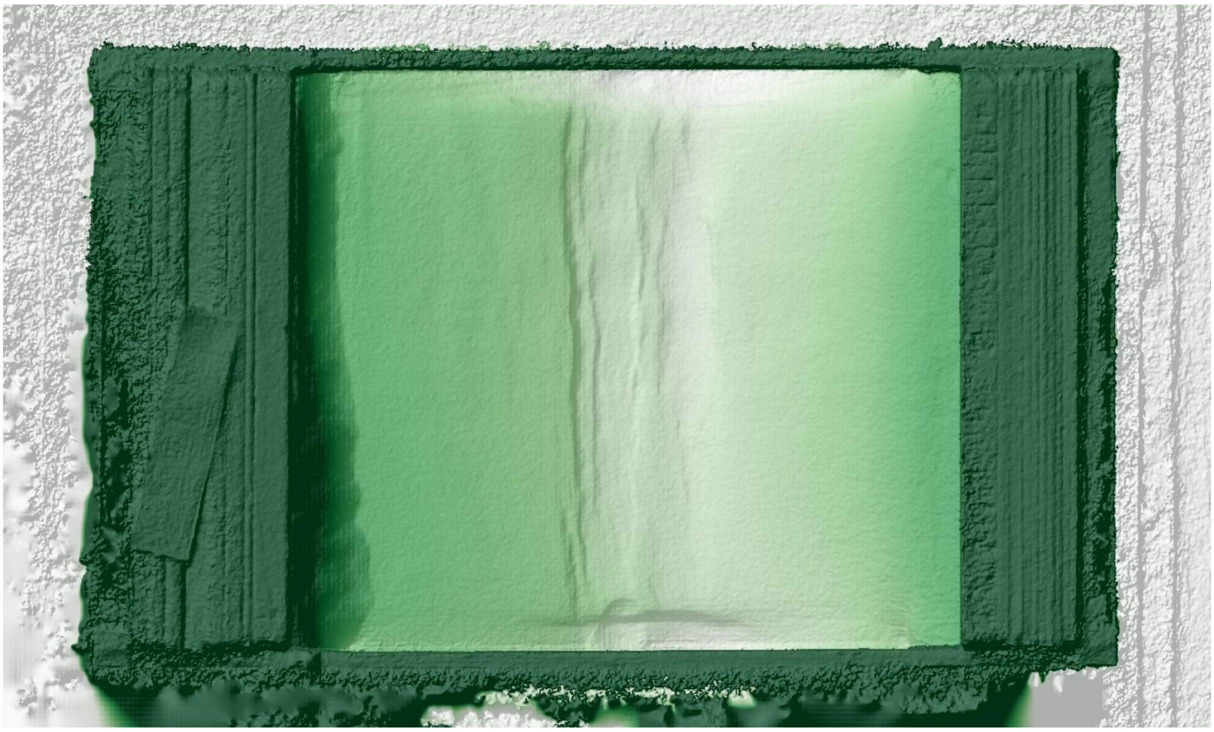

Figure 8: Example of topography video still (Model D/WAM_04 at the end of the experiment).

4. File description

For the 17 experiments the following data are provided:

(i) DEMs of the available deformation intervals (geotiff format).
(ii) Surface view overview images of the experiments (jpeg format)
(iii) Side view overview images of the experiments (jpeg format)
(iv) Profiles of the experiments' subsidence (jpeg format)
(v) Surface view videos of the experiments (mov format)
(vi) Side videos of the experiments (mov format)
(vii) Surface view videos of the experiment topography (mov format)

An overview of all files of the data set is given in the **List of Files.**

4. Acknowledgements

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5. References

Zwaan, F., Corti, G., Keir, D., & Sani, F. (2020a). A review of tectonic models for the rifted margin of Afar: Implications for continental break-up and passive margin formation. Journal of African Earth Sciences 164, 103649. https://doi.org/10.1016/j.jafrearsci.2019.103649

Zwaan, F., Corti, G., Sani, F., Keir, D., Illsley-Kemp, F., Papini, M. (2020b). Structural Analysis of the Western Afar Margin, East Africa: Evidence for Multiphase Rotational Rifting. Tectonics 39, e2019TC006043. https://doi.org/10.1029/2019TC006043

Zwaan, F., Corti, G., Sani, F., Keir, D., Illsley-Kemp, F., Papini, M. (2020c). Geological data from the Western Afar Margin, East Africa. GFZ Data Services. https://doi.org/10.5880/fidgeo.2020.017

Zwaan, F., Corti, G., Keir, D., & Sani, F. (2020d). Analogue modelling of marginal flexure in Afar, East Africa: Implications for passive margin formation. Tectonophysics, 228595. https://doi.org/10.1016/j.tecto.2020.228595