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SHORT-TERM SCIENTIFIC MISSION (STSM) – SCIENTIFIC REPORT

Topic: Shear Strain Localization during Evaluation of NAF
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PURPOSE OF THE STSM

The main objective of the STSM conducted at CEREGE (Marseille, France) under the supervision of Pierre Henry was two folds:

- discuss the strain accumulation between the major segments of the northern branch of the North Anatolian Fault (NAF);
- consider the tectonic setting of the NAF and the Marmara Sea in the frame of lithosphere dynamics.

In particular we were interested in the comparison of offshore data on fault activity acquired from the Sea of Marmara, investigated by Pierre Henry on board "Pour quoi Pas?" during the MARSITE cruise, and geodetic data. This comparison was important because it offered a complete overview of the modern NAF system, a key dataset to unravel the geometric evolution and kinematic of the west part of the NAF system, over the last few Ma years of the fault system's evolution.

A further step was the association of this dataset with the results of analogue modeling performed last year during my STSM in Parma. In this, we were aiming to test the localization of strain allowing us to investigate how the deformation is distributed in each section of western part of the NAF and why it is more active in the Sea of Marmara.

This short term scientific mission was an important contribution toward my ongoing thesis, but also a key step to finalize a manuscript draft and to collect information on available data for future work.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSM

During the month spent at CEREGE, we analyzed and interpreted independent measurements from different data sets. The data sets were obtained from 3D deformation in sandbox experiments. In these experiments, performed during the first STSM in Parma University, Italy, we reproduced releasing bend and restraining bend geometry analogous to the western part of the NAF. The analogue models were scanned by light laser every 5mm deformation and sequential photographs were taken from the top of the model every 5 minutes. These scans served to monitor progressive displacement and rotations during the physical experiments. Further Particle Image Velocimetry (PIV) analysis provided us with incremental particle displacements and velocity fields throughout the experiments. From these data, we calculated the simple

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shear rates and areal rate of changes along the strike-slip fault system in the pull-apart basin.
The scan data were processed with MATLAB to create gridded elevation models for every 5-mm deformation. The rate of topography change was calculated by subtracting each elevation model iteration. Comparisons with subsidence rates, uplift rates and sedimentation rates in the Sea of Marmara were also performed. We calculated the strain tensors from the gradients of the velocity components. Incremental simple shear rate is approximated as the strain component parallel to the velocity discontinuity applied at the base of the model (E_{xy}). Incremental areal strain is the sum of the diagonal components (E_{xx}+E_{yy}). These were used to obtain inferences on the strain accumulation and shear transition between the major segments of the northern branch of the NAF.

We related the incremental topography rate of changes with the incremental strain patterns to show how much stretching of compression is taking place in each segment of fault. Shear strain map showed how much shearing deformation is taking place. The areal strain maps showed the rate of which area have the extension and compression. The areal strain can be less than the simple shear rates and it is showing less clear patterns with some noise on the data. However, we demonstrated that the results of strain patterns correlated well with the results of the rate of topography changes.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

The results obtained during this STSM are within the scope of FLOWS. In particular we concentrated on the west portion of the North Anatolian Fault in the Sea of Marmara, a transform type plate boundary, a key site of working group 4.

We extracted the position on the master fault of fault tips and folds integrated over time, analyzing these positions in the experiment to find how the fault evolved. We showed how the master fault and newly formed faults changed geometry during its evolution. These results will advance our current knowledge of the structure and activity of the west part of the NAF.

In the analogue models, the patterns indicated that a transition from single fault to two branches occurred for a total displacement of 30 mm (Fig.2) and it is associated with a reduction of uplift rates and compressive strain above the restraining bend. We considered and presented the fault evolution in three stages; 1. before the single fault to two branches transition (Fig.1), 2. during the transition (Fig.2), and 3. after the transition (Fig.3). Also, our results revealed that a depocenter migration has occurred during the evolution of the fault (Fig.3c).

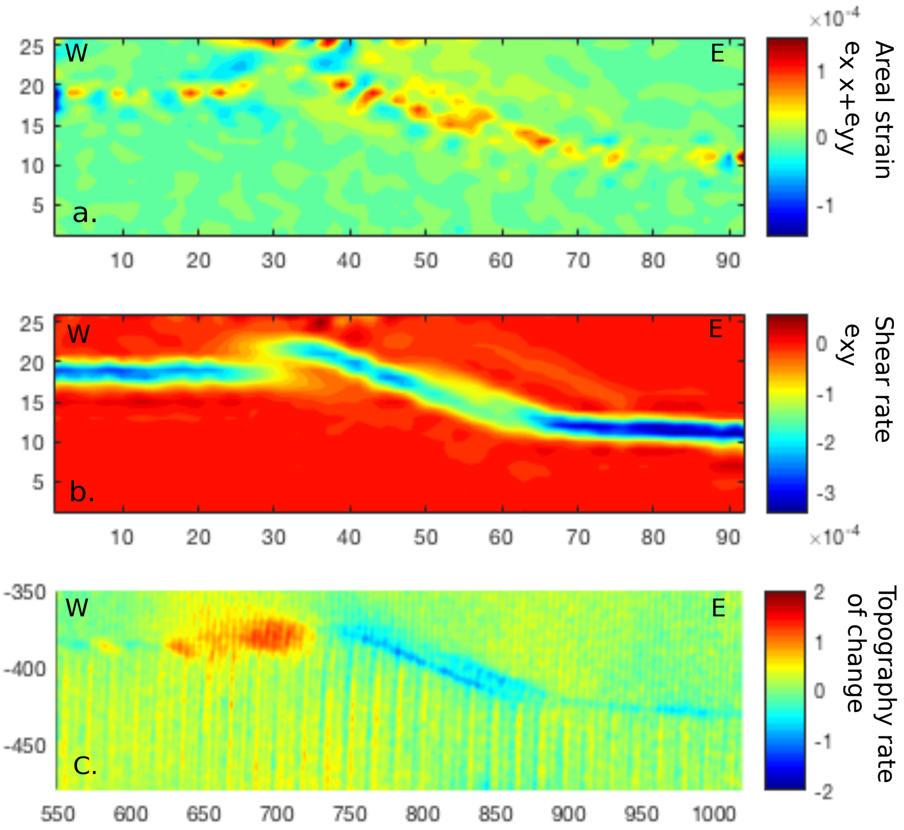

Figure 1: Comparison the strain patterns with the rate of topographic change before the transition of from a single to a two-branches fault, @ 20 mm displacements of fault. a) Areal strain distribution along the fault zone: red fields represent extension, the areas in blue are compressional. The extension is localized on topographic highs, while compression is concentrated on the side of the hill. There is extension also where the graben is developing and a secondary extension zone initiates NE of the releasing bend. b) Shear rate distribution along the fault zone correspondent to 1a. c) Differential topography. Uplifted areas in red, blue areas represent subsidence. The uplift is concentrated in the western part of the fault.

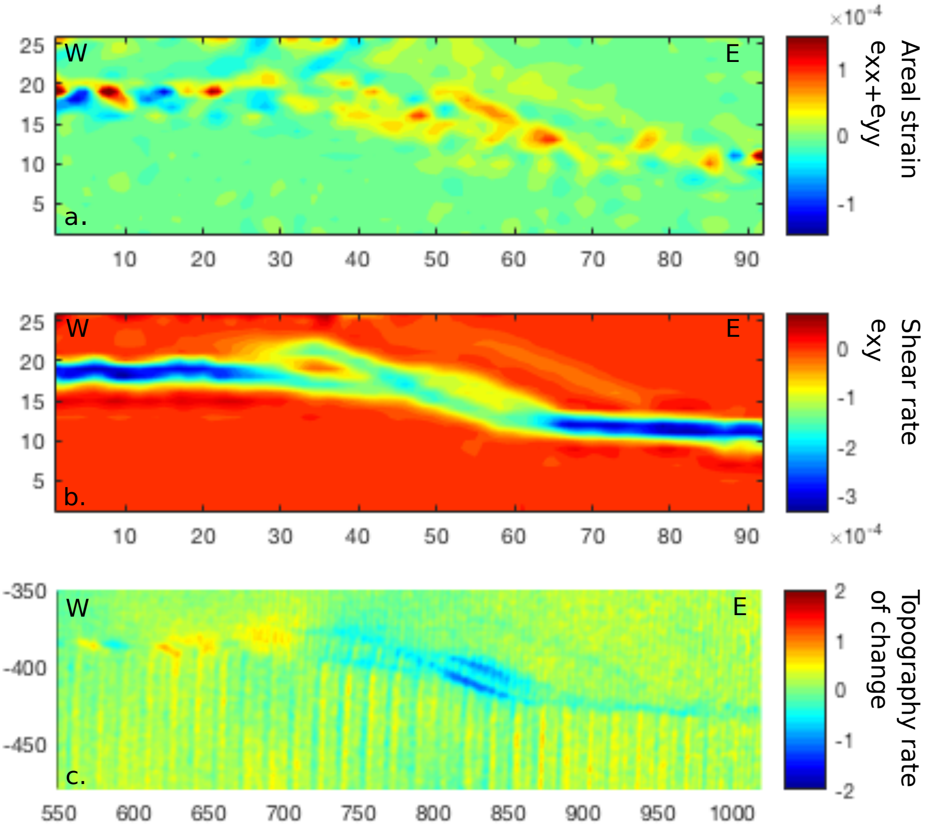

Figure 2: Comparison the strain patterns with the rate of topographic change during the transition of from a single to a two-branches fault, @ 30 mm displacements of faults. a) Areal strain distribution along the fault zone: red fields represent extension, the areas in blue are compressional. Here the areal strain is more distributed than in figure 1a. Although there is some noise, the extension is concentrated where the graben is developing. Two shear zones became active. b) Shear rate distribution along the fault zone correspondent to 2a. The transition zone is here clearly formed already. c) Differential topography. Uplifted areas in red, blue areas represent subsidence. Two faults have become active, they border the graben zone and are causing subsidence. The strain and the topographical configuration changed when compared to figure 1c, in particular the ongoing uplift was deactivated by the extensional field.

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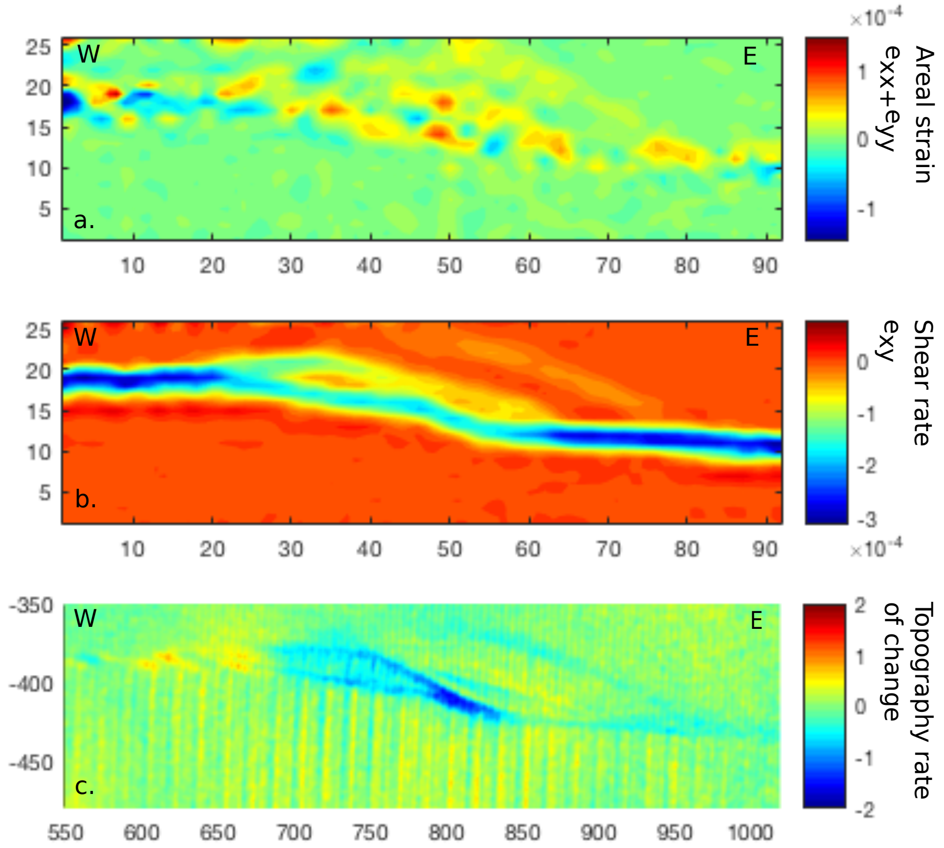

Figure 3: Comparison the strain patterns with the rate of topographic change after the transition of from a single to a two-branches fault, @ 50 mm displacements of faults. a) Areal strain distribution along the fault zone: red fields represent extension, the areas in blue are compressional. The compressional field was deactivated and the extensional fields became more distributed than shearing. b) Shear rate distribution along the fault zone correspondent to 3a. c) Differential topography. Uplifted areas in red, blue areas represent subsidence. The development of the two-branches fault results in: the basin becoming asymmetric, the depocenter becoming localized at the fault intersections, ongoing subsidence in the minor extension zone NE of the releasing bend.

This STSM helped to analyze, interpret and discuss the data obtained from analogue experiments, conducted during the first STSM in Parma University, Italy. It was also important for my training in terms of data processing in MATLAB and planning of future works.

FUTURE COLLABORATIONS (if applicable)

Our study in CEREGE will be a primary topic of a manuscript under preparation. The manuscript describes the strain localization along the west part of the NAF by the analogue modelling. Collaboration between Pierre Henry and us will continue in the following year. We have planned to support the result with the real subsidence data from Marmara, calculated by C. Grall, one of Pierre's students - she submitted a paper for publication. Also, we established that depocenter migration within the basin can be comparable with the data sets in Sea of Marmara - already published by Rangin et al.

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(2004) Sorlien et al. (2012), and Kurt et al. (2013). Our schedule is to finalize the paper just after the STSM.

On a different point, we went back to the design of the analogue models where the crustal scale geometry mimics that of the western part of the NAF. Because of some limitations on the analogue modelling, we simplified the geometry of the fault to take best performance from the lateral movement of the fault. When we fit the map of study area with our model, it doesn't match at some points. We established if we convert the projection system from WGS-84 to the oblique-Mercator projection, it will allow us to rotate the geometry of fault (McKenzie et al., 1970) and will give best fit with Sea of Marmara.

Your sincerely,

Sibel Bulkan

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