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Earthquake Recurrence Patterns and Spatiotemporal Variations of Strain Release Along Faults

Short-and-long-term Slip Rates along the Carboneras Fault in the Betic Cordillera, Spain

Giorgi Khazaradze, Robert López, Raimon Pallàs, Maria Ortuño, Jaume Bordonau, Eulàlia Masana

University of Barcelona, Faculty of Earth Sciences, Department of Earth and Ocean Dynamics, Barcelona, Spain (gkhazar@ub.edu)

Universitat de Barcelona · B:KC Barcelona Knowledge Campus · RISKNAT Riscos Naturals · geomodels institut de recerca

Introduction

As part of the recently initiated research project we are in the process of studying in detail the geodynamic behavior of the Carboneras fault in the SE Betics in Spain. Specifically, we plan to quantify the geodetic and geologic slip rates for the onland section of the fault, as well as getting some insight on the state of locking of the fault. As a result of our previous GPS observations, we have been able to illustrate the continuing tectonic activity of the Carboneras fault, expressed mainly as a left-lateral strike slip motion of 1.3±0.2 mm/yr (Echeverria et al., 2015). To reveal how the deformation is partitioned between different structures, 3 new continuous GPS points are being established along the fault-perpendicular profile. In addition, since the summer 2016, we have conducted surveys of the nearby CuaTeNeo Echeverria et al., 2013) and IGN Regente points. We have also established and measured several new geodetic points in the vicinity of the fault, with the aim of increasing the spatial coverage around it.

Seismo-Tectonic setting

The Betic Cordillera in southern Spain (Figure 1), together with the Rif Mountains in northern Africa, represent an arcuate shaped fold-and-thrust belt, which was formed as a result of complex tectonic processes that involved a convergence between Africa and Eurasia tectonic plates.

The Betic-Rif region is seismically most active region of the Iberian Peninsula and Africa (Figure 2). Only in Spain and Portugal, since the 15th century at least 15 earthquakes with intensities greater then IX have been registered. In northern Africa there have been at least 5 earthquakes of similar intensities, since the 17th century.

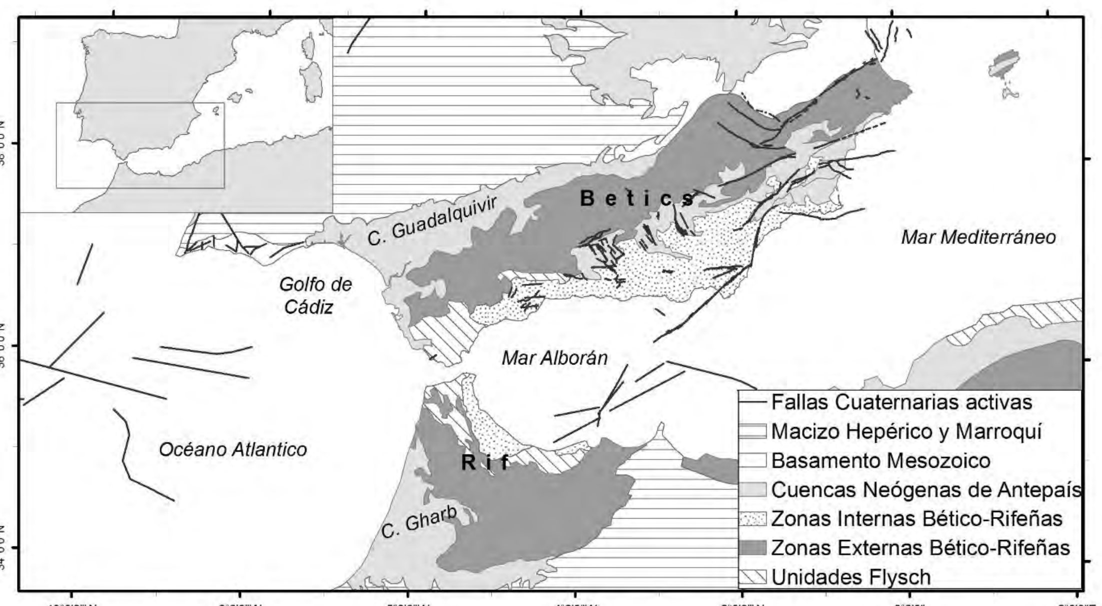


Figure 1: Geo-tectonic map of the Betic-Rif arc. Black thick lines indicate Quaternary active faults according to QAFI database (García-Mayordomo et al., 2012). Inset shows a location of the study area with respect to the Iberian Peninsula.

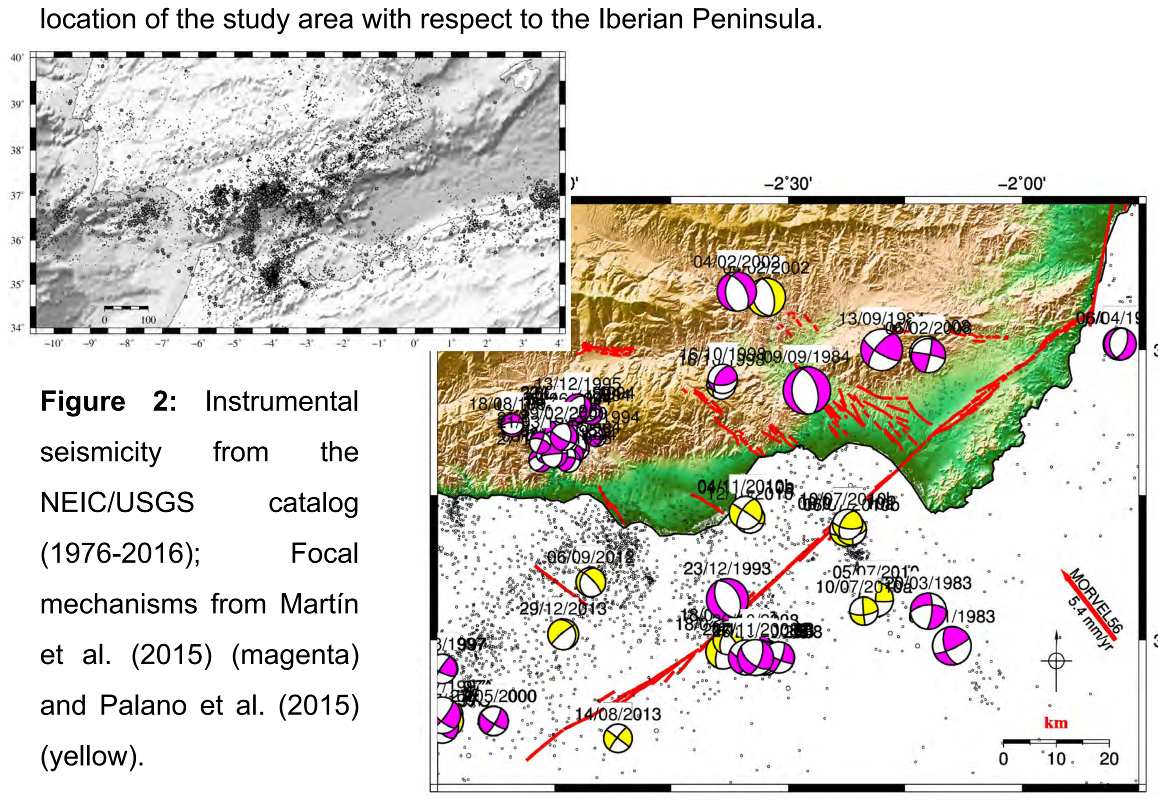


Figure 2: Instrumental seismicity from the NEIC/USGS catalog (1976-2016); Focal mechanisms from Martín et al. (2015) (magenta) and Palano et al. (2015) (yellow).

GPS Velocity Field

The crustal deformation field of the Iberian peninsula is complex, although, some expected features could be easily identified. Considering the Eurasia fixed frame, the highest velocities, as expected, are observed in Morocco, where the velocities reach 4.7±0.2 mm/yr. In southern Spain, stations located west of Almeria exhibit a westerly trend of motion, which reach 3.2±0.1 mm/yr at station SFER.

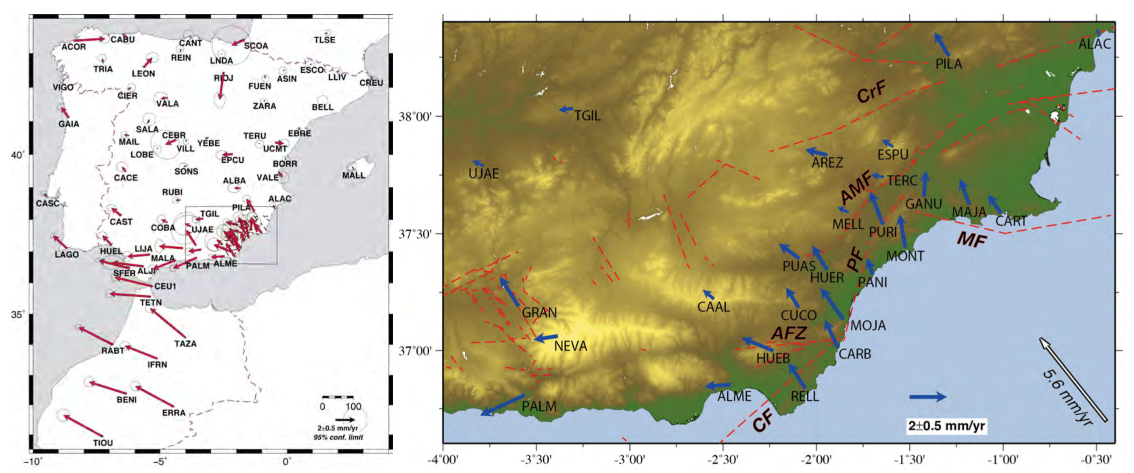
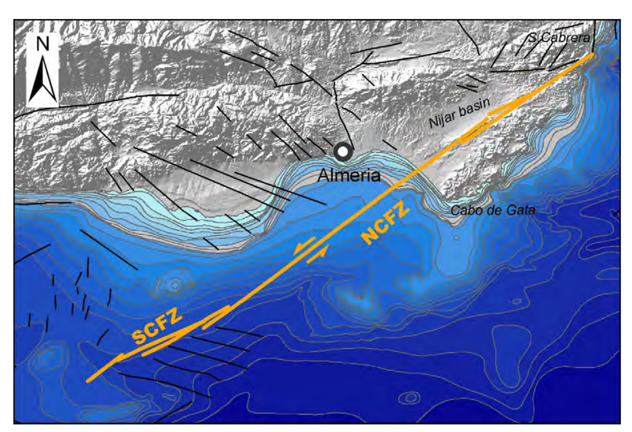


Figure 3: a) GPS velocity field of present-day crustal deformation of the Iberian Peninsula and northern Morocco. Eurasia fixed reference frame with 95% confidence error ellipses. b) Detailed map of the GPS velocity field in SE Betics. Eurasia fixed reference frame with 68 % confidence error ellipses. Big arrow shows a convergence velocity between Nubia and Eurasia according to (Argus et al., 2011). Abbreviations of faults in bold letters:: CrF-Crevillente fault; AMF-Alhama de Murcia fault; PF-Palomares fault; CF-Carboneras fault; AFZ-Alpujarras fault zone; Figures from Khazaradze et al., 2014.

Carboneras Fault



	NCF	SCF
Average strike (º)	N048	N057
Dip (º)	90	90
Rake (º)	10	0
Depth (km)	0-11	0-11
Width (km)	11	11
Vertical slip rate (mm/yr)	>0.04	0.04
Horizontal sip rate (mm/yr)	>1.1-1.3	(?) 0
Net slip rate (mm/yr)	>1.1-1.3	0.04
Max. earthquake mag.	7.4±0.3	6.9±0.3

Figure 4: Map of the northern (NCFZ) and southern (SCFZ) segments of the Carboneras fault and summary of the main parameters of fault activity for each segment. Map and table from Echeverria (2016),with data based on Moreno (2011), Moreno et al. (2015);

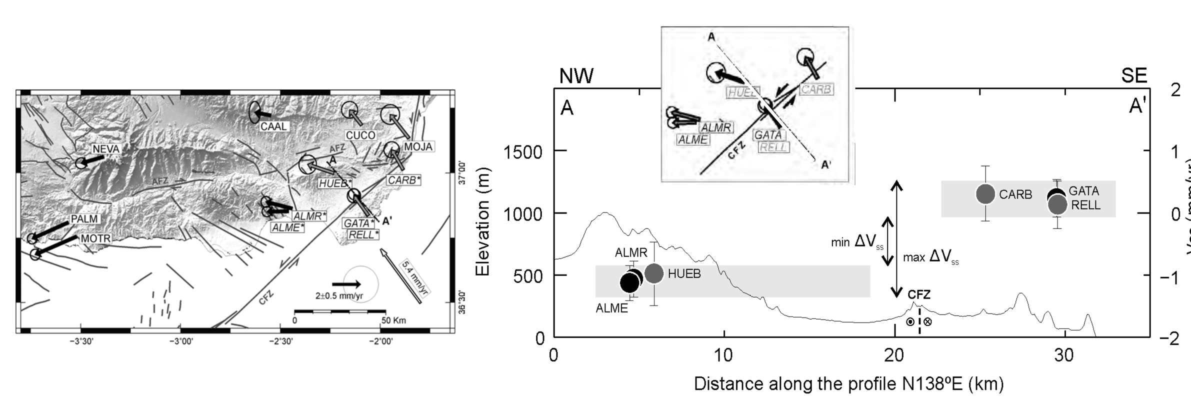


Figure 5: We estimated that the geodetic slip rates for the Carboneras fault equals1.3±0.2 mm/yr, where most of the motion is accommodates as a strike-slip type motion. Specifically, the left-lateral slip rates are between: min ΔVss= 1.1 mm/yr; max ΔVss =1.5 mm/yr. These estimate is in agreement with the previous paleoseismological and geomorphologic studies, which suggest similar Quaternary geologic strike-slip rate for the Northern segment of the CF (Moreno 2011; 2015) > 1.1-1.3 mm/yr.

With the new GPS and paleoseismological data we hope to further refine these results and shed some light on the possible along-strike variation of the slip, as as well as, it's state of locking.

Paleoseismic Studies

One of the main objective of this work in progress is the paleoseismic study of the Carboneras, with special emphasis on obtaining detailed parameters on its past seismic activity. The main objectives of this part of the work are:

a) Taking advantage of the previous studies (e.g. Moreno et al., 2015), identify a new segment of the fault, in order to extend the study area, and obtain more detailed paleo-seismic parameters. Thus, obtained seismic parameters such as the pale-earthquake repeat times, the maximum magnitude and the time elapsed since the last earthquake.

b) b) Obtain values of lateral dislocation of geological and geomorphological elements separated by the repeated action of the fault. The study will involve a geomorphological analysis based on a Digital Terrain Model of high resolution airborne LiDAR-based technology and 3D trenches.

c) c) Obtain precise dates of the geological units affected by the earthquake related failure. To do this, will plan to use the ^{14}C, OSL (quartz and feldspar) and U-Th dating techniques. As a result of the dating, we hope to obtain geologic slip rates of the fault.

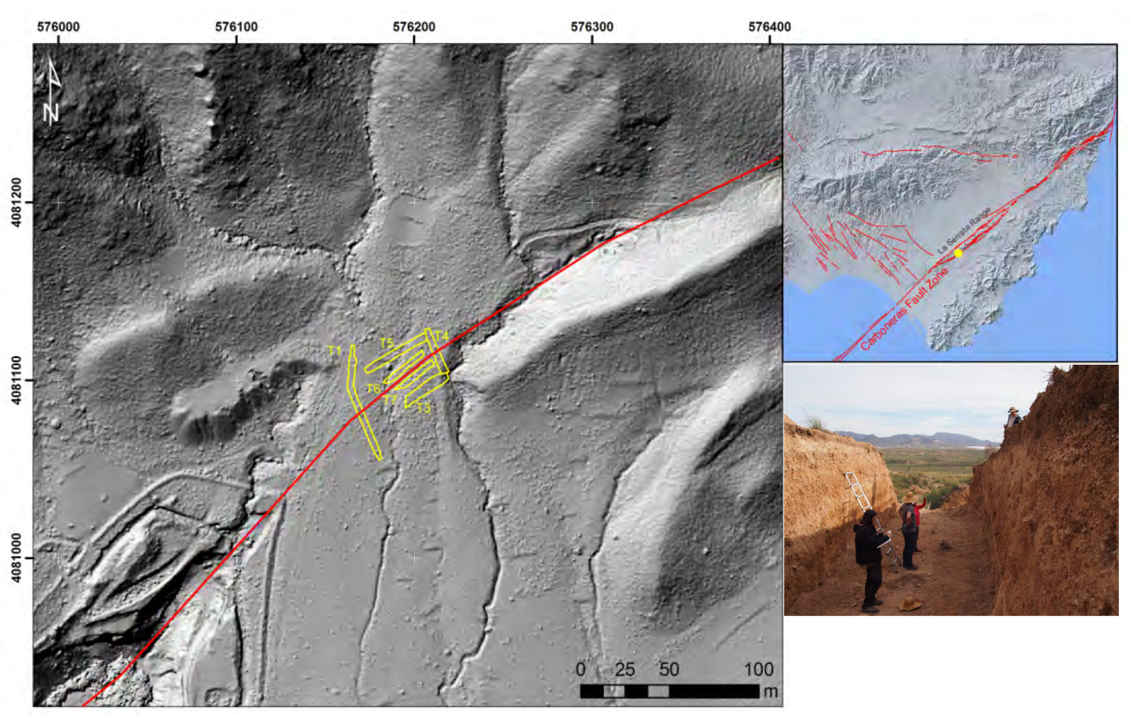


Figure 5: Active faults in the Almería region and location of the trenching site Tostana on the southern trace of Carboneras Fault near La Serrata Range. B) Members of the PREVENT project working on Tostana trench 4.

Figure 6: Panoramic photo of the trenching site Tostana.

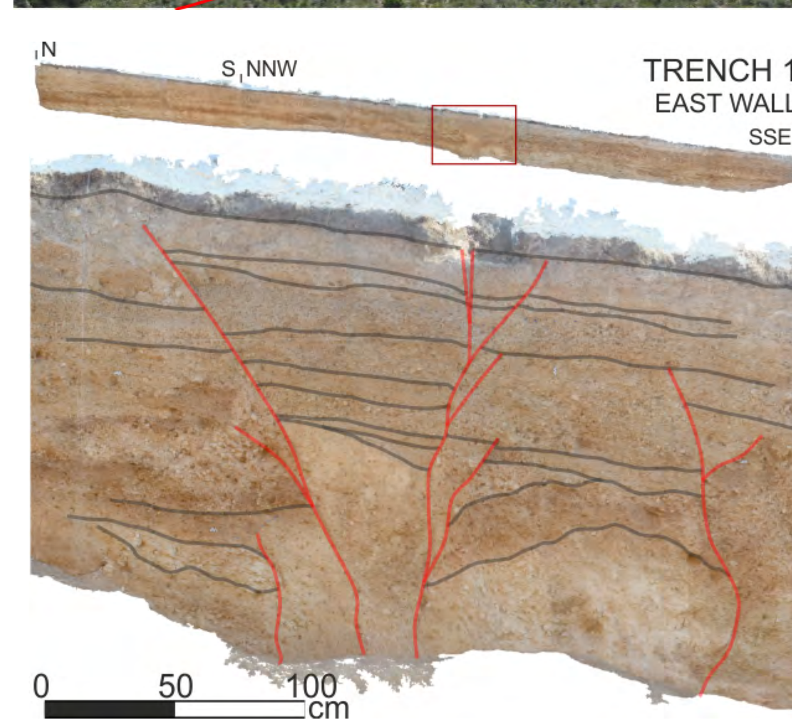


Figure 7: Orthophoto of the eastern wall of the Tostana trench T1, with a preliminary interpretation of the observable fault traces, depicting at least 4 paleo events

New CGPS sites

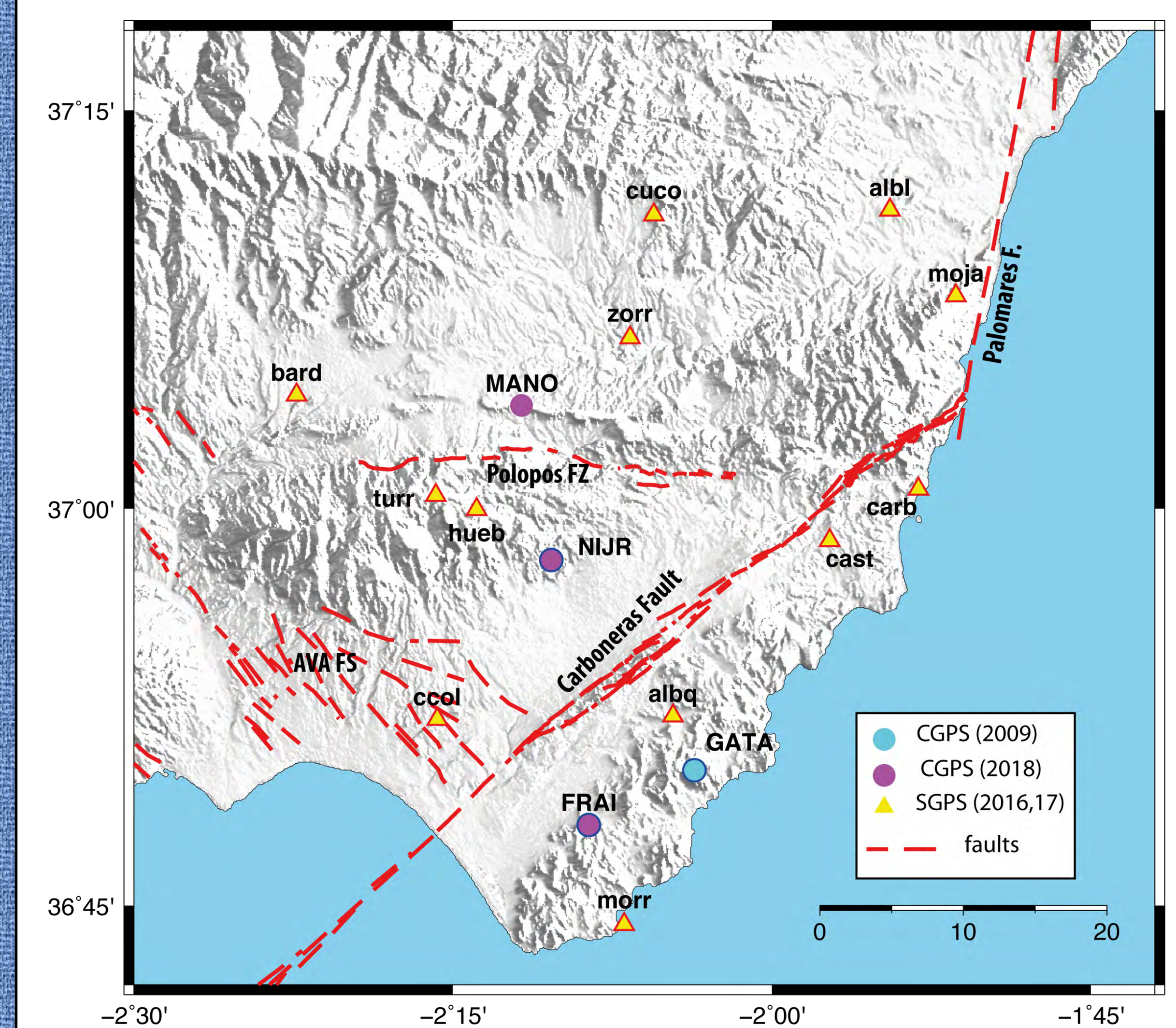


Figure 8: GPS sites around the Carboneras fault observed and installed by the UB group during the last years. The faults are from QAFI database (García-Mayordomo et al., 2012). Abbreviations used: AVA FS: Andarax Valley and El Alquián Fault System; SGPS: Survey GPS: CGPS: Continuous GPS.

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