Active Transpressive Faulting Along the High Atlas Mountains: the 8 September 2023, M_W 6.8, Morocco Earthquake

D. Cheloni[1], N. A. Famiglietti[2], R. Caputo[3], C. Tolomei[1], A. Vicari[2]

[1] *Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy*
[2] *Istituto Nazionale di Geofisica e Vulcanologia, Sezione Irpina, Italy*
[3] *Department of Physics & Earth Sciences, Ferrara, Italy*

The 2023 Morocco earthquake sequence started on September 8th 2023 with a M_W 6.8 event in the western sector of the High Atlas Mountains, triggering significant aftershocks (including a M4.9 event). The earthquake caused extensive damage, claiming at least 2900 lives and affecting around 320,000 people. The seismicity in Morocco is attributed to the convergent motion between the African and Eurasian plates, with the Atlas region experiencing moderate seismic activity. Morocco's seismic history includes notable events like the 1994, 2014 and 2016 earthquakes in the Rif and Alboran Sea and the 1960 Agadir earthquake. The 2023 event, the strongest recorded in modern times, occurred in the High Atlas region. The seismic regime is characterized by a present-day compressional regime with active deformation along the High Atal, accommodating about 1.7 mm/yr of WNW-ESE shortening (Serpelloni et al. 2007).

We employed Interferometric Synthetic Aperture Radar (InSAR) data from Sentinel-1 and ALOS-2 satellites to study ground displacement associated with the mainshock of the 2023 seismic sequence. The coseismic deformation field displayed a WSW-ENE striking lobe, suggesting a blind rupture. Two fault scenarios were investigated using geodetic modelling: an NNW-dipping fault in agreement with the focal mechanism and an SSW-dipping fault consistent with seismic data. We performed the geodetic modelling using the formulation of Okada (1985), following a standard two-steps procedure (e.g. Atzori et al., 2009; Cheloni et al., 2020). Both models effectively explained the observed data, indicating ambiguity in fault identification. Coulomb stress analysis implicated stress redistribution in aftershock occurrence.

Uncertainties in fault dip direction persisted, with seismic databases showing discrepancies in aftershock distribution. On the other hand, gravity and heat-flow data (Teixell et al., 2005), coupled with geodynamic considerations, favoured the SSW-dipping fault model. The analysis suggested that the high-angle fault model was unrealistic based on rheological arguments and regional geodynamic constraints. Integrating interferometric analyses with geological, tectonic, and seismological data is crucial for resolving ambiguities in satellite-based models. The study therefore underscores the complexity of fault identification and the need for a multidisciplinary approach in understanding seismic events.

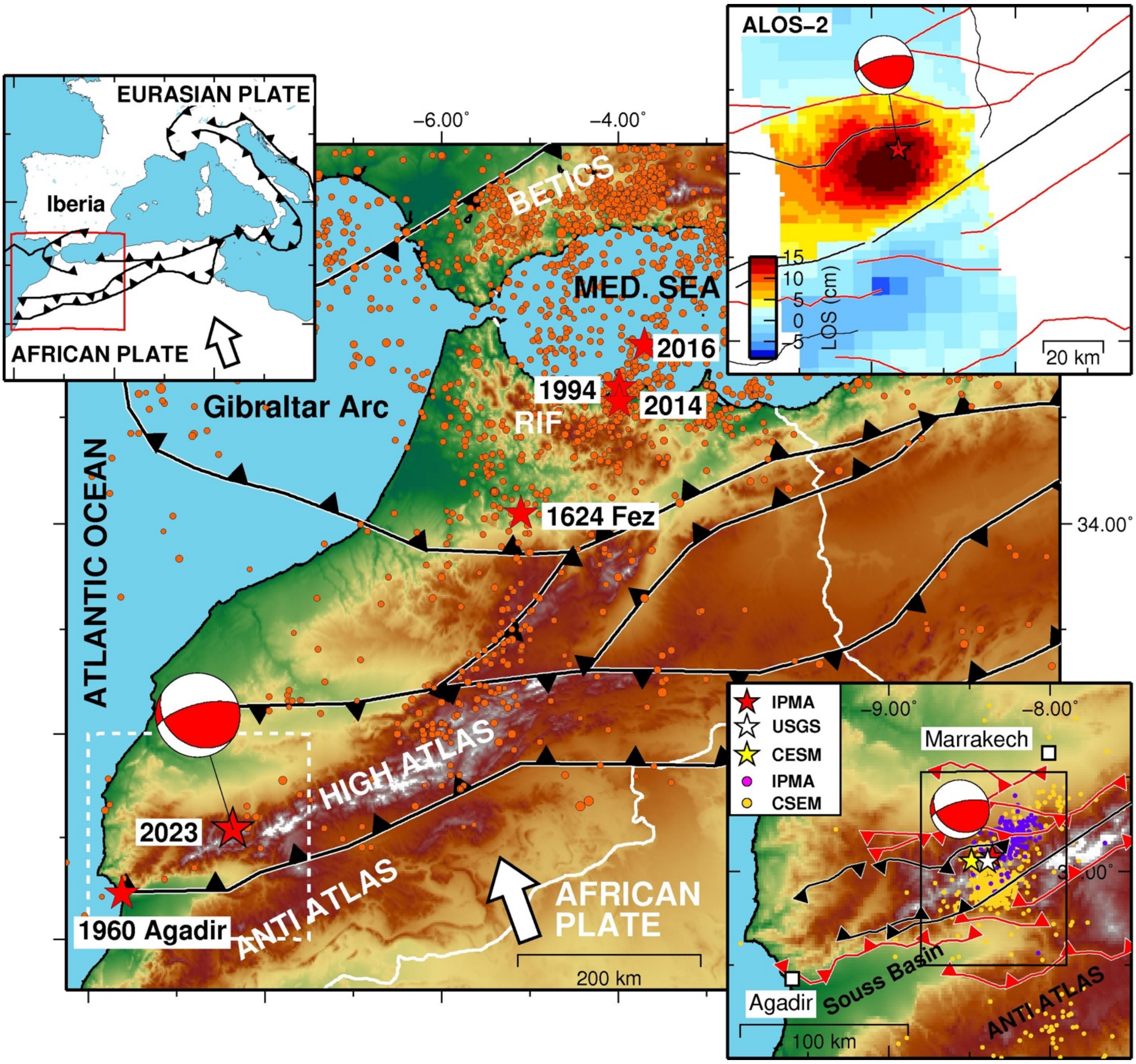

Fig. 1 – Seismotectonic settings of the study area. Solid barbed lines represent the major tectonic lineaments of the area. Orange circles are instrumental seismicity from the ESHM20 catalog (Grunthal and Whalstrom, 2012; Rovida and Antonucci, 2021); red stars are the greatest seismic events (M>6). The bottom inset is a sketch map of the active faults (Sebrier et al., 2016) and of the 2023 seismic sequence in Morocco; the box is the area of the right upper inset showing the ALOS-2 displacement map. The left upper inset is a tectonic sketch of the western Mediterranean region.

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Corresponding author: daniele.cheloni@ingv.it