

The Al Hoceima earthquake sequence of 1994, 2004 and 2016: Stress transfer and poro-elasticity in the Rif and Alboran Sea region

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The 25 January 2016 earthquake (Mw 6.3) follows in sequence the 26 May 1994 earthquake (Mw 6.0) and the 24 February 2004 earthquake (Mw 6.4) in the Rif Mountains and Alboran Sea. The earlier two seismic events which were destructive took place on inland conjugate faults, and the third event occurred on an offshore fault. These earthquake sequences occurred within a period of 22 years at ~ 25 km distance and 11 – 16-km-depth. The three events have similar strike-slip focal mechanism solutions with NNE-SSW trending left lateral faulting for the 1994 and 2016 events and NW-SE trending right-lateral faulting for the 2004 event. This shallow seismic sequence offers the possibility a) to model the change in Coulomb Failure Function (CFF) with $\mu' = 0.4$ including the pore pressure change) and understand fault-rupture interaction, and b) to analyze the effect of pore-fluid on the rupture mechanism, and infer the clock-time advance. The variation of static stress change has a direct impact on the 1994 mainshock, aftershocks and related positive lobes of the 2004 earthquake rupture with a stress change increase of 0.7 – 1.1 bar. Similarly, the 2004 mainshock and aftershocks indicate loading zones with a stress change (> 0.25 bar) that includes the 2016 earthquake rupture. The tectonic loading 19 - 24 nanostrain/yr obtained from the seismicity catalogue of Morocco are comparable to the 5 1017 N.m/yr seismic strain release in the Rif Mountains. The seismic sequence is apparently controlled by the poro-elastic properties of the seismogenic layer that depend on the undrained and drained fluid condition. The short interseismic period between mainshocks and higher rate of aftershocks with relatively large magnitudes ($4 < M_w < 5.5$) implies the pore-fluid physical effect in an undrained condition. The stress-rate ranges between 461 - 582 Pa/yr with a CFF of 0.2 – 1.1 bar. The computed clock-time advance reaches 239 ± 22 years in agreement with the ~ 10 years delay between mainshocks. The calculated static stress change of 0.9 – 1.3 bar, under pore-fluid stimulus added with well-constrained geodetic and seismic strain rates are critical for any seismic hazard assessment.