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Comment

Comment on "Active coastal thrusting and folding, and uplift rate of the Sahel Anticline and Zemmouri earthquake area (Tell Atlas, Algeria)", by S. Maouche, M. Meghraoui, C. Morhange, S. Belabbes, Y. Bouhadad, H. Haddoum. [Tectonophysics, 2011, 509, 69–80]

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ABSTRACT

Based on geomorphologic analyses and leveling survey of Quaternary coastal indicators (i.e. marine terraces and notches) along of a 50-km-long coastal stretch of the Algerian coast west of Algiers, Maouche et al. (2011) interpret the coastal segment to have undergone high uplift rates, i.e. 0.84–1.19 mm/yr since last interglacial maximum (MIS 5e, 122 ± 6 ka in Table 1, ~140 ka in Maouche et al., 2011) and ~2.5 mm/yr for the last 31 ka. This uplift was said to be due to repeated seismic events that would have occurred during the last ~140 ka, and more particularly during the late Pleistocene.

We raise major issues about the interpretation proposed by Maouche et al. (2011). These issues deal with 1) the use of previous chronological data and the chronostratigraphy proposed, 2) processes involved in the creation of coastal staircase morphology on the coast west of Algiers, 3) anomalously high uplift rates compared to other available data on the same geomorphic features (marine terraces) in the same setting of reactivated passive margins, and 4) the fold geometry used for modeling of fold growth and its implications for coseismic surface deformation and uplift estimates.

In other words, we contest the statements that coseismic deformation is the cause of staircase morphology on the Mediterranean coast west of Algiers and that very large (M > 7) earthquakes have occurred there in the past.

1. Introduction

Maouche et al. (2011) propose a rather provocative interpretation for the recent tectonic history of the Algerian coast around Algiers. According to their statements, this coastal segment experienced high uplift rates, mainly due to repeated seismic events that would have occurred during the last ~140 ka, and more particularly in the last 31 ka. In other words, according to these authors, the active tectonics of this region is associated with large shallow earthquakes (M ≥ 6.5), numerous thrust faults and surface fault-related folds.

Here, we raise issues concerning the following: 1) erroneous use of previous and original chronological data and the consequent morpho-chrono-stratigraphical interpretation that results into unrealistic regional uplift rates; 2) processes invoked to create the coastal staircase morphology west of Algiers (i.e. strong coseismic component); 3) the questionable interpretation proposed in this article (Maouche et al., 2011) when compared to other studies on coastal deformation for this re-activated passive margin (see Pedoja et al. (2011) and Table 1 for synthesis), 4) the use of a poorly constrained data on fold geometry that has an impact on the coseismic uplift estimates. These considerations lead us to question the unrealistically elevated uplift rates proposed by Maouche et al. (2011) and their coseismic hypothesis for the origin of uplift in the coastal area around Algiers.

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2. Use of previous and new chronological data and chrono-stratigraphy proposed

Our major issue with Maouche et al. (2011) concerns the use of chronological data, both with the re-use of some dates and with their interpretation of ^{14}C dates. Based on these dates, Maouche et al. (2011) postulate that the upper marine terrace (T1) of the Sahel anticline has been carved out during the last interglacial maximum highstand (MIS 5e, 122 ka) and that the lower terraces (T6 and T7) are respectively 30 and 14 ka. Due to the erroneous chronostratigraphic interpretation, Maouche et al. (2011) calculate a very high uplift rate (0.84–1.2 mm/yr), which has a major impact on earthquake magnitude estimates. Also, this uplift rate is not discussed with respect to previously published uplift rates of 0.13 and 0.11 mm/yr (Table 1; Meghraoui et al., 1996; Morel and Meghraoui, 1996) based on some of the same data.

Most of Maouche et al.'s (2011) interpretation relies on a two U/Th date on seashells taken in coastal deposits around Tipaza and performed by Stearns and Thurber (1965). Maouche et al. (2011) use the dates to correlate the shoreline angle of the upper terrace of the sequence (T1) describe at 175–185 m, a correlation we contest for the following reasons. In the original article, Stearns and Thurber (1965) present a short description of the outcrop where the samples (two for the Algerian coast, respectively L-779A and L-779B in their study) were taken. For the first sample, L-779A-A, they propose a correlation of the narrow marine terrace (i.e. bench) where the sample was taken to what is called “basse plage quaternaire” (low Quaternary beach-deposits) by French-speaking authors (Dalloni, 1949 in Saoudi, 1989; Lamothe, 1911 in Saoudi, 1989; Vita-Finzi, 1967). The second sample, L-779B, was taken in the mouth of the Oued Rhiran, midway between Bérard and Tipaza. This means that the samples were taken in low Quaternary beach-deposits and certainly not in deposits of a marine terrace raised at 175–185 m. The methods yielded ages of 140 ± 10 (L-779a) and 125 ± 10 ka (L-779B). “Classical interpretation” (e.g. Saoudi, 1989; Vita-Finzi, 1967) of this date suggest the occurrence of last interglacial maximum paleoshoreline (MIS 5e) at altitudes below 10 m above mean sea-level (~6 m as suggested in Saoudi (1989). Note that well-developed low standing terrace was observed during field work by members of our team). Please also note that this classical interpretation was formerly accepted by some of the co-authors of Maouche et al. (2011) (e.g. Meghraoui et al., 1996; Morel and Meghraoui, 1996) but this is not mentioned or discussed in Maouche et al. (2011).

In their paper, Maouche et al. (2011) also propose a compilation of ^{14}C dates obtained in the zone (supplementary materials 1) to which they add new dates. Our concerns are twofold. First, Maouche et al. (2011) regard old ages (> 30 ka) as relevant whereas such data are generally dismissed by other authors working on the same morphologies in other parts of the world because too close to the limit of the method (e.g. Pedoja et al., 2006). Second, Maouche et al. (2011) consider ages obtained on charcoal, which is often found as a consequence of anthropogenic use of the land. Without clearly showing that human occupation was coeval with formation (carving) of the preserved paleocoast (e.g. marine terrace), one can only interpret such an age as a minimum value. Consequently, T7 and T6 ages are probably older than those stated by Maouche et al. (2011).

Based on their age assignments for T1 and T7, the intermediate marine terraces (T6–T2) thus have been correlated with other relatively high sea-stands between 120 ka and 30 ka (Figure 6 of Maouche et al., 2011). However, these relatively high sea-stands (between −60 m and −80 m for MIS 3, see Siddal et al., 2006) are not recorded as emerged paleocoasts except for sequences located on tectonically active (subduction, collision) coastlines with uplift rates commonly > 1.5 mm/yr, such as the Mahia Peninsula in New Zealand (Berryman, 1992, 1993a,b); on the Huon Peninsula in Papua New Guinea (e.g. Chappell, 1974); in Vanuatu archipelago (Cabioch and Ayliffe, 2001; Galipaud and Pineda, 1998; Jouannic et al., 1980, 1982; Taylor et al., 1980, 1982, 1985, 1987); and in the Ryukyus archipelago (Ikeda et al., 1991; Ikeya and Ohmura, 1983; Inagaki and Omura, 2006; Konishi et al., 1970 ; Maejima et al., 2005 ; Ota and Omura, 1992; Sasaki et al., 2004).

Maouche et al. (2011) also make a mistaken correlation concerning the T4 marine terrace (their Figure 6), which does not have the same high sea-level correlation in Profile P1compared with Profiles P2 and P3. We also note that the authors did not include any sea-level correction (see Figure 6) nor discuss the apparent absence, in their interpretation, of the globally frequently preserved MIS 5a terrace (see Pedoja et al., 2011).

3. Process involved in the creation of staircase morphology on the Algerian coast west and east of Algiers: coseismic versus interseismic uplift

We disagree with Maouche et al.'s (2011) interpretation that the sequence of marine terraces on the Sahel anticline was uplifted through coseismic uplift, with our argument based on the misapplied chronology, as discussed above, and on timing and geomorphology. Typically, and in our suggested alternative interpretation, a broad staircase topography of coastal marine terraces such as present on the Sahel anticline would be associated with Quaternary sea-level fluctuations and more particularly interglacial periods (stage and substage) superimposed on a rising coastline, producing a classic marine-terrace sequence (Lajoie, 1986). The summit (oldest) of such sequences can be found at altitudes of a few hundred meters and several kilometers inland. The height differences between adjacent paleocoasts are generally > 10 m (see Figure 4A in Pedoja et al. (2011) for a cross section of such sequences).

The sequence of marine terraces located on the Sahel area describe and interpreted by Maouche et al. (2011) is developed over a 50-km-long stretch of coast between Ain Benian and Tipaza and locally reaches more than 3.5 km inland (see Figure 4B in Maouche et al., 2011). The landscape is characterized by widespread development of a low sequence of four marine terraces superceded by wide, compound marine surfaces called “rasa” that can be wider than 2 km (e.g. Saoudi, 1989). The scale of the Algerian marine terrace sequence fits the classic glacioeustatic model and does not fit with the worldwide observation on the size of coseismic sequence of coastal indicators.

Whereas Maouche et al. (2011) ascribe terraces as old as ~140 ka and up to 200 m in elevation as co-seismically generated, elsewhere coseismic coastal uplift has been described only for the Holocene epoch and generally only for the later Holocene since glacioeustatically driven sea level slowed and reached approximately its present level ~5–6 ka. Documented cases of coseismic uplift describe staircase topography reaching only a few tens of meters altitude at most: e.g., ~30 m in Oiso Bay, Japan (Ota, 1980, 1985) and in northern California (Merritts and Bull, 1989; Merritts et al., 1991) and extending at most < 1 km inland; the height difference between each step is usually on the scale of 3–5 m. The ages and elevation of the these co-seismically generated steps are not consistent with eustatic sea-level change (Ota and Yamaguchi, 2004), as Maouche et al. (2011) seem to indicate in their case (their Figure 4).

4. Uplift rate comparison along the North African margin: why a major anomaly along the Sahel coast?

If major co-seismic events had occurred during the last 140 ka in Algeria or nearby, as proposed by Maouche et al. (2011), additional sequences of repeated uplifts similar in age should be present and identified west and east of the study area. Moreover, the interpretation by Maouche et al. (2011) produces a 10 times faster uplift rates than what was described before by some of the same co-authors of this article (Meghraoui et al., 1996; Morel and Meghraoui, 1996). This change in interpretation should be at least mentioned in Maouche et al. (2011), if not discussed.