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Neogene exhumation of the Internal Rif units (Northern Morocco) evidenced by low- temperature thermochronology

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The Rif Chain (Northern Morocco) belongs, with the Betic Cordillera (Southern Spain) to the westernmost part of the Alpine belt. There, the Beni Bousera peridotite massif is exhumed and corresponds to one of the deepest exhumed lithospheric rocks of the chain. Tectono-metamorphic studies showed that the internal units were subjected to very fast exhumation during the late Oligocene – early Miocene interval in relation with a crustal thinning and the Alboran sea rifting (synthesis in Chalouan et al., 2008). However, no data are available for the subsequent period despite that Neogene uplift sediments are well known in the internal domain since the work of Wildi and Wernli (1977) and predicted during the Messinian by thermomecanical modelling (Duggen et al., 2003). We present here for the first time a low temperature thermochronologic study (apatite (U-Th)/He and fission tracks; AHe and AFT) of these rocks in order to date and quantify the Neogene exhumation history of internal units of the Rif Chain.
Most AHe ages are comprised between 14.25 $\pm$ 0.21 and 21.32 $\pm$ 0.31 Ma however some are younger (e.g. 6.92 $\pm$ 0.14 Ma). AHe ages are closed to fission tracks ages, indicating a very rapid cooling. Moreover they do not show any clear age-elevation relationship that is consistent with a very rapid cooling. Youngest ages correspond to apatite with low eU concentration and thus are interpreted in terms of lower closure temperatures. We performed thermal modelling with HeFTy software (Ehlers et al., 2005; Ketcham et al., 2007) on fission tracks lengths and He diffusion data as they provide a statistical but more complete temperature-time history for the samples. We also used available 40Ar/39Ar data on biotite and field data to better constrain thermal modelling. Exhumation occurred in two main steps: i) a very rapid cooling between 22 and 17 Ma until rocks reached the top of the PAZ (80 to 60°C) at a rate of $\sim$70 to 120°C/Ma) and ii) a very slow cooling between 17 and 4 Ma with a rate of $\sim$5°C/Ma.

Modelled thermal histories do not show an increased cooling rate during late Miocene times in relation with the Messinian sea-level drop despite that accelerated denudation rates or rapid uplifts are expected on the Alboran margins during this period. This may be related to the very fast exhumation prior to this event that brought the present-day outcropping rocks at depth less than 2-3 km before late Miocene. Moreover, it must be noticed that mean AHe ages from the Internal Rif are much older than that from the Internal Betics, which are comprised between 6.2 and 12.9 Ma (Vazquez et al., 2011). The different AHe ages suggest a diachronous exhumation between the two branches of the Gibraltar Arc. However, this result has to be taken with caution because only few data are available in both chains.