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Damages dependent sensitivity of Zircon (U-Th)/He ages to thermal processes: the case of Pyrenean samples

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During the last decade (U-Th)/He thermochronology experienced important developments and improvements based on the combined use of extensive age documentation on various contexts and numerous experimental data. The main advance has been achieved when it has been shown that He diffusion in apatites is partly controlled by the amount of radiation damages accumulated in the grains. Concerning zircons, it has been noticed that Z-He ages could positively or negatively correlate with the amount of effective uranium (eU) of the grains (a parameter proportional to the accumulated damages). It has been shown that the alpha-dose is correlated to the amount of accumulated radiation damages and controls the diffusivity of helium by first inhibiting helium migration at low damage, before a threshold (2 x 1018 alpha/g), after which interconnection of damage zones drastically drives higher diffusivity at high damage (Gunethner et al., 2013).
In this study we provide new Zircon Fission Track ages (ZFT) and single grain Zircon (U-Th)/He ages (Z-He) from Hercynian Pyrenean granites. The time-temperature history of exhumation for the western part of the Axial Zone in the Pyrenees is particularly well suited for such an investigation given that (1) the age of granite bodies is very well known ($\sim$ 305 Ma), and (2) they have spent a large part of their Mesozoic history close to the surface favoring accumulation of radiation damages before Paleocene sedimentary and tectonic burial 5. In general, data exhibit a wide range of ages with maximum variation mainly recorded for a narrow eU concentration window from 200 to 500 ppm, with a first steep positive gradient, and a subsequent more gentle negative one up to the youngest ages recorded for the highest eU. For individual localities, the total age variation range from published AFT dates for the lower bound to ages in good agreement with ZFT for the upper bound. Such pattern is qualitatively in pretty good agreement with the model of Guenthner et al. 4, yet it is not possible to fit the data with a t-T history constrained by independent parameters (age of granites, old exhumation period followed by Cretaceous sediment burial). Even considering the maximum alpha-dose experienced by the samples (i.e. produced by the grains since granites emplaced without any annealing), the inversion of positive to negative trends in Bielsa and Neouvielle samples is centered at about 2 - 3 x 1017 alpha/g, significantly lower than the value used in the models 3,4. Preliminary Raman Spectroscopy data indicate that the total amount of damages experienced by these samples is well correlated with this double-trend pattern, and in the range of values used for quantification of the model with experimental diffusion data.
These data from Pyrenean granites represent a good and independently constrained dataset to test the new complex models of age simulation and to optimize their calibration. They suggest in particular that the quantification, nature and preservation of damages acting for the modulation of He diffusion in zircons should be investigated and documented more extensively in the future.