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Interactive comment on "Extracting information on the spatial variability in erosion rate stored in detrital cooling age distributions in river sands" *by* Jean Braun et al.

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INTRODUCTION

This section needs some improvements and reference to previous work, in order to properly emphasize the complexities of the thermochronologic record and the main assumptions of the detrital thermochronology approach (see below):

1) "Thermochronometric methods provide us with estimates of the cooling age of a rock, i.e. the time in the past when the rock cooled through a so-called closure temperature (Dodson, 1973), which varies between systems and minerals."

The concept of a closure temperature and a cooling age only applies in the case where rocks are cooling monotonically from high to low temperature (e.g., Dodson 1973; Villa 1998). For example, if a rock cools rapidly into the partial retention zone and is resident therein for a period of time before cooling again, its thermochronologic age cannot be recognized as a "cooling age". It is a common assumption in detrital thermochronology studies that all ages represent cooling ages, but this is not necessarily the case. This assumption should be properly underlined in the revised main text.

2) "One of the main geological processes through which rocks experience cooling is exhumation towards the cold, quasi-isothermal surface (Brown, 1991)."

I would underline here that the thermal reference frame relevant for isotopic closure is generally dynamic, which makes the interpretations of thermochronologic ages even more challenging, especially in detrital thermochronology.

3) "Young ages are commonly interpreted to indicate rapid exhumation and old ages should correspond to slow exhumation."

Old ages can also reflect denudation of shallow crustal levels that lay above the isothermal surface corresponding to the closure temperature of the thermochronologic system under consideration (e.g., Rahl et al. 2007).

4) "Cooling ages can also record more discrete cooling events such as the nearby emplacement of hot intrusions (Gleadow and Brooks, 1979) or the rapid relaxation of isotherms at the end of an episode of rapid erosion (Braun, 2016)."

A similar interpretation as Braun (2016) was also proposed for the European Southern Alps by Zanchetta et al. 2015 - Lithosphere. Cooling ages can also record thermal relaxation during the rifting to drifting transition (Malusà et al. 2016a - Gondwana Research), or mineral crystallization that has occurred at shallow crustal depth above the closure temperature isothermal surface (e.g., Malusà et al. 2011 - EPSL).

5) "Datasets are now routinely assembled by collecting and dating a large number of

mineral grains from a sand sample collected at a given location in a river draining an actively eroding area. Such detrital thermochronology datasets provide a proxy for the distribution of surface rock ages in a given catchment (Bernet et al., 2004; Brandon, 1992)"

This only applies in case of uniform mineral fertility in eroded rocks (Malusà et al. 2016b - Gondwana Research).

6) "By repeating this operation at different sites along a river stream, one obtains redundant information that can be used to document more precisely the spatial variability of in-situ thermochronological ages in a river catchment (Bernet et al., 2004; Brewer et al., 2006)."

The detrital thermochronologic record reflects both the thermochronologic complexities of eroded bedrock, and the bias acquired during erosion, transport and deposition (e.g., hydraulic sorting and mineral fertility bias, see Malusà et al. 2013 - Chemical Geology; Malusà et al. 2016b - Gondwana Research). All of these complexities and potential sources of bias should be properly taken into account and mentioned in the revised main text.

7) "However, these methods have not taken advantage of the fact that detrital age distributions contain two separate pieces of information concerning the spatial patterns of present and past rates of erosion. The first piece of information comes from the ages themselves: catchments or sub-catchments where the proportion of grains with young ages dominates are likely to experience rapid exhumation today or in the recent past; whereas catchments or sub-catchments where the proportion of grains with old ages dominates are more likely to have experienced rapid erosion in a more distant past."

This is not novel. The dual information (long-term vs short-term erosion/exhumation) provided by detrital thermochronology datasets was first discussed by Malusà et al. 2009 (Geol Soc London Spec Publ) under the assumption of constant mineral fertility in the eroding sources. This topic was further developed by Resentini and Malusà

2012 (Geol Soc Spec Papers) and Malusà et al. 2016b (Gondwana Research), taking into account the dishomogeneous mineral fertility in the source rocks. All these papers should be quoted in the revised manuscript.

THE METHOD

8) "In each Area i, we will assume that alpha i is the relative abundance of the mineral used to estimate the age distribution in rocks being eroded from the surface. We take the convention that 0 < alpha i < 1, with alpha i = 1 corresponding to an area i with surface rocks that contain the mineral in abundance (for example granite for muscovite) and alpha i = 0 corresponding to an area i with surface rocks that do not contain the mineral (for example carbonates for muscovite). If, for example, the area is made of 60% granite and 40% carbonates, and we have measured ages using a mineral that is abundant in granites (like muscovite) but absent in carbonates, then alpha = 0.6."

Alpha just provides a rough estimate of the mineral fertility bias. Malusà et al (2016b) demonstrated that major mineral fertility variations can be observed even in tectonic units with similar lithology, and showed that the relationships between bedrock geology and mineral fertility are complex and hardly predictable. They depend not only on lithology, but more in general on the whole magmatic, sedimentary or metamorphic evolution of eroded rocks. Careful approaches to mineral fertility measuremens are consequently required (see Malusà et al. 2016b - Gondwana Research). I think that this issue should be discussed in more detail in the revised manuscript.

APPLICATIONS TO DETRITAL AGE DISTRIBUTIONS

9) "Table 2" The lithological factor shown in Table 2 is very similar for different catchments. Is this correct? Was the mineral fertility measured accurately? Expected mineral fertility variations in Alpine-type orogenic belts should be on the order of 10e2-10e3 (see, e.g., Malusà et al. 2016b - Gondwana Research).

10) "Interestingly, there is a good correspondence between present-day erosion rate

and where the youngest ages are being generated (compare upper left panel showing relative concentration of youngest age bin, to central panel showing predicted present-day erosion rate), with the notable exception of the most downstream catchment (Z). In other words, where the mixing analysis predicts high erosion rate to account for a substantial change in the age distribution between two adjacent catchments, is also where it predicts the highest concentration of young ages in the surface rocks."

The short-term erosion rates calculated by Braun et al. are strongly influenced by the mineral fertility bias. Without an accurate measurement of mineral fertility and a proper consideration of hydraulic sorting effects, the comparison between long-term and short-term erosion rates performed here is rather weak.

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