Solid Earth Discuss.,
https://doi.org/10.5194/se-2020-26-AC2, 2020

Solid Earth
Discussions

Interactive comment on "Chronostratigraphic framework and provenance of the Ossa-Morena Zone Carboniferous basins (SW Iberia)" *by* M. Francisco Pereira et al.

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Received and published: 8 April 2020

We are grateful for the comments of referee#2 (Daniel Pastor-Galán) that are helpful to improve our paper.

Referee's comment 1: "From the studied datasets, I am happy with the study, statistical treatment and age interpretation of the igneous rocks. It is robust and well reasoned. However, you give and thoroughly describe U/Th but you never discuss them. Potential readers not familiar with zircon geochronology will wonder why is U/Th ration important at all and what is the meaning of those numbers you give and their average (does the average have any meaning considering some of the zircons are inherited?). I

encourage you to discuss the meaning of the U/Th ratios and their implications to understand the origin of the zircons (metamorphic vs. igneous and the prospective igneous provenance of zircons - higher or lower temperatures). Otherwise, you may opt to not discuss at all the results, but once the results are there, I think it is interesting to give the whole picture."

- Author's reply 1: "Most zircon grains from both samples SCV-2 and TM-1 of rhyolitic tuff show moderate to high Th/U (0.11-0.95) and 0.42 < Th/U average < 0.53, indicating an igneous origin (Heaman et al., 1990; Hanchar and Miller, 1993; Hoskin and Schaltegger, 2003), and precipitation from felsic-intermediate metaluminous sources; sample TM-1also have 16% of grains with very low Th/U (less than 0.1) typical of the zircon precipitated during the metamorphism or partial melting of a peraluminous rock in the presence of minerals with high Th/U (Williams and Claesson, 1987; Heaman et al., 1990; Williams, 2001; Rubatto 2002), and less than 3% with Th/U > 1, suggesting precipitation from a mafic source (Wang et al., 2011; Pereira et al., 2014). Sample SCV-30 of porphyritic rhyodacite-rhyolite have zircon grains that fall within the range 0.34< Th/U < 0.52 (Th/U average = 0.41), suggestive of crystallization from a relatively chemically homogeneous felsic-intermediate metaluminous source, close to the field of felsic peraluminous sources. Sample SCV-7 of granite include zircon grains with moderate to high Th/U (0.3-0.76) and Th/U average = 0.5 that are compositionally similar to those of sample SCV-30, indicating a comparable source. A simple comparison between igneous and sedimentary rocks illustrates that zircon grains of siliciclastic rocks show higher average Th/U ratios ranging from 0.66 to 0.81. However, if we complement the data from the sample CBR-11 with those from sample OM-200 (Pereira et al., 2012a), we find that the zircon grains fall within the range 0.2< Th/U < 1.69 and Th/U average = 0.5. Most zircon grains from sample TM-3 of siltstone show moderate to high Th/U (0.11-0.95), indicating precipitation from felsic-intermediate metaluminous sources; sample TM-3 also has 9% of grains with very low Th/U (less than 0.1) typical of the zircon precipitated during the metamorphism or partial melting of a peraluminous rock, and 26% with Th/U > 1, suggesting precipitation from a mafic source, which is consistent with a high Th/U average = 0.75. The detrital zircon populations from samples SS-1 and SS-2 of sandstone are mostly represented by grains (81-84%) showing moderate to high Th/U (0.13-0.99) and 0.66 < Th/U average < 0.72, followed by a group of grains (14-15%) with Th/U > 1, probably derived from a mafic source, and a few grains (1-5%) with very low Th/U (less than 0.1) precipitated during the metamorphism or partial melting of a peraluminous rock. Nevertheless, we have to be aware that the concentrations of Th and U in zircon are primarily influenced by factors such as element availability within a reaction environment and partitioning behavior of these two actinide elements between zircon and co-existing minerals (i.e. high-Th minerals such as monazite and allanite), melts and fluids (Harley et al., 2007; Wan et al., 2011). The existence of monazite, epidote, and allanite, or concurrent growth of this high-Th phase may result in precipitation of zircon with a low Th concentration, and therefore a low Th/U ratio. Zircon precipitation from a partial melt before the crystallization of high-Th minerals may have higher Th concentration and therefore a moderate to high 0.15 < Th/U average < 3.2 (Carson et al. 2002; Kelly and Harley 2005), and therefore very low Th/U <0.1 metamorphic and recrystallized zircon could be not observed in high-grade metamorphic rocks (Wan et al., 2011). Given the evidence for variable zircon Th/U described above, Th/U values can only be used with caution and in concert with other, more integrative, chemical criteria to assess the origin of zircon within its textural context (Harley et al., 2007). This discussion is quite interesting but also rather complex, and so we prefer to leave it out of this work."

Referee's comment 2: "I am a little less happy with the results of the detrital samples. I have noticed several minor but relevant issues (see the annotated PDF). Among them the relatively low number of analyzed zircons (some cases <40) in samples with too many peaks. In such cases, every single zircon con turns easily the distribution. You are comparing these datasets with others to check their provenance, and with such short datasets, the results can be misleading. I think the limitations of your new datasets should be, at least, mentioned in the paper."

- Author's reply 2: "We agree with referee #2 when he says that the detrital zircon population of sample TM-3 is small (N = 36) instead of gathering the minimum of 60-100 grains generally used for this type of provenance studies (Vermeesch, 2004); on the other hand, it also states that we must make this limitation known to the reader. We agree with his recommendations and we will introduce in the final version a sentence referring that comparisons based on the proportions of ages need to be conducted with caution in such cases. Despite the difficulty in finding zircon grains in sample TM-3 of siltstone, 82 were analyzed but the results obtained reduced the concordant ages to less than half of the analyses performed. Kolmogorov-Smirnov test can be meaningful when comparing age populations with distinct sizes and for detecting differences using smallish datasets (N $\geq$20). It is important to note, that the Kolmogorov-Smirnov test is very sensitive to the proportions of ages present (Gehrels et al., 2012) so that this preliminary comparison between sample TM-3 and the other siliciclastic rocks should not be disregarded. K-S test highlights a significant difference concerning Precambrian grains; they are much less represented (8%) in the Cabrela volcano-sedimentary complex (10%; sample CB), than in the Toca da Moura volcano-sedimentary complex (64%; sample TM-3) and the overlying Santa Susana Formation (samples SS-1 and SS-2), suggesting changes in sediment sources during the Carboniferous. The minimum number of detrital zircon grains which is advisable to use in provenance analysis lead me to the study of Murphy et al. (2004) published in Geology using only two samples and very few detrital zircon grains (N = 23 and N = 28). They have discussed, in a preliminary way, the sources of the siliciclastic rocks from West Avalonia and Meguma terrains based on the presence or absence of Mesoproterozoic, Ordovician and Silurian detrital zircon grains. The new geochronological results were decisive to improve the paleogeographic models of the peri-Gondwanan realm of the Appalachian orogeny. The main differences in detrital zircon age populations described by Murphy et al. (2004) have been corroborated through new studies based on a larger number of detrital zircon ages (Waldron et al., 2009; White et al., 2018; Shellnutt et al., 2019).

Referee's comment 3: "Also, treatment of the minimum depositional age, which sometimes is an average of several zircons (still don't get why the youngest zircons in a detrital sample do not need to come all from the same rock and/or age) instead of giving the youngest concordant zircon with its uncertainty."

- Author's reply 3:" We only used the term "minimum depositional age" when using a zircon crystallization age of igneous rocks (sample SCV-30) and not detrital zircon ages from siliciclastic rocks."

Referee's comment 4: "Finally, I am unsure of how the K-S test gives any further or better information compared to MDS. MDS is basically the same but compares all the samples together and plots a really easy to understand graphics. Unless there are some relevant differences (not discussed in the txt right now, and I could not fine any) I recommend to move the K-S to the repository and treat it as a proof of concept instead."

- Author's reply 4:" We agree with referee #2. Kolmogorov-Smirnov (K-S) test results will be removed from Figure 9."

Referee's comment 5: "Finally, as a curious note since I know it is not a major conclusion of this paper. I have problems to see how the subduction of the Paleotethys more than 600 km to the east (in present day coordinates and following Pereira's 2014; 2017a paleogeography) could cause arc magmatism in the sampled area. The average dip of the slab would be between 9ËŽ and 18ËŽ (assuming dehydration happens up to 200 km which is quite optimistic). Even a Puna style slab (with an initial steeper 30ËŽ slope to become later flat) dehydrates at some point 300-350 km far from the trench resulting in no more volcanism."

- Author's reply 5:" When the paleogeographic map was drawn up with the representation of the Paleotethys subduction (Pereira et al., 2015b, 2017b) our main purpose was to explain the late Carboniferous-early Permian magmatism in Iberia. In this paleogeographic reconstruction, the late Carboniferous-early Permian OMZ and CIZ plutons, and the same age Pyrenees volcanism and plutonism (Pereira et al. 2014), are roughly located about 200-300 km far from the trench "what is quite optimistic". In Pereira et al.

(2015b, 2017b), the intention was to illustrate the Paleotethys subduction simplistically and preliminarily, far from considering the effect of kinematic variables on the thermal structure of the mantle wedge and the location of melting related to water transport in subduction zones with distinct slab dips (Grove et al., 2009). As we are now considering that the putative Paleotethys subduction started earlier in the early Carboniferous, the magmatism of this age found in the OMZ will have been displaced to the west by left-lateral strike-slip fault systems that were active until Moscovian (Pérez Cáceres et al., 2015) to early Permian (García-Navarro and Fernández, 2004). We will improve Figure 10 so that the tectonic model can be better understood by readers."

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