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Comment on "Origin of pre-Mesozoic xenocrystic zircons in Cretaceous sub-volcanic rocks of the northern Andes (Colombia): Paleogeographic implications for the region" by Cetina et al. (2019)

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ABSTRACT

Cetina et al. (2019) presented new geochronological, geochemical and isotopic data obtained from volcanic and sub-volcanic rocks exposed in the northern segment of the Western Cordillera of Colombia, which are interpreted as related to a Cretaceous island arc-plateau system. These data are used to come up with a paleogeographic model for the circum-Caribbean realm that may account for the presence of old (Paleozoic – Proterozoic) xenocrystic zircons in the analyzed units. Nevertheless, the authors ignored previously published geological, geochemical, geochronological, thermochronological and provenance constraints from Cretaceous rocks of northwestern Colombia, which refuse the plausibility of their proposed models. Particularly, the occurrence of Cretaceous subduction-related metamorphism, magmatism and construction of marginal sedimentary basins, documented by several published papers in the last decade, renders the paleogeographic reconstructions of Cetina et al. (2019) to be unlikely. We demonstrate that when considering the ignored geological evidences, alternative explanations for the origin of pre-Mesozoic xenocrystic zircons are required.

1. Introduction

The recently published paper by Cetina et al. (2019) provided new SHRIMP and LA-ICP-MS geochronological data, together with whole-rock geochemical, and Rb-Sr and Sm-Nd isotopic constraints from volcanic rocks exposed in the northern segment of the Western Cordillera of Colombia. They combine this new dataset with previously published data to reconstruct the geodynamic and paleogeographic setting on which the studied volcanic rocks were formed in the Cretaceous circum-Caribbean regional context. The proposed paleogeographic models are used in order to explore for a tectonic scenario that may satisfactorily explain the presence of continent-derived old xenocrystic zircons in a Cretaceous intra-oceanic magmatic system, which has been matter of recent debate given the major role that such processes play in the recycling of continental crust (e.g. Rojas-Agramonte et al., 2016 and references therein).

During the last decade, the Cretaceous tectonic evolution and paleogeography of the northern Andes have been focus of extensive discussion. As a result, large datasets and several alternative geodynamic models have been proposed (Fig. 1; e.g. Avellaneda-Jiménez et al., 2019; Duque-Trujillo et al., 2019; Jaramillo et al., 2017; León et al., 2019; Spikings et al., 2015; Villagómez et al., 2011; Villagómez and Spikings, 2013; Zapata et al., 2019). Nevertheless, Cetina et al. (2019) grossly omit geochemical, geochronological, thermochronological and provenance data available from the above-mentioned works.

In this contribution, we will discuss some of the aforementioned data, which Cetina et al. (2019) ignored, in order to demonstrate that their proposed models are not plausible if omitted evidences are considered, and in consequence, alternative explanations are required for the origin of the reported pre-Mesozoic xenocrystic zircons. We claim that poor or selective gathering of previously published geological constraints certainly resulted in weak and refutable interpretations, which finally hinders the elaboration of a processes-oriented

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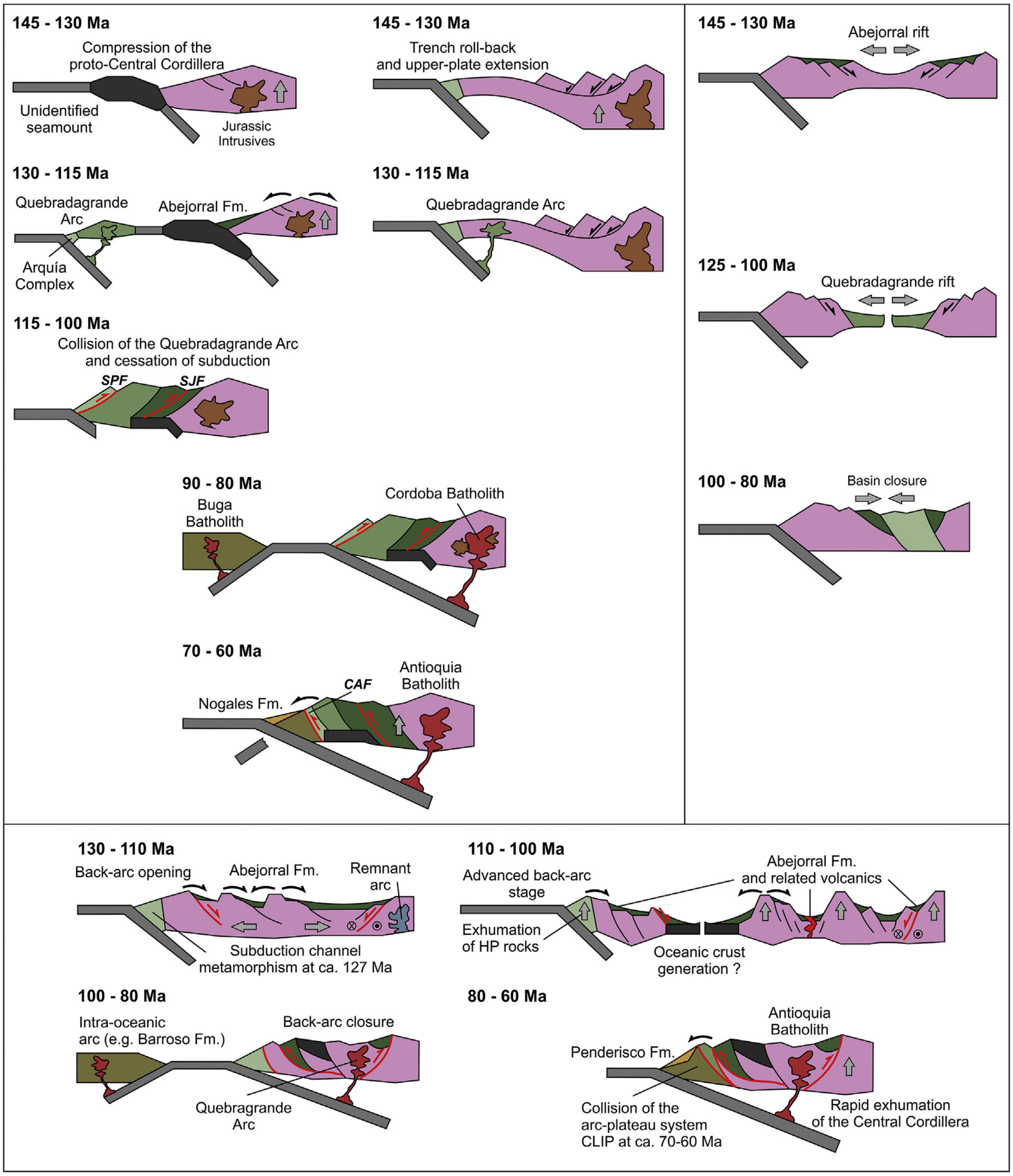

Fig. 1. Schematic illustrations of the previously proposed tectonic models for the Cretaceous evolution of the northern Colombian Andes. Upper-left panel: tectonic scenario modified from Spikings et al. (2015) and Villagómez and Spikings (2013). Upper-right panel: tectonic model modified from Nivia et al. (2006). Bottom panel: own proposed model, modified from Zapata et al. (2019). SPF = Silvia-Pijao Fault, SJF = San Jerónimo Fault, CAF = Cauca-Almaguer Fault.

contribution.

2. Regional setting and comparison between the previously proposed models for the Cretaceous of the northern Colombian Andes and that proposed by Cetina et al. (2019)

The northern segment of the Western Cordillera of Colombia, where the study area of Cetina et al. (2019) is located, mainly consists of two magmatic provinces with contrasting lithological, geochemical and geochronological features. A series of ca. 100-90 Ma plateau-like basalts (i.e. San Jose de Urama Diabase; e.g. Rodríguez and Arango, 2013; Villagómez et al., 2011) and plutonic units (i.e. Buriticá Tonalite; e.g. Weber et al., 2015), which are interpreted as accreted fragments of the Caribbean Large Igneous Province (CLIP; e.g. Kerr et al., 2002, 1997). Contrasting ca. 90-80 Ma volcanic and sub-volcanic basic-intermediate rocks with island arc geochemical affinity both intrude and overlain the basaltic rocks of the CLIP (i.e. Barroso Fm., Altamira Gabbro and Santa Fe Batholith; Villagómez et al., 2011; Weber et al., 2015; Zapata et al., 2017). This island arc-plateau system is considered allochthonous at least until ca. 90 Ma based on paleomagnetic constraints (Hincapié-Gómez et al., 2018), and is interpreted as associated to the allochthonous evolution of the CLIP (e.g. Kerr et al., 1997; Sinton et al., 1998). These island arc-plateau system is unconformably overlain by siliciclastic and hemipelagic Late Cretaceous to Paleogene rocks sourced from continental-affinity terranes (León et al., 2018).

In the next sections we discuss three lines of evidence ignored by Cetina et al. (2019), as well as their implications for the inconsistency of the presented tectonic models.

2.1. Timing of the collision between the CLIP and the South-American continental margin

Several stratigraphic, thermochronological, geochemical and geochronological data has been interpreted to document the collision of the CLIP against northwestern South America during the Late Cretaceous – Paleocene (~70 - 60 Ma, Bayona, 2018; Jaramillo et al., 2017; Spikings et al., 2015; Vallejo et al., 2006; and references therein). This proposed timing is based on the occurrence of ca. 70-60 Ma major shifts in the accumulation environments from marine-deltaic to fluvial and changes in the sedimentary provenance of foreland basins, tectonic inversion of early Cretaceous extensional basins, accelerated exhumation/erosion of the hinterland massifs, and coeval generation of collision-related magmatism. However, Cetina et al. (2019) did not or barely discussed any of the above mentioned constraints and rather proposed an alternative scenario for the CLIP already docked to the continental margin at 110-100 Ma (see Fig. 14 in their paper), without considering the major implications that such proposition may have on the Cretaceous evolution of the northern Andes. Widespread regional evidences for an early Cretaceous extensional tectonic regime in the Colombian Andes (Cardona et al., 2019; Sarmiento-Rojas et al., 2006; Zapata et al., 2019) is not compatible with collision-triggered compressional tectonics.

2.2. Subduction-related Cretaceous magmatism along the South-American continental margin

The existence of subduction-related magmatism along the Central Cordillera during the Cretaceous (at least since ~130 Ma) until the Eocene (ca. 53 Ma) has been widely documented (Bayona et al., 2012; Bustamante et al., 2017; Cardona et al., 2019, 2018; Duque-Trujillo et al., 2019; Villagómez et al., 2011; Zapata et al., 2019 and references therein). This arc system is in part contemporaneous with the intra-oceanic arc described above (Barroso Fm and related intrusives of the Western Cordillera). Therefore, the existence of coeval but different continental and oceanic arcs requires the existence of multiple subduction zones, which is a neglected scenario in all models proposed by Cetina et al. (2019). Instead, their paper proposed two unlikely scenarios with a single subduction system: 1) an active westward subduction where the island arc-related rocks was being emplaced over the CLIP together with a passive South-American margin between 110 Ma and 80 Ma. The absence of an active continental margin that apparently extends to Peru is used in order to explain how zircon xenocrysts were able to reach the trench of the intra-oceanic arc (see Fig. 13 in their paper). This scenario is not plausible when the widely documented Cretaceous continental arc-related magmatism of Colombia and Peru (e.g. Coastal Batholith; Mukasa, 1986) is taken into account. 2) An alternative model consists of a single east-dipping subduction involving both the South-American basement and the already accreted CLIP between 110 Ma and 80 Ma. Nevertheless, as discussed above, the CLIP rather collided at least 10 Myr later at ca. 70–60 Ma. Moreover, if we consider a single subduction zone for the ca. 100-80 Ma magmatism of both the Western and Central cordilleras, the arc front width would have exceeded 170 km (measured on a geological map without accounting for Cenozoic shortening). This is infeasible since the average width of magmatic arcs is between 20 and 30 km, and rather takes tens of millions of years to widen in the order of hundreds of kilometers (Ducea et al., 2015). Therefore, a single east-dipping subduction system, proposed by Cetina et al. (2019) and Rodríguez et al. (2012) is also unlikely from a geodynamic point of view. However, beyond the geodynamic plausibility of their proposed models, the critical issue is that the authors did not mention or discuss the role of the Cretaceous arc magmatism in the north Andean paleogeography.

2.3. Subduction channel metamorphism and sedimentary provenance of marginal basins

The Central Cordillera of Colombia comprises a series of Aptian – Albian transgressive volcano-sedimentary sequences (i.e. Abejorral and Quebradagrande Fms.), which are interpreted as the infilling record of an extensional marginal basin (Zapata et al., 2019). These rocks are in fault contact to the west by medium-to high-pressure rocks, which are interpreted as the record of a subduction related metamorphism with a peak age of ca. 128 Ma (Arquía Complex; e.g. García-Ramírez et al., 2017 and references therein). Recently conducted provenance analysis on the Aptian – Albian sediments suggests that high-pressure rocks of the Arquía Complex sourced the early Cretaceous marginal basin (Fig. 1; Avellaneda-Jiménez et al., 2019; León et al., 2019). Thus, the occurrence of subduction-related metamorphism, together with the formation of extensional marginal basins in the South-American margin, also buttress the existence of an active continental subduction zone, coeval with the late stage of growth of the intra-oceanic arc studied by Cetina et al. (2019).

3. Alternative models for the existence of Paleozoic and older zircon xenocrysts

In their paper, Cetina et al. (2019) analyzed samples from two subvolcanic units (Guarco Andesite and Porphyritic Intrusives), which are reported intruding both the plateau-like basalts and arc-related rocks from the Barroso Formation. Samples analyzed by SHRIMP geochronology yielded Paleozoic (~400–600 Ma) and Paleoproterozoic ages (> 2000 Ma), which they interpret as inherited or xenocrystic zircons. Scarce and disperse Cretaceous ages between 142 and 77 Ma (a total of 13 out of 56 individual analyses from six samples) are used to constrain the crystallization age of the studied units. Conversely, twenty-nine zircons dated by LA-ICP-MS from the Guarco Andesite (sample 901204), yielded a weighted mean age of 92.1 ± 1 Ma (MSWD = 3.1), with no old xenocrystic grains. Despite the geochronological database is quite limited (few or none overlapping Cretaceous analyses per sample), and the high dispersion of the SHRIMP ages, the authors estimated a ca. 92 Ma crystallization age for the Guarco Andesite and suggested a rough Late Cretaceous age for the Porphyritic Intrusives.

Recent mapping work conducted by the Colombian Geological Survey in the same area of the study of Cetina et al. (2019), together with geochemical and geochronological analyses, were used to propose an 8.08 ± 0.13 Ma arc-related origin for the Porphyritic Intrusives (Correa et al., 2019, 2018). Widespread late Miocene volcanic and subvolcanic rocks have been reported along the northernmost segment of the Western Cordillera of Colombia (e.g. Rodríguez and Zapata, 2012), which are intruding both the island arc-plateau system and the Cretaceous – Paleocene sedimentary cover (i.e. Penderisco Formation). These siliciclastic and hemipelagic rocks were sourced by the continental pre-Cretaceous paleomargin as suggested by the presence of Triassic-Permian and older (including 400–600 Ma and > 2000 Ma) detrital zircon U-Pb ages (León et al., 2018). Furthermore, the porphyritic rocks analyzed by Cetina et al. (2019) have similar Sm-Nd and Rb-Sr isotopic signatures when compared with available data from nearby late Miocene volcanic rocks (Gil-Rodríguez, 2014; Jaramillo et al., 2019; Leal-Mejía, 2011; Tassinari et al., 2008), which considerably differ from the more juvenile character of the CLIP (Fig. 2; Kerr et al., 2002, 1997).

When considering the previously proposed late Miocene age for the Porphyritic Intrusives (surprisingly not discussed by Cetina et al., 2019), the cross-cutting relationship with the Penderisco Fm., and the similar isotopic signature with late Miocene rocks, it is likely that the Paleozoic and older xenocrysts would have been incorporated from the host rocks into the magmatic units during their emplacement. This over-simplified alternative explanation, although barely supported, must be considered or at least discussed in the light of the limited

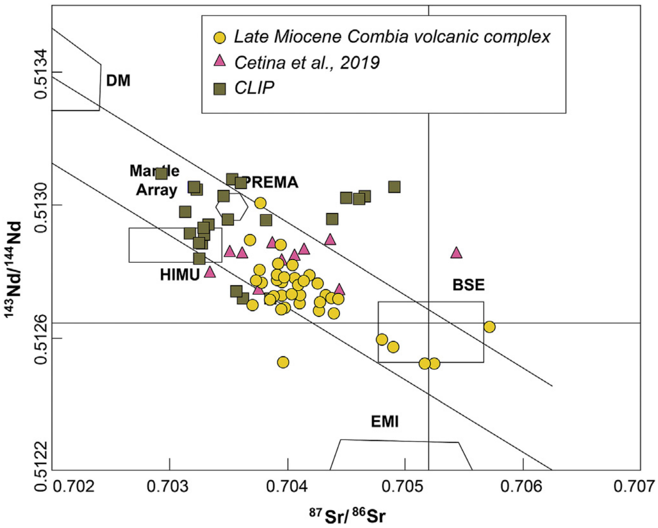

Fig. 2. Initial $^{143}Nd/^{144}Nd$ vs. $^{87}Sr/^{86}Sr$ diagram, comparing available data from the CLIP (Kerr et al., 2002, 1997), the late Miocene Combia volcanic complex (Jaramillo et al., 2019 and references therein), and data from (Cetina et al., 2019). All data was recalculated to 90 Ma.

geochronological dataset in order to construct an integrative paleogeographic model that may account for the existence of old xenocrystic zircons.

4. Conclusions

Cetina et al. (2019) based their main paleogeographic interpretations on a limited research of the available geological data, as demonstrated in the discussion above. This resulted in a weak explanation for the mechanism responsible for the incorporation of the old xenocrystic zircons found in the studied magmatic rocks. For this reason, we felt compelled to recall and discuss all the geological data ignored by these authors, which when considered, hinders the plausibility of their proposed models. We claim that robust regional models are primordial to elaborate a geological framework that allows conducting processes-oriented research such as testing the fate of continental crust, particularly xenocrystic zircons, recycled into the Earth's mantle.

Declaration of competing interest

The authors declare no conflict of interests.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jsames.2019.102400.

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