PNAS LETTER

Uplift of the Puna Plateau was not limited to Miocene and younger time

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Fig. 1. (*A*) Original figure S1A from Pingel et al. (1); (*B*) larger overview photo of the same outcrop showing the relationships between aeolian deposits and alluvial conglomerates; (*C*) typical eolian dune deposits incorrectly interpreted by Pingel et al. (1) as deformed beds; (*D*) aeolian foresets; (*E*) subhorizontal alluvial conglomerates interfingering with aeolian sandstones.

Pingel et al. (1) combined δD analyses of volcanic glass from a few new samples with selected published paleoaltimetry proxy data and putative field relationships in the Puna Plateau to argue for ~2 km of surface uplift since the early-middle Miocene. They challenged previously published interpretations of Eocene high paleoelevations in the Puna (2, 3), and lithospheric removal as the mechanism of formation of the Arizaro basin (e.g., refs. 4–7). We argue that the field observations used by ref. 1 to infer significant deformation after 20 Ma, their paleoaltimetry analysis, and their reinterpretations of previous literature are flawed.

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Author contributions: B.C. designed research; B.C., P.G.D., R.R.D., J.Q., M.T.C., and L.S. performed research; B.C. contributed new reagents/analytic tools; B.C., P.G.D., R.R.D., J.Q., and M.C. analyzed data; and B.C. wrote the paper.

The authors declare no competing interest.

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Published May 20, 2024.

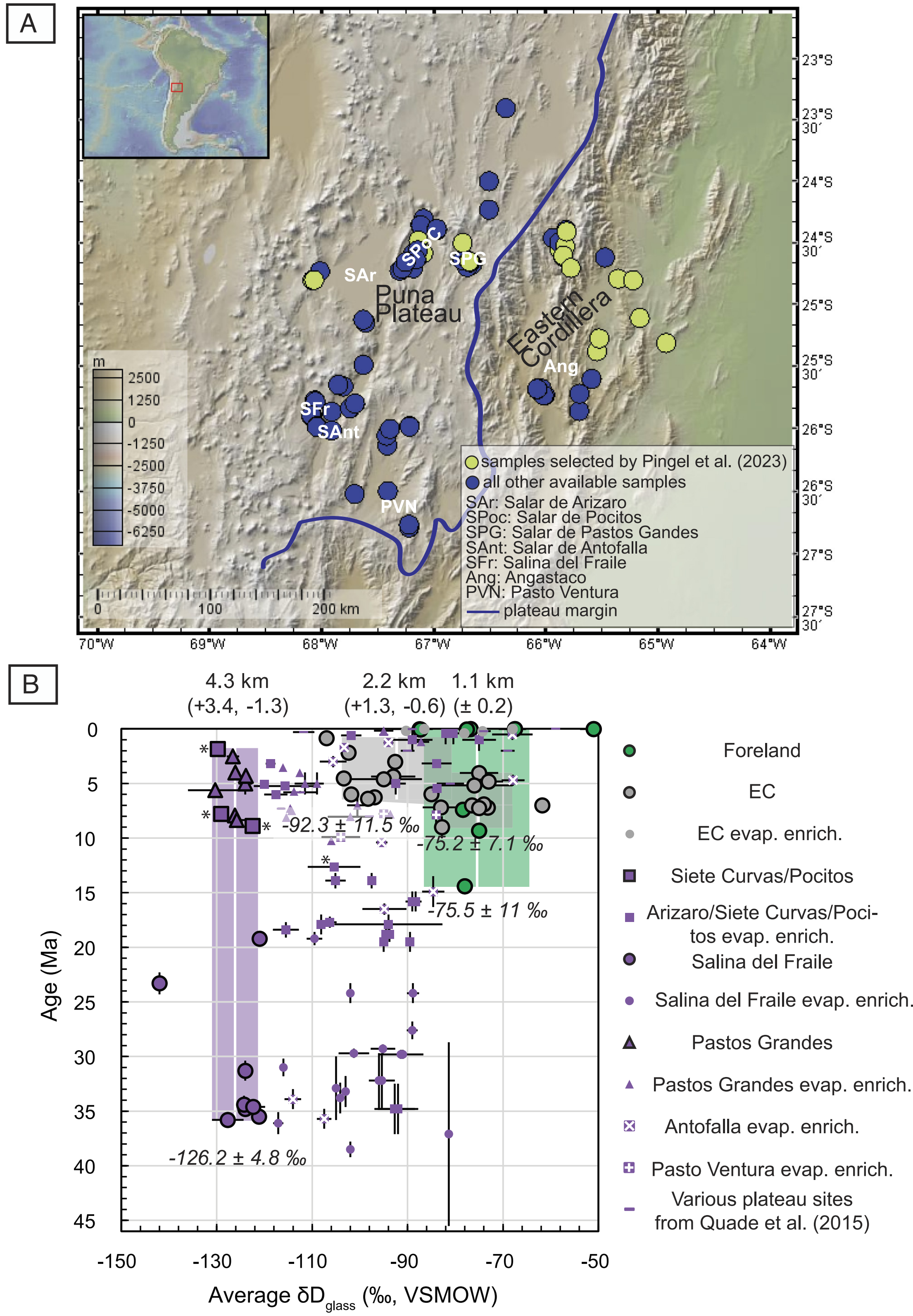

Fig. 2. (*A*) Topographic map of the Puna Plateau and Eastern Cordillera with locations of the available published paleoaltimetry proxy data. (*B*) Hydrogen stable isotope data of volcanic glass and paleoaltimetry estimates for the Central Andes. Average δD_{glass} vs. depositional ages from the low-elevation foreland (green) from refs. 3 and 10, and ref. 1 and references therein; Eastern Cordillera (EC, gray) from refs. 10, 1 and 3 and references therein, plateau samples (purple) from refs. 1 (asterisked), 2, 3 and 10 and references therein. Paleoaltimetry estimates (*Top*) were made using the methods and lapse rate (−15.8 ± 7.9‰) from ref. 1. Plateau samples above −120‰ and EC samples above −90‰ and younger than 0.8 Ma were excluded from paleoaltimetry estimates due to evaporative enrichment following the same criteria in ref. 1 but allowing for possible evaporative enrichment before 10 Ma. Colored bars and associated values indicate the average and SD of binned δD_{glass} values not excluded due to evaporative enrichment and used for paleoaltimetry calculations. The foreland value (green shading) was used as the δD_{low} value for calculating $\Delta\delta_{high\text{-}low}$. The EC δD_{glass} value <6.5 Ma (gray shading) and grouped δD_{glass} values from Salina del Fraile, Siete Curvas, Pocitos, and Pastos Grandes (purple shading) were used as the δD_{high} values to calculate paleoelevation of the EC and Puna Plateau respectively. Error bars on individual points are ±1SD.

Their structural interpretation is compromised by misleading representation of field relationships and erroneous interpretation of syndepositional deformation near the Arizaro basin. A key outcrop in the Quebrada Quiron is interpreted to depict ~13.4 Ma 38°SE-dipping structurally tilted strata beneath ~9.1 Ma 10°SE-dipping strata (Fig. 1*A*). The steeply dipping strata are ~10° to 35° dipping, large-scale cross-strata deposited on eolian dune slip faces; master bedding is subhorizontal. The cross-beds are laterally intercalated with flat-lying conglomerates and are stratigraphically conformable with overlying subhorizontal conglomerates (Fig. 1). The ~13.4 Ma strata were deposited on a topographically irregular Ordovician paleosurface, but they are not deformed. Other field localities interpreted as evidence for Miocene uplift exhibit ~10° dipping alluvial strata which can be explained as primary depositional dip or by local deformation associated with Arizaro basin dynamic processes (5, 6). Their interpretation of deformation onset suffers from arbitrary distortion of previous literature and the incorrect assumption that deformation in the Eastern Cordillera requires synchronous deformation in the Puna Plateau. For example, the Lina and Del Cobre ranges in the Puna were deforming and exhuming at ca. 45 to ca. 35 Ma and ca. 32 to ca. 25 Ma, respectively (8), and the western side of the Arizaro basin and the Macon Range during the Eocene-Oligocene (6, 9), and not during the Miocene. In general, >50% of total Central Andean shortening was accommodated in the Puna between the Eocene and ~20 Ma (8).

The paleoaltimetry analysis of Pingel et al. (1) ignores published data from several relevant sites including Pastos Grandes, Salina del Fraile, Antofalla, and Angastaco basins (2, 3, 10) (Fig. 2*A*). Even when applying the same evaporation criteria as Pingel et al. (1) but allowing for evaporative enrichment of samples older than 10 Ma on the Puna (consistent with Eocene-Oligocene evaporites) high elevations starting from ~35 Ma are required but still permit some dynamic Miocene surface uplift (Fig. 2) and are not inconsistent with lower elevations at the plateau margin (e.g., Salar de Pastos Grandes). When all samples are considered, they show large variability and underscore a complex uplift and paleoenvironmental history and the need for a comprehensive approach that appropriately deals with uncertainties and acknowledges all available data.

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