SD Text 1. Analytical methods: Mineralogy and petrology-geochemistry, Ar^{40}/Ar^{39} geochronology and La-ICP-MS U-Pb geochronology.

1. Mineralogy and petrology - geochemistry

Pyroclastic rocks were embedded in epoxy resins and analysed in Blaise Pascal University (Clermont-Ferrand, France) using Cameca EMP SX-100 and in Hacettepe University (Ankara, Turkey) using Carl-Zeiss EVO 50 EP SEM. The lithologic components (crystals, glass and xenoliths) and vesicles of the principal ignimbrites have been quantified by conventional point-counting method using James Swift semi-automatic counter integrated with a polarized microscope. For geochemical analyses, pumice samples from ignimbrites were crushed into rock chips by hammering, cleaned with compressed air, and then were crushed and milled in an agate mortar. Major element analyses have been performed at Blaise Pascal University using Jobin Yvon 70 ICP-OES. 200 mg of powdered samples were fluxed with $LiBO_2$, and dissolved by HNO_3. Prepared solutions were analyzed by the automatic procedure installed in the system. Results are displayed in Figure 5B and SD Table A in SD Text 2.

2. $^{40}Ar/^{39}Ar$ geochronology

Alkali feldspars (average K/Ca= ~ 1) were isolated from the ignimbrites and groundmass/glass separates were prepared from the Quaternary lavas via magnetic sorting and density separation using methylene iodide. All purified separates were weighed and then irradiated at the Oregon State University TRIGA reactor in the Cadmium-Lined In-Core Irradiation Tube (CLICIT) in several batches spanning a three year period. $^{40}Ar/^{39}Ar$ incremental heating experiments were undertaken on groundmass/glass separates following Jicha et al. (2012). Single crystal fusions were performed on the feldspar separates following the methods of Meyers et al. (2012). Argon isotope analyses were done using a MAP 215–50, and the data was reduced using ArArCalc software version 2.5 (http://earthref.org/ArArCALC/). All age data presented here are calculated relative to 28.201 Ma for FCs (Kuiper et al., 2008), the decay constants used are those of Min et al. (2000), and the age uncertainties reported in Table 2 & SD Table 3 reflect analytical contributions only at the 2σ level.

3. U/Pb analytical techniques

U-Th-Pb isotopic data on separated zircons were obtained by laser ablation inductively coupled plasma spectrometry (LA-ICPMS) at the Laboratoire Magmas & Volcans (Clermont-Ferrand, France). The analyses involved the ablation of minerals with a Resonetics M-50 laser system powered by an ultra-short-pulse (<4ns) ATL Atlex Excimer laser operating at a wavelength of 193 nm (Müller et al., 2009). Spot diameters of 33-40 µm were associated to repetition rates of 3 Hz and fluency of 3 J/cm^2 resulting in a spot depth of 12-15 µm. The ablated material was carried into helium and then mixed with nitrogen and argon before injection into the plasma source of a Thermo Element XR Sector Field high-resolution ICP-MS. The alignment of the instrument and mass calibration were performed before every analytical session using the NIST SRM 612 reference glass, by inspecting the signals of ^{238}U, ^{232}Th and ^{208}Pb and by minimising the ThO^+/Th^+ ratio. The analytical method for isotope dating with laser ablation ICPMS (see Supplemental Data SD2 for details) is basically similar to that reported in Paquette and Tiepolo (2007), Hurai et al. (2010) and Paquette et al. (2014). The occurrence of common Pb in the sample can be monitored by the evolution of the ^{204}(Pb+Hg) signal intensity, but no common Pb correction was applied owing to the large isobaric interference from Hg. The ^{235}U signal is calculated from ^{238}U on the basis of the ratio ^{238}U/^{235}U= 137.88. Single analyses consisted of 30 seconds of background integration with laser off followed by 1 minute integration with the laser firing and a 30 seconds delay to wash out the previous sample and prepare the next analysis.

Data are corrected for U-Pb fractionation occurring during laser sampling and for instrumental mass bias by standard bracketing with repeated measurements of two GJ-1 zircon standards (Jackson et al., 2004) every eight unknowns. Repeated analyses of 91500 zircon standard (Wiedenbeck et al., 1995) at the beginning and the end of each analytical session and treated as unknown, independently control the reproducibility and accuracy of the corrections. Data reduction was carried out with the software package GLITTER® from Macquarie Research Ltd (van Achterbergh et al., 2001; Jackson et al., 2004). ^{230}Th disequilibrium was corrected according to Schärer (1984) and considering a Th/U_{melt} value of 3 ± 1. According to Ickert et al. (2015), the uncertainties related to these values are added to those incident to regression calculation. Calculated ratios were exported and Concordia ages and diagrams were generated using Isoplot/Ex v. 2.49 software package by Ludwig (2001).The concentrations in U-Th-Pb were calibrated relative to the certified contents of GJ-1 zircon (Jackson et al., 2004 standards. The zircon analytical results were projected on ^{207}Pb/^{206}Pb versus ^{238}U/^{206}Pb diagrams (Tera and Wasserburg, 1972), where the analytical points plot along a mixing line between the common Pb composition in the upper intercept and the zircon age in the lower intercept. This method is commonly used to date Phanerozoic zircons using *in situ* techniques (Baldwin and Ireland, 1995; Jackson et al. 2004).

LA-ICP-MS U-Th-Pb dating methodology, LMV, Clermont-Ferrand, France

Laboratory & Sample Preparation	
Laboratory name	Laboratoire Magmas & Volcans, Clermont-Ferrand, France
Sample type/mineral	Magmatic zircons
Sample preparation	Conventional mineral separation: Wilfley Table, heavy liquids, Frantz magnetic separator, handpicking under binocular microscope 1 inch Epotek® resin mount, 0.25um polish to finish
Imaging	CL, Jeol JSM-5910 LV, 15 kV, 19mm working distance
Laser ablation system	
Make, Model & type	Resonetics/M-50E 193nm, Excimer
Ablation cell & volume	Laurin Cell ® two volumes cell, Laurin Technic Ltd., volume ca. $1cm^3$
Laser wavelength	193 nm
Pulse width	< 4 ns
Fluence	$3 J.cm^{-2}$
Repetition rate	3 Hz
Spot size	33 and 40 µm
Sampling mode / pattern	Single spot
Carrier gas	100% He, Ar make-up gas and N_2 combined using the Squid® device from RESOlution Instruments.
Background collection	30 secs
Ablation duration	60 secs
Wash-out delay	30 secs
Cell carrier gas flow	0.70 l/min He
ICP-MS Instrument	
Make, Model & type	Element XR SF-ICP-MS
Sample introduction	Via conventional tubing
RF power	1200W
Make-up gas flow	0.98 l/min Ar
Detection system	Single collector secondary electron multiplier (Faraday cup)
Masses measured	204, 206, 207, 208, 232, 238
Integration time per peak	20 ms
Sensitvity / Efficiency	150 000 cps/ppm ^{238}U (47µm, 10Hz, $9J/cm^2$)
Dead time	6 ns
Data Processing	
Gas blank	30 second on-peak
Calibration strategy	GJ-1 used as primary reference material, 91500 and Plesovice used as secondary reference material (Quality Control)
Reference Material info	91500 (Wiedenbeck et al., 1995) Plesovice (Slama et al., 2008) GJ1 (Jackson et al., 2004) Temora (Black et al., 2003)
Data processing package used / Correction for LIEF	GLITTER ® (van Achterbergh et al., 2001)
Mass discrimination	Standard-sample bracketing with $^{207}Pb/^{206}Pb$ and $^{206}Pb/^{238}U$ normalized to reference material GJ-1
Common-Pb correction, composition and uncertainty	No common-Pb correction. Analyses discarded when discordance >10% (except for Cenozoic zircon grains reported in Tera & Wasserburg diagrams)

Uncertainty level & propagation	Ages are quoted at 2sigma absolute, propagation is by quadratic addition according to Horstwood et al. (2003). Reproducibility and age uncertainty of reference material are propagated.
Quality control / Validation	91500: Wtd ave $^{206}Pb/^{238}U$ age = 1066 ± 3 (2SD, MSWD = 0.3) Plesovice: Wtd ave $^{206}Pb/^{238}U$ age = 339 ± 2 (2SD, MSWD = 0.9) Temora: Wtd ave $^{206}Pb/^{238}U$ age = 415 ± 2 (2SD, MSWD = 1.2)
Other information	For detailed method description, see Hurai et al. (2010). For detailed laser technical description, see Müller et al. (2009).

U/Pb results from zircons grains of five ignimbrites

Alpabamba ignimbrite

A dataset of 33 U/Pb analyses of light pink to colorless, euhedral and prismatic zircon crystals was performed with 30 points yielding a lower intercept age of 20.13 ± 0.17 Ma (Fig. 8 and SD Table 2). The U-Pb age is interpreted as the crystallisation of the zircons. Three remaining grains are significantly older: one at about 32 Ma may have been inherited from the magma reservoir or during the magma eruption; two additional grains around 1.9 Ga are related to a contamination by the crystalline basement.

Chuquibamba ignimbrite

Zircon morphology is broadly similar to that of Alpabamba. Thirty analyzed zircon grains plot in concordant or sub-concordant position yielding a lower intercept age of 13.60±0.14 Ma (Fig. 8, SD Table 2). This age falls between the Ar/Ar ages (13.19-14.25 Ma). Interestingly, some Th/U ratios are higher that 1, pointing to a possible alcaline affinity of the magma.

Huarcaya ignimbrite

U/Pb analyses of 27 euhedral, colourless and elongated zircons yielded a lower intercept age of 10.78 ± 0.13 Ma (Table 2; Fig. 8, SD Table 2), which is interpreted as the time of crystallisation of the zircons in the magma reservoir. In this sample, the mean Th/U value of 1.6 suggests an alkaline magma source. U content c. 100 ppm of the zircons is low. Both parameters help to distinguish inherited zircon crystals with an age of 33 Ma. The radiogenic Pb content is especially low for zircons having the lowest U content, which move their analytical points toward the common Pb compositions. Consequently, the discordancy to common Pb composition is not related to the occurrence of common Pb into the zircon lattice but rather to a lower radiogenic Pb versus common Pb ratio, which is directly connected to U depletion in some grains.

Lower Sencca ignimbrite

Small, pink and prismatic zircon crystals from sample PIG-13-29 (n= 20) yield a lower intercept age of 4.32±0.06 Ma (Fig. 8, SD Table 2). A single inherited grain, concordant at

92±3 Ma, is most probably related to plutons of the Late Cretaceous ‘Toquepala’ arc. Zircons of PIG-13-25 and PIG-13-24 display a similar morphology than those of PIG-13-29 with a very pale colour. The 33 analyzed grains of PIG-13-25 define a lower intercept at 3.84±0.06 Ma (Fig. 8, SD Table 2). A similar result was obtained from the 29 analyzed grains of PIG-13-24 (Fig. 8, SD Table 2). In the latter sample, three inherited zircon grains define a lower intercept age of 11.23±0.27 Ma comparable to that of the Huarcaya ignimbrite.

Zircon crystals of PIG-13-27 (n= 33) yield a lower intercept age of 2.82±0.04 Ma (Fig. 8, SD Table 2). The high Th/U ratio observed in the four samples suggests an alkaline source. Similarly to the Huarcaya ignimbrite, the three last samples with U-depleted zircons (contents between 30 and 350 ppm) display significantly more discordant analyses than the U-enriched zircons from PIG-13-29, with a U content range between 500 and 2000 ppm.

Upper Sencca ignimbrite

Small, prismatic and colourless zircons from samples PIG-10-51 (n= 18) and PIG-11-43 (n= 21) yield lower intercept ages of 2.10 ± 0.12 Ma and 1.90 ± 0.11 Ma respectively (Fig. 8, SD Table 2). Owing to the low U content c. 100 ppm in both samples, the amount of radiogenic Pb is often less than 0.1 ppm, which is difficult to measure accurately. Consequently, discordance, MSWD and analytical uncertainty (about 6%) are large and both ages are undistinguishable.

Lomas PDC deposits

In PIG-13-12, 23 analysed euhedral, light pink zircons yield a lower intercept age of 1.54±0.04 Ma (Fig. 8, SD Table 2). U content is approximately twice as high as in Lower Sencca samples, providing a lower discordance, better MSWD and less analytical uncertainty. A significant number of inherited zircons are present; some with ages of 9.6±0.6 Ma may be possibly related to the Caraveli ignimbrite, while other with ages of 12.3±0.4 Ma and 30.9±1.0 Ma may be related to older ignimbrites.

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