Climate-controlled shifts in sediment provenance inferred from detrital zircon ages, western Peruvian Andes

Litty et al.

1 **SUPPLEMENTARY MATERIAL**

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3 **1. Age compilation and references of the coastal batholith intrusions**

4   Magmatic activity in the Lima segment is clustered in three intrusive episodes; 105-85 Ma ago,

5 75-56 Ma ago and 39-35 Ma ago (Wilson, 1975). In the Pisco-Ica region, intrusion has been dated at 96 ±

6 3 Ma (Beckinsale et al., 1985). Near Pativilca, the intrusion has an age of c. 37 Ma (McCourt, 1981;

7 Pitcher, 1985). Intrusions in the Arequipa region close to the Majes catchment show U-Pb crystallisation

8 ages of 90 Ma (Mukasa, 1986).

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10   **References supplementary material[1]**

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22   batholith (Ph.D. thesis): Liverpool, England, University of Liverpool, p. 299.

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25 **2. Method and sensitivity**

26   All grains were imaged by a ZEISS EVO 50 Scanning Electron Microscope at the University of

27 Bern in order to investigate their morphology and collect high-resolution images unravelling the internal

28 microstructures. The first observations on zircon crystals were realized by VPSE (Variable Pressure

29 Secondary Electrons Detector) using 20–10 kV, 100 μA beam current, ~10 mm working distance at ~20–

30 10 Pa chamber pressure, to examine the possible presence of inclusions of other minerals that can impact

31 the U-Pb isotopic results. The most suitable locations of the spots for U-Pb analyses were then selected on

32 the grain rims where neither inclusions nor strong chemical zonation were found (Fig. DR1). U/Pb

33 measurements were conducted at the Institute of Geological Sciences in Bern using a GeoLas-Pro 193 nm

34 ArF Excimer laser system combined with a quadrupole mass spectrometer. Ablation was done using an

35 energy density at the sample surface of 2.5 J/cm^2 with a repetition rate of 9 Hz using spot sizes of 24 μm.

36 Zircon standard GJ-1 (Jackson et al. 2004) and NIST SRM 612 have been used for quantification of

37 element concentrations. Accuracy and long term reproducibility was monitored using zircon standard

38 Plešovice (337.13 ± 0.37 Ma; Sláma et al. 2008; Fig. DR2). Data reduction for U/Pb-dating was done

39 using the software Iolite 2.5 (Paton et al. 2010, 2011) using Petrus and Kamber's (2012) Visual age data

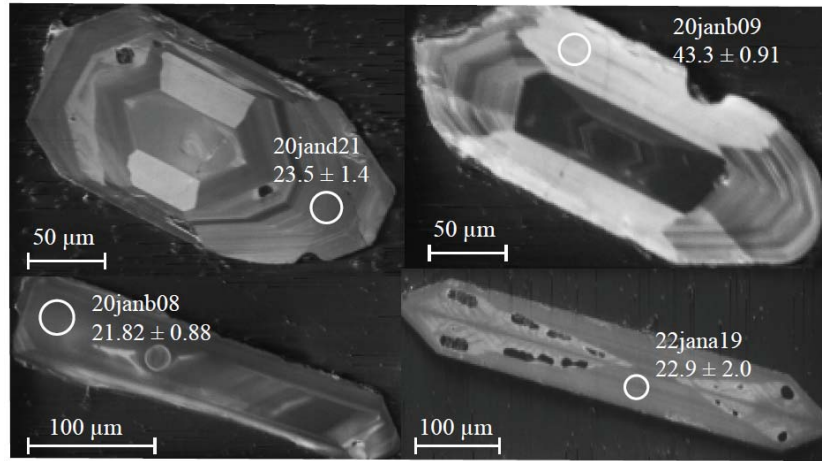40 reduction scheme and the error propagation method built into Iolite (Table 2).

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Figure DR1: Variable Pressure Secondary Electron (VPSE) images of four dated zircons of sample LIM-ME. The white circles indicate the positions of 24 μm diameter laser ablation pits used for ^{238}U-^{206}Pb isotope acquisition. The images show that the crystals dated at 20 Ma are mainly needle shaped zircons.
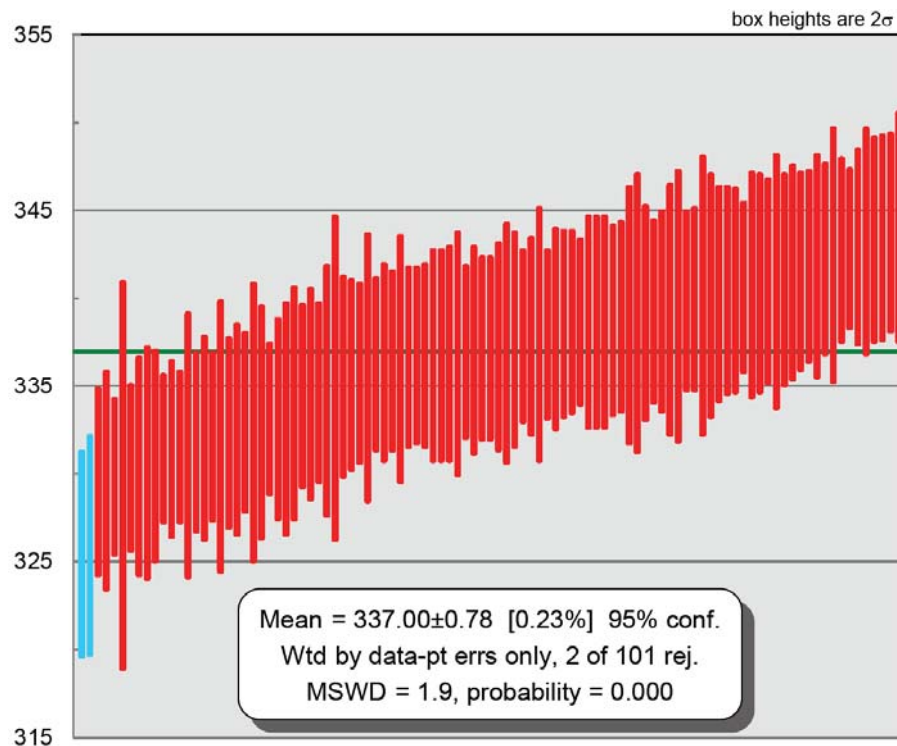

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Figure DR2: Graph of all the measured concordant Plesovice ^{206}Pb/^{238}U ages with 2σ error bars during dataacquisition for this study.

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49   One of the main problems in detrital zircon geochronology is to determine the minimum number

50   of grains to ensure that all populations are detected. In addition, the geological information that can be

51   extracted from a set of age data on detrital zircons is critically dependent on the number of analyzed

52   grains (Vermeesch, 2004). Indeed, a distribution with one single age cluster is unlikely to occur in natural

53   sediments. In a more realistic scenario, sediments may contain several age populations, each of which has

54   a non-uniform age distribution. Previous studies of sedimentary provenance that used U–Pb dating of

55   detrital zircons (Morton et al., 1996) have shown that precise and accurate U–Pb ages of 80 to 100 zircon

56   grains in each sample are needed for a reliable identification of the major sedimentary sources (Dodson et

57   al., 1988). However, Andersen (2005) suggested that the random fraction should comprise 35–70 grains

58   or more, depending on the complexity of the pattern at which ages are distributed. We only used grains

59   where the U-Pb ages were concordant.

60   Andersen (2005) suggested that the relative error in the population size decreases with increasing

61   number of analyses, but that this decrease occurs only slowly for small populations. The same author also

62   showed that the abundance of any zircon population amounting to less than ca. 10% of the analyzed

63   zircons is systematically underestimated in data sets comprising less than ca. 100 analyses.

64   Another important point is that sediment size strongly influences the provenance results. Looking

65   at the grain scale, Tertiary-aged grains along with those derived from the Coastal batholith are mostly

66   observed in the Lima catchment. However, Le Roux et al. (2000) have shown that the clasts in the Rio

67   Rimac (trunk stream of the Lima catchment) reflect the composition of the Coastal batholith, together

68   with Mesozoic rocks, while clasts derived from the Tertiary rocks are absent. This could indicate that the

69   Tertiary rocks, mainly exposed on the Altiplano, have been less eroded than what the detrital zircon signal

70   would imply. Such variation is highlighted in the probability density diagrams of the coastal samples,

71   which show that 20-Ma zircons are more abundant in the terrace deposits than in modern sediments. This

72   observation would infer that today, the major sediment sources areas are situated in the Coastal batholith

73   that is exposed along the middle reaches of the catchment. In contrast, the ages of detrital zircons

74   encountered in the terrace deposits at Lima were derived from both the Coastal batholith (middle reaches)

75   and the Tertiary rocks (Altiplano).

76   **References supplementary material[2]**

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Table DR1

Catchment	Sample name	Latitude (°S)	Longitude (°W)	Altitude (m)	Description	Age of the terrace	Trunk or tributary	Number of dated grains	Zircon age population (Ma)
Majes	PRC-ME702	16.0037	72.4759	700	Modern sand		Trunk	35	20 - 185
	CL-PE3	15.8691	72.45	870	Terrace matrix	100 ka	Trunk	22	25 - 120
Pisco	PRC-ME16	13.7285	75.8859	401	Modern sand		Trunk	48	62 - 90
	PI-DP	13.7285	75.8859	390	Terrace matrix	40 ka	Trunk	50	20 - 62 - 90
	PISCO2	13.5684	75.538	1247	Modern sand		Tributary	40	62
	PISCO3	13.5684	75.538	1247	Terrace matrix	40 ka	Tributary	39	62
Lima	LIM-ME2	12.02703	76.9903	229	Modern sand		Trunk	63	20 - 62
	LIM-ME	11.9165	76.6178	1110	Modern sand		Tributary	58	20
	LIM-PE1	12.121	77.044	64	Terrace matrix	Unknown	Trunk	47	20 - 45 - 62 - 80
Pativilca	PAT-ME	10.7174	77.7672	71	Modern sand		Trunk	46	35 - 250
	PAT-PE	10.7081	77.248	75	Terrace matrix	20 ka	Trunk	50	35 - 80 - 250

Table DR2