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THE AGE OF THE COSTA VERDE CONGLOMERATES IN LIMA: FIRST RESULTS OF THE BARRANCO SECTOR

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1. Introduction

The age and geological development of the alluvial fan on which Lima is built have been a topic of debate for a long time. The issue receives much attention amongst geologists and non-geologists because the fan terminates at the current coast line and forms up to 70-m-high cliffs which are one of the most well-known landmarks of Lima. But the absence of fossils, organic material and volcanic ash layers in the predominantly gravelly sediments has hampered the development of a temporal framework in which to place the geological development of the fan. Also the fact that the base of the fan is almost nowhere exposed makes it difficult to infer when the development of the fan begun. Volcanic tuffs in alluvial fans further along the coast have been dated at late Miocene with noble gas spectrometry using Ar-Ar (Noble et al., 2009) and it was proposed that the Lima fan should be from the same age (Noble et al., 2009). On the other hand, the recognition of four dubious distinct stratigraphic units in the Costa Verde conglomerates was tentatively tied to the last four Pleistocene glacial cycles by Le Roux et al. (2000). More recently, Villacorta et al. (2015) suggested that the fan gravels were deposited during the transition from glacial to interglacial condition as they claim to have found marine, interglacial sediments in the lowermost part of the Costa Verde gravels. The ideas put forward by all these authors remain speculative in the absence of a robust age chronology. For that reason, we initiated a combined effort to date the alluvial deposits with both ^{10}Be cosmogenic nuclide dating and optically stimulated luminescence (OSL) dating. A combination of both techniques has shown to improve the reliability of the age estimates of alluvial deposits (Viveen et al., 2012) and generally allows age calculations of up to ~1 Ma.

2. Methodology

The first batch of three samples was collected in the distal part of the fan in the Barranco district of Lima close to the "Club de Regatas" (Figs. 1 to 4). The samples were taken in PVC tubes hammered into three sand lenses with fine to medium-sized sands close to the surface of the fan up to a depth of ~16 m below the fan surface. The difficult access to the cliff and the scarcity of sand lenses with suitable grain sizes led to the collection of three samples at distinct sites, within a radius of approximately 500 m.

The samples were then prepared and analysed in the Luminescence laboratory of the University of A Coruña in Spain. They were dried and sieved under subdued red light and fine-sand sized quartz grains were obtained after an acid attack and density separation. The samples contained abundant fine sand quartz grains to be used for OSL dating. Small aliquots of quartz grains were mounted on stainless steel discs and measured in an automated Risø DA-15 TL/OSL reader system equipped with blue light-emitting diodes (LEDs) for stimulation of multi-grain

aliquots. OSL signals were measured with a coupled 9235QA photomultiplier tube using an optical Hoya U-340 filter to measure the UV range emission. Laboratory doses were given using a $^{90}Sr/^{90}Y$ beta source mounted on the reader giving a dose rate of 0.130±0.003 Gy s^{-1}.

The Single Aliquot Regeneration protocol (SAR, Murray and Wintle, 2000) was used. Around 50 accepted aliquots (N) per sample were used to estimate the ages and incomplete bleaching of many of the grains were observed.

High-Resolution Gamma Spectrometry was used to measure the ^{238}U and ^{232}Th decay chains, and ^{40}K activities, with a Canberra XTRA gamma detector (Ge Intrinsic), to estimate the annual dose rates. Conversion factors of Guerin et al. (2011) were used neglecting the alpha dose and correcting the beta dose-rate due to the HF etching of the outer quartz layers during quartz extraction steps. The cosmic dose rates were calculated according to Prescott and Hutton (1994).

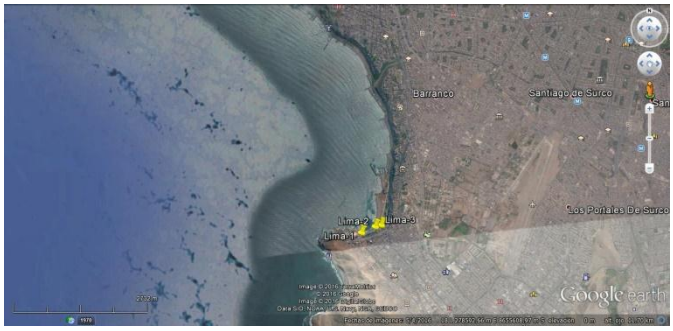

Fig. 1. Overview of the Barranco sector of the Lima fan.

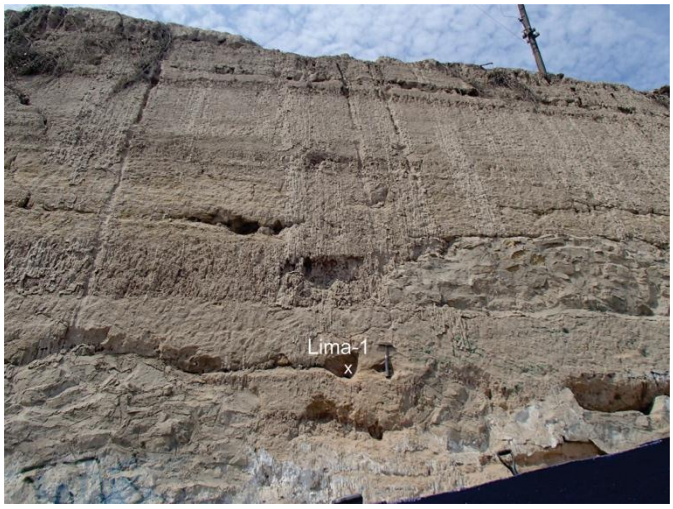

Fig. 2. Location of sample Lima-1

Fig. 3. Location of sample Lima-2.

Fig. 4. Location of sample Lima-3.

3. Results

Gamma spectrometry results indicate high content in radioactive isotopes, being ^{40}K activity concentrations around 600 Bq/kg. ^{238}U and ^{232}Th activity concentrations were around 30 and 40 Bq/kg, respectively.

OSL signals were bright considering the young age of the sediments. Evidences of incomplete bleaching of many of the grains were observed, above 50% for samples Lima 1 and Lima 2 and around 40% for sample Lima 3. Thus, the Minimum Age Model was used to assess the equivalent dose (Galbraith et al., 1999). This does not imply a

minimum age for the samples, though, but an absolute age.

The results (Table 1) indicate an age of 0,94±0,14 ka for the Lima 1 sample at 5.7 m depth; an age of 3,79±1,18 ka was obtained for Lima-2 at 15.2 m depth; and an age of 3,88±0,49 for Lima-3 at 16.3 m depth. The error of Lima-2 is rather large due to an incomplete bleaching of the quartz grains, but the smaller error of the positionally slightly lower Lima-3 sample gives a similar age, thus restraining the margin of error of Lima-2.

Table 1. Age estimates and dating parameters.

Sample	Depth (m)	DR (Gy/a)	ED	N	Age (ka)
Lima-1	5.7	3,02±0,28	**2,83±0,33**	**51**	**0,94±0,14**
Lima-2	15.2	3,08±0,37	**11,70±3,35**	**47**	**3,79±1,18**
Lima-3	16.3	3,13±0,38	**12,13±0,37**	**51**	**3,88±0,49**

4. Discussion

These surprisingly young ages might be related to three mechanisms: i) Only the upper part of the fan was dated, so it is likely that the underlying sediments, which attain depths of almost 600 m below fan surface level (Arce, 1984), are progressively older. Perhaps a continuous sedimentation has occurred since the onset of fan sedimentation which may extent back as far as the lower Quaternary (Le Roux et al., 2000) or even the Miocene (Noble et al., 2009); ii) The Barranco sector consists of extensive sand lenses whereas the other sectors of the fan further north are mainly gravels. Perhaps the Barranco sector comprises recent channel fills incised in a much older –perhaps even Miocene- fossil fan system; iii) These channel fills might either be the result of natural processes, but also be the result of prehistoric anthropogenic processes leading to erosion in the upstream part of the fan. The onset of human occupation on the fan, however, is still not well constrained.

5. Conclusions

The first results of dating the Barranco sector with Optically Stimulated Luminescence dating reveals that the upper 16 m of the distal part of the Lima alluvial fan is much younger than thought. Mid-to late Holocene ages indicate that fan activity during the Holocene was very high, which might be related to natural or anthropogenic processes further upstream. Continued OSL dating of sediments taken from the Magdalena sector of the Lima fan, as well as the results from the samples that are currently analysed for cosmogenic ^{10}Be concentrations, will hopefully lead to a better temporal framework for the entire Costa Verde area.

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