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Reassessing the seismic hazard in the Cusco area, Peru: New contribution coming from an archaeoseismological survey on Inca remains

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ABSTRACT

Devastated by two earthquakes in historical times (1650 and 1950 CE), the Cusco Basin is now characterized by dense and chaotic urbanization that makes it even more vulnerable. Unfortunately, the large recurrence intervals of the local crustal earthquakes, the shortness of the historical record (~500 yr) and the persistent lack of palaeoseismological studies hamper considerably the seismic hazard assessment. In such context, the outstanding archaeological heritage of the Cusco area turns out to be a relevant marker of past seismic activity.

We carried out a systematic archaeoseismological survey in nine Inca sites close to Cusco and registered almost 3,000 Earthquake Archaeological Effects. Thanks to a semi-quantitative approach, we show a clear anisotropic seismic deformation on the Inca fine stonework, consistent at the regional scale. In Cusco, the architecture exhibits the impact of two different and strong ancient seismic events (M.M. intensity > VII).

By combining these results with the analysis of historical photographs, our work supports, the occurrence of an unreported event during Inca times (~1400–1533 CE). More broadly, by providing new data on the destructive potential of past earthquakes, this study urges us to conduct further research on the faults near Cusco.

1. Introduction

Crustal faults in continental interiors constitute a direct threat for millions of people around the world (Silva et al., 2017). Despite its harmfulness, this type of hazardous faults remains understudied and hence underestimated (England and Jackson, 2011; Liu and Stein, 2016). The diffuse and unpredictable nature of intraplate earthquakes as well as the related long return periods (1–10 kyr) hamper considerably the seismic hazard assessment (SHA) based on instrumental data. The SHA needs, therefore, to rely on complementary and innovative approaches (McCalpin, 1996) such as geomorphology, historical seismology, palaeo- and archaeoseismology.

Lying within the "Pacific Ring of Fire" and characterized by the subduction of the Nazca plate below the South American plate, Peru is particularly prone to earthquakes (Oliver-Smith, 1994; Petersen et al., 2018). Regarding the active margin, several seismic disasters have punctuated its recent history and affected the populations (Lima 1746: Walker, 1999, 2018; Arica 1868: Seiner Lizárraga, 2013; Ancash 1970: Plafker et al., 1971; Caruso and Miller, 2015; Pisco, 2007: D'Ercole et al., 2007). Since then, much work has been done on this topic, contributing to improving the SHA and to size the prevention strategies (e.g., Pulido et al., 2015; Villegas-Lanza et al., 2016; Aguilar et al., 2017; Das et al., 2020).

On the contrary, the Andean highlands that extend on a large portion of the Peruvian territory and are crossed by many active faults, lack studies (Dorbath et al., 1990; Costa et al., 2006). Besides the instrumental network coverage that remains sparse, the absence of writings during pre-Columbian times constitutes an aggravating factor. In contrast to the Mesoamerican area (Garduño-Monroy, 2016; Suárez and García-Acosta, 2021), we cannot, therefore, rely on comprehensible reports of earthquakes before 1533 CE. This results in an incomplete seismic catalog, limited to the last 500 years, i.e. insufficient to cover the entire seismic cycle of crustal faults. The consequences of modern crustal and strong earthquakes such as the M_S7 1946 Ancash (Silgado Ferro, 1951), M_w5.6 1986 Cusco (Cabrera and Sébrier, 1998) and M_w5.4 2014 Paruro events (Tavera et al., 2014) urge for the development of innovative approaches in this part of the Andes.

The region of Cusco, which encompasses densely populated basins

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