Archaeoseismology in the Inka Sacred Valley and in the Cuzco region

An interdisciplinary approach for past seismic impacts characterization on Cultural Heritage as a new marker for paleoevents ?

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For several decades now, engineers **have assumed** that the Inkas developed seismic-resistant construction techniques. Did it reflect **a deliberate disaster risk management** strategy? – **Post-disaster** strategy? If so, which event? – Through an **archaeoseismological approach**, we hope to shed a new light on the close relationship between Inkas and earthquakes and thus provide a **valuable complement** to historical and paleoseismological investigations.

Geographical/Archaeological Context

Located in the southeastern part of Peru, the Cuzco region lays on the Eastern Cordillera of the Andes, more than **450 km away from the Pacific fringe**. Less affected by subduction activity than the Peruvian Coast, Cuzco region is nonetheless crossed by **large active crustal fault segments** that shape the landscape. Around 1400, that landscape turns into the focal point of the Inka culture from which florish and expand the Empire. This culture developed advanced skills in **dry and monumental masonry** (Fig.II) and is well-known for their perfectly fitting stones in Machu Picchu or Cuzco.

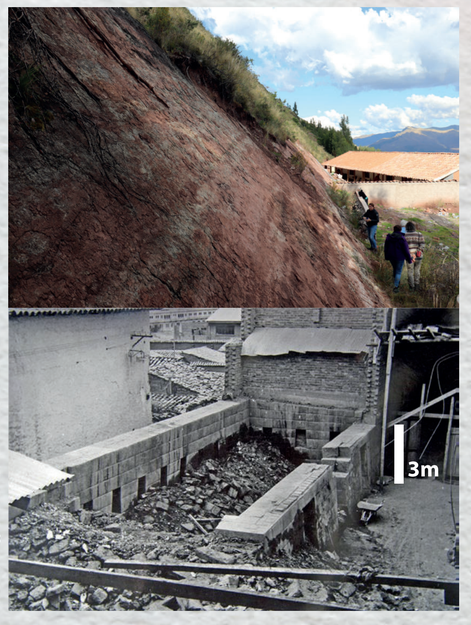


Fig.I *Picture of the Tambomachay Fault scarp above Cuzco*
Fig. II *Inka compound in the Qorikancha (Cuzco) after the 1950 earthquake (Ladrón de Guevara, archives)*

Objectives

While the Cuzco area exhibits a combination of **strong seismic hazard** (Fig.II-V) and **high vulnerability** through the presence of active fault segments in densely populated areas (Fig.I - Benavente *et al.*, 2013), the seismic risk remains **largely overlooked**.
By applying for the first time an archaeoseismological approach in Peru, we want to:

- **improve the seismic catalogue** (Fig.II) by detecting new paleoevents and providing complementary information (dating, location and intensity);
- **evaluate the Inka's risk perception** as well as the potential measures implemented by this society.
- **emphasize the importance of the seismic risk** to build new preservation and conservation plans for the Cultural Heritage.

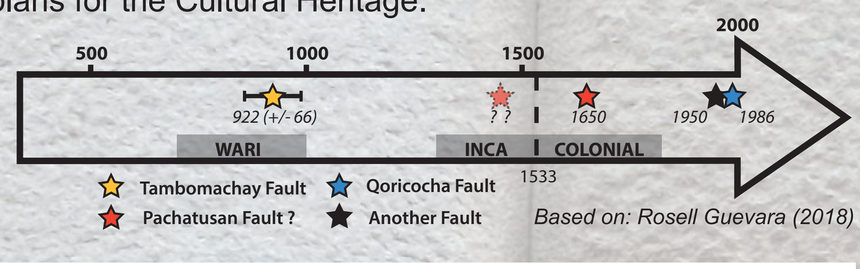
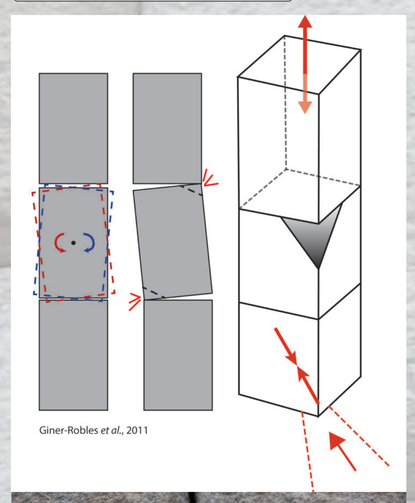


Fig.III *Large historical earthquakes that struck the Cuzco region.* *Based on: Rosell Guevara (2018)*

Methodology



From its beginning, archaeoseismological studies have been subject to **constant methodological debate and controversies** (Galadini *et al.*, 2006). That is why we decided to base our investigation on a **field-tested** approach. It is the **first attempt** to register and document a great amount of "Earthquake Archaeological Effects" (EAE) (Rodríguez-Pascua *et al.*, 2011) – defined as seismically induced disorders in archaeological buildings – in pre-Columbian architecture (Fig.IV). The method is based on the principle of **directionality** of the EAE (good indicators of the direction of deformation) that is now well accepted in the archaeoseismological community (Berlin, 2018).

To that end, we develop our own **database (RISC)** that deals only with the **short one hundred years** inka period. RISC allows us to a quick registration of the location (geographical and architectural), the type and the orientation (azimuth) of the damages as well as the probability of their seismic origin and indications about *post quem* and *ante quem* dating.

Fig.IV *Diagram of one of the most common type of EAE: the Dipping Broken Corner (DBC) with an illustrative example.*

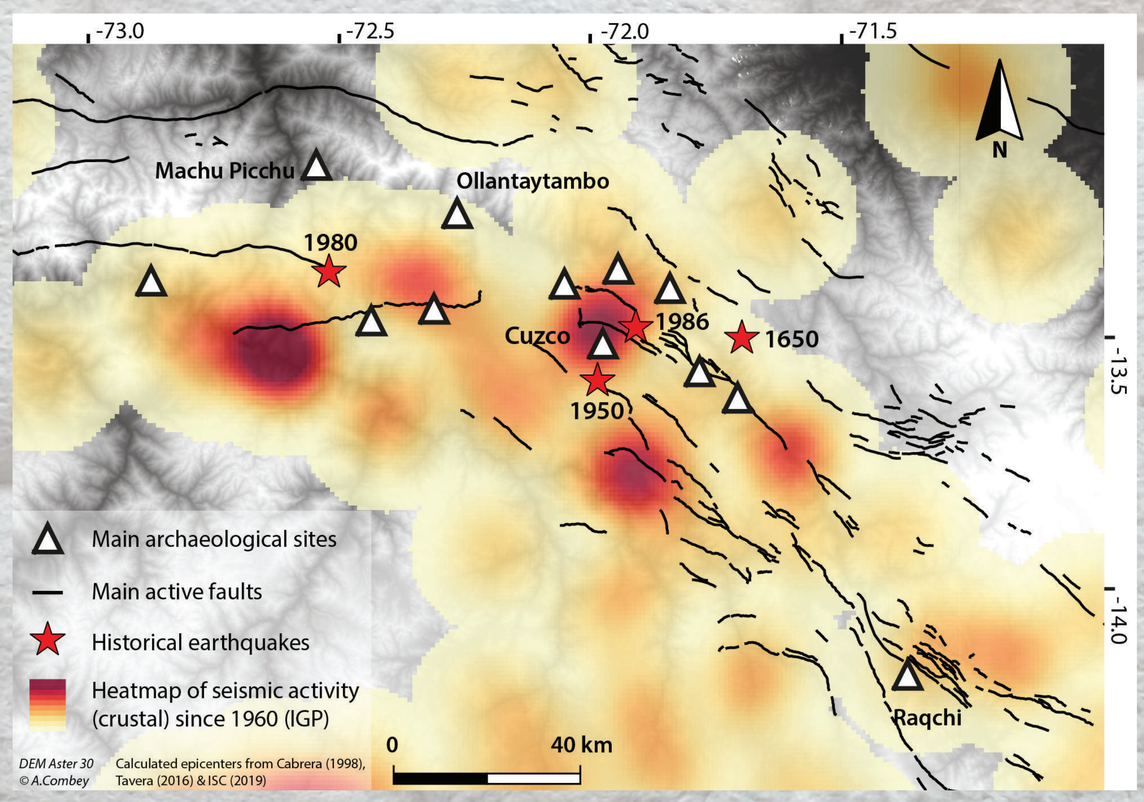


Fig.V *Map showing the «density» of crustal seismic activity in the Cuzco area since 1960 as well as the calculated epicenters of important historical earthquakes.*

Preliminary Results

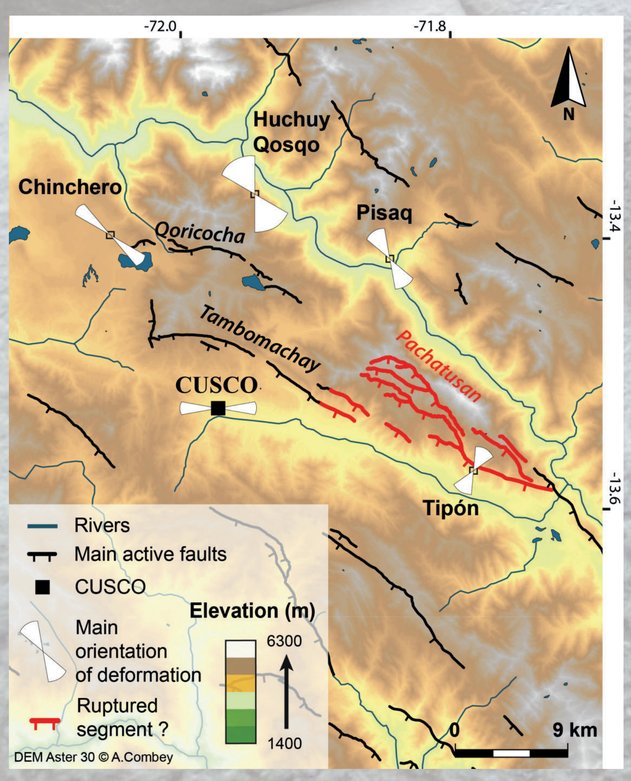


Fig.VII *Map of the Cuzco basin showing the main orientation of deformation calculated in various archaeological sites of the valley.*

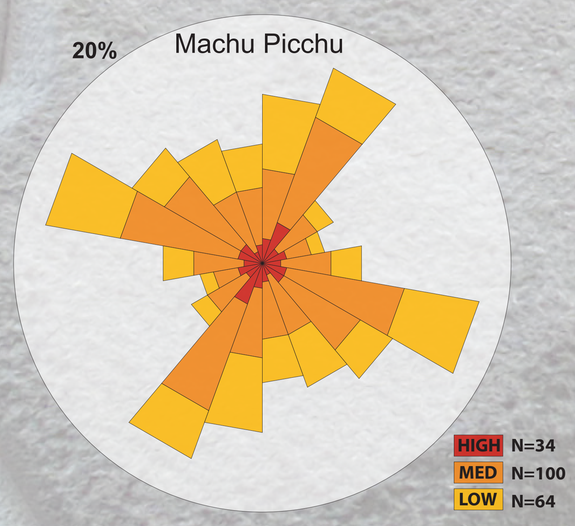


Fig.VI *One example of the Rose Diagram created from the Dip azimuth values of the Broken Corners. Categorized according to the level of confidence of the seismic origin.*

Discussion

1) The **large amount of EAE** (5273 records during 2 field campaigns) observed and registered in 17 sites, located in different geological contexts, are confirming the relevance of Inka sites as **good "seismoscopes"**(Fig.VI).

2) The data collected in **Machu Picchu** are **contradicting a deep-rooted idea**: the absence of seismic hazard in the archaeological site thanks to the batholith, that would mitigate the intensity of the seismic waves.

3) **Main orientations of deformation** in several sites appears to be exceptionally consistent, pointing at the Pachatusan fault complex located at the southeast of the city. Rose diagrams as well as paleotrenching and inka oral tradition are confirming the **occurrence of one large seismic event during or just after the inka occupation** ("prehistoric» or 1650 earthquake?) in this delineated area (in red, Fig.VII).

Conclusion

Our field campaigns carried out this year demonstrate the **relevance** of the archaeoseismological approach applied to inka sites. The interdisciplinary results are revealing the occurrence of **several seismic events** including the suspected "prehistorical" event. We call therefore for a **re-evaluation of risk mitigation plans** in cusquenan sites.

References

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