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Evidence of a large «prehistorical» earthquake during Inca times? New insights from an indigenous chronicle (Cusco, Peru).

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Abstract

A colonial chronicle written by the indigenous Peruvian author Pachacuti Yamqui Salcamaygua ([1613?]) relates a legend of the sudden appearance of a huge animal – kilometres in length and approximately 4 m in width – and described as the Andean snake-like deity *amaru*. Pachacuti Yamqui alleged that this fantastic event occurred on the day that the sovereign Pachacuti Inca Yupanqui's eldest son was born around 1440 CE, and was named “Amaru”. We suggest that the underlying event was an earthquake, and that the propagation of the surface rupture across the landscape resembled a sudden appearance of a snake-like being wriggling over the mountains and leaving an undulating surface trace. The concordance between the snake's route and the layout of a major fault complex above Cusco, as well as several ethnographic testimonies, support this hypothesis. Although little is known about pre-1532 CE seismicity, the current tectonic settings of the Cusco area point to seismic awareness of the Incas (ca.1300–1532 CE). Independent results from architectural and paleoseismological fields in the Cusco area corroborate a significant impact of large earthquakes on local societies. In Peru, without pre-Hispanic written sources, the oral folklore and traditions preserved in Spanish chronicles offer a relevant, but still underexploited resource for identifying paleo-extreme events. Combining multidisciplinary geomorphic observations, archaeological evidence and historical sources, we revisit this legendary episode and its possible implications.

1. Introduction

What could be the nature and degree of influence of thousands of years “long-term” geological dynamics on decade-scale, “short-term”, human expansion and evolution? Without considering and adopting a deterministic perspective, this question remains nevertheless worthy of debate (Force and McFadgen, 2010; King and Bailey, 2006; Nomade et al., 2016). Severely affected by floods, climate variations, volcanic eruptions, and earthquakes, the Andes appear to be suited well for assessing the influence of natural phenomena on past human societies. In Peru, particularly, numerous studies have demonstrated correlations between climatic events and the emergence or demise of archaeological settlements (Binford et al., 1997; Chepstow-Lusty et al., 2003, 2009; Christol et al., 2017; Sandweiss, 2003; Sandweiss et al., 2009, 1996). Volcanoes and sudden eruptions have also had a great impact on the worldview and organization of the pre-Columbian cultures (Bouysse-Cassagne, 2006; Bouysse-Cassagne and Bouysse, 1984; Chávez Chávez, 2001; Reinhard, 1983). Few academic investigations, however, seem to have focused on the impact of earthquake activity, and almost exclusively in the Mesoamerican world (Garduño Monroy et al., 2020; Garduño-Monroy, 2016). Although valuable work has been carried out in the aftermath of devastating earthquakes that struck the Peruvian coast during colonial and modern times (D’Ercole et al., 2007; Seiner Lizárraga, 2013; Walker, 2018, 1999), little has yet been done regarding pre-Hispanic seismic risk management and perception. Beyond megathrust earthquakes that affect mainly coastal areas, crustal faults within the Andes present a major threat for local populations as demonstrated by the 1946 Ancash (Silgado Ferro, 1951) and 1950 Cusco (Kubler, 1952) earthquakes. It therefore seems unlikely that earthquakes large enough to rupture the earth’s surface did not affect local inhabitants before the Spanish Conquest (1532 CE).

In the absence of an intelligible pre-Columbian writing system, indigenous oral tradition and folk tales preserved in colonial chronicles represent a particularly relevant source of information for the identification and perception of past disastrous events. Often disregarded for their lack of scientific rigor and chronological context, transgenerational oral memories originate, however, from empirical environmental knowledge that may describe true natural events in an alternative narrative system (Cohen et al., 2017; King et al., 2007; Masse and Masse, 2007; McMillan and Hutchinson, 2002; Nunn, 2014; Troll et al., 2015). Through a geological, archaeological and ethno-historical reading, we argue in this paper for a reinterpretation of an extract from Pachacuti Yamqui Salcamaygua’s chronicle (Pachacuti

Yamqui Salcamaygua, 1993). Recounting seemingly a mythological event, a passage from the *Relación de antigüedades deste reyno del Piru*, written in the mid-XVIIth century, alludes to the activation of the major fault system crossing the Cusco Basin. Dated around 1440, it might be the oldest seismic event reported by written sources in South America.

2. Background

2.1. Incas and ground motions

While earthquakes have frequently shaken the Cusco region (Peru) in the last 500 years, Spanish chronicles are surprisingly quiet about the occurrence of any seismic event during Inca times (ca. 1300–1532 CE). The only references to earthquakes before the Spaniards arrived are imprecise and come from secondary sources (Garcilaso de la Vega, 1609, pp. 477–Lib IX, CAP XIV; Silgado Ferro, 1978, p. 16). This situation is all the more striking because Bernabé Cobo mentioned in his *Relación de las guacas del Cuzco* (1979, pp. 16-Ch-2:1) the existence of a powerful Inca shrine, *Guaracince*, whose location was considered as the focal point of ground shakings. Convinced of the occurrence of destructive “prehistorical earthquakes” in the Cusco area, Bandelier (1906) was the first to address the issue of the perception of natural hazards by pre-Columbian societies. He demonstrated the relevance of examining and interpreting pre-Columbian legends and myths to assess the volcanic risk at this period, for the Quinsachata and Misti eruptions.

In spite of abundant evidence of destruction (burnt daub, collapsed walls, smashed vessels) registered in archaeological sites from the Late Intermediate Period (LIP: 1000–1400 CE) and Late Horizon (LH: 1400–1532 CE) around Cusco (Covey, 2006; Kendall et al., 1992; McEwan et al., 2005; Quave et al., 2018; Vargas P., 2007), very few were interpreted as consequences of earthquakes (Fig.1 – note A). The extended layer showing collapsed structures within the site of Warq’ana, near Huchuy Qosqo, constitutes unique evidence of a hypothesized seismic event in the Cusco area (Kendall et al., 1992, p. 224). Even recognizing that earthquakes do not provide the sole explanation of such types of evidence (instead, for example, of war, raiding, or ritual behaviour), the small number of inferences of earthquakes as the potential cause of destruction is particularly striking.

Recent paleoseismological and archaeoseismological research carried out within the Cusco region may shed new light on this topic. The paleoseismological trenches excavated in only two segments of the Cusco Fault System (Palomino Tacuri, 2020; Rosell Guevara, 2018 - Fig.1) indicate at least four large and crustal seismic events ($M_w > 6$) during the last three

millennia, and argue for a reappraisal of the seismic impact on Cusquenian populations. Although in its infancy, the results of an archaeoseismological survey in Machu Picchu attest to the occurrence of at least one major and regional earthquake during the occupation phase (Rodríguez-Pascua et al., 2019). Sudden and violent, this type of natural hazard may have generated stress and panic in the population, leaving its imprint in the pre-Hispanic worldview.

2.2. The *amaru* entity in the Andean worldview

In contrast to common snakes called *mach'aqway* in Quechua (Santo Tomás, 2003, p. 285), *amaru* describes a mythological and chthonian serpent-like monster (likened to the European dragon in the first Spanish description). Based on colonial definitions, the *amaru* was associated with snakes of great dimension (González Holguín, 2007, p. 408) and coming from the hot and humid Amazonian lowlands (Garcilaso de la Vega, 1609, pp. 196, 221; Huaman Poma de Ayala, 1979, p. 190). This deity, particularly important in the Andean pantheon, and having inspired names of Inca and indigenous leaders, as well as the appellation of the large Inca compound of Cusco, the Amarukancha, seems to have covered a wide spectrum of meanings and cosmologic notions. Urton (1981) described it as a double-headed and rainbow serpent whose extremities are anchored in water sources. Its relation with meteorological processes may have been much broader, such as associations of the *amaru* with the wet season, with water streaming or lightning (Boelens, 2014). Finally, as Hocquenghem (1989, pp. 212–213) explained, the rupture of equilibrium in the Andean conception of the world, called a *pachacuti*, is often synonymous with the liberation of an *amaru* and its subsequent petrification. Several phenomena could have triggered this disequilibrium: war, epidemics, floods, and earthquakes.

Snakes and earthquakes are commonly linked in human folklore, all around the world. The animal is often described as a reptile, a serpent, or even a dragon of great dimensions living underground (Ludwin et al., 2007, p. 88). Ground shaking, as occurs during earthquakes, is hence explained as the direct consequence of the movement of the serpent-like animal (Fig.2; Kirikov, 1992). The Chumash Indians that inhabited the south coast of California believed in the existence of two underground snakes that were responsible of the frequent ground shaking produced by earthquakes on the San Andreas Fault (Fradkin, 1999, p. 70). Although less common in Mediterranean legends, the snake or the dragon appears, nonetheless, as a secondary character (Piccardi, 2007, 2005, pp. 98, 103). If this quick overview does not

demonstrate a widespread representation of earthquakes by serpent-like entities in past human societies, it reveals at least a common association between this animal and the seismic phenomenon, based probably on environmental and ecological observations. Several references to the snake in the Andean mythology seem to endorse this assumption.

According to Martín de Murúa, a snake called *chipiroque* ou *pichiniqui* appeared to the Indians some time before the Huaynaputina eruption (1600 CE) to warn them about this subterranean punishment (Bouysse-Cassagne and Bouysse, 1984, p. 58). In the Huarochiri manuscript (Ávila, 1980), the appearance of an *amaru*, created by the pre-Hispanic deity *Huallalu Carhuinchu* during his legendary struggle with *Pariacaca*, is also accompanied by intense ground shaking. Similarly, a Jesuit text of 1624 (Polia Meconi, 1999, sec. 37) describes how the arrest of a sorceress that was breeding snakes in her house triggered lightning strikes and tremors. As a chthonian creature, related to the underground world, the serpent seems to be frequently related to earth motions in the Andean worldview (Gentile, 2017; Hocquenghem, 1989).

3. The study area - The Cusco Valley and its seismic setting

At an elevation of 3400 m, Cusco lies in the south-eastern part of Peru, in the Eastern Cordillera. The region displays a long human occupation that dates back to, at least, 10,000BP. Characterized, until the end of the Middle Horizon (MH: 600–1000 CE) by small-clustered polities, the Cusco Valley experienced then a gradual state formation process throughout the LIP (Bauer, 2018; Covey, 2006) that turned it into the geographical centre and political core of the Inca empire during the XVth century. Densely inhabited since the Formative Period (~2000 BCE–400 CE), the Cusco Basin has resulted from the continuous action of active tectonic processes, which probably foster human settlement.

The Cusco Basin is an intra-montane valley bounded along its northern margin by a complex of active crustal faults. Trending mainly NW-SE, the Qoricocha, Tambomachay, Pachatusan and Cusco normal faults control the subsidence and the filling of the basin (Benavente Escobar et al., 2013; Cabrera, 1988; Cabrera and Sébrier, 1998 - Fig.1). Overlying the Cenozoic and Mesozoic basement is a thick, extensive layer of unconsolidated lacustrine and fluvial sediment of Quaternary age (Gregory, 1916; Marocco, 1978). Suitable for water retention and farming activity that unconsolidated sandy sediment also amplifies seismic waves, producing major site effects and making the area more sensitive to ground motions than where rock is solid. Indeed, the lake deposits are ~300 m thick and show deformed

sedimentary structures (seismites), which are secondary effects of earthquakes (Benavente Escobar et al., 2013, pp. 27–44).

The active tectonic structures crossing the Heartland of the Incas are part of the Cusco Vilcanota fault zone (CVFZ) that generates frequent seismic activity (Fig.1). Historical documents refer regularly to *temblores* (slight shakings) that cause stress and panic (Esquivel y Navia, 1980; Gade, 1970; Palma and Biblioteca Nacional, 1901). Two violent *terremotos* (devastating earthquakes) in 1650 (Julien, 1995; Villanueva Urteaga, 1970) and 1950 (Ericksen et al., 1954; Kubler, 1952) led to these acute reactions. In terms of structural impacts, and despite their limited scope, both earthquakes destroyed buildings in the city of Cusco, and the main colonial structures in particular. The high level of amplification of the soft sediment lying in the Cusco valley-bottom explains a large part of the severity of the damage.

In terms of cultural impact, the high frequency of ground shaking (Silgado Ferro, 1978) has caused a persistent trauma in inhabitants' minds since the Spanish Conquest, while both maintaining and fostering a collective seismic concern. The Lord of the Earthquakes (*Señor de los Temblores*) cult, still celebrated each Holy Monday in Cusco, is one of the most salient examples. The intense devotion attached to the patron saint originated in the 1650 earthquake, but may have taken root in a pre-Columbian belief (Gade, 1970; Hajovsky, 2018; Rossano Calvo, 1994).

4. Methods

4.1. Historical material

Juan de Santa Cruz Pachacuti Yamqui Salcamaygua was an indigenous chronicler living during the XVIIth century. We know little about him, for his own writings constitute the only source of information. Native of the Canas-Canchis region, approximately 130 km southeast of Cusco, he claims a direct familial ascendancy in the local *curacas* of Guaygua Canchi, which soon converted to Catholicism. Through his *Relación de antigüedades deste reyno del Piru*, Pachacuti Yamqui (1993) claims to have written about the main events that shaped the history of Peru. Imbued with catholic references (Duviols, 2017), his text is, arguably too often, regarded exclusively as an early indigenous Christian worldview. Because of the direct influence and contribution of the oral tradition in his work, we consider this source particularly valuable for studying mythological stories coming from the local collective memory. In his presentation of the Inca sovereign Pachacuti Inca Yupanqui, Pachacuti

205 Yamqui wrote about a fantastic event that allegedly occurred the day of birth of the eldest son
206 of the emperor.

207 “In that time, they say that news arrived of a miracle in Cuzco, consisting of something
208 like a *yauirca* or *amaru* [snake in Aymara or Quechua, respectively – note B] that had
209 emerged from the mountain of *Pachatusan*, a very fierce beast, half a league long and
210 thick, of two and a half fathoms in width, and with ears and fangs and whiskers. And it
211 came by *Yuncay Pampa* and *Sinca*, and from there it entered the lake of *Quibipay*, and
212 so, two *sacacas* of fire came out of *Aosancata*, and [one] passed *Pontina* of *Arequipa*;
213 and the other came down to and passed *Guamanca*, where there are three or four very
214 high mountains covered with snow, those in which they say that there are animals with
215 wings and ears, and tails and four feet, and on top of their backs many spines like a fish,
216 and from afar they say that it appeared to them [to be] all fire. (f.21-21v / Translation
217 modified from Bauer and Dearborn, 1995, p. 148 – note C)

218 The extract cited above reports the sudden appearance of a snake-like animal, commonly
219 called *amaru* in the Andean mythology. Due to the importance of the event, the Inca
220 Pachacuti decided to name his son Amaru Tupa Yupanqui. The supernatural entity had
221 impressive dimensions: 2.75 km long and almost 4.2 m thick (note D). The quoted text
222 describes the pathways of the snake to different key places along the traces of active faults
223 that define the geologic landscape of Cusco. The snake appeared at Pachatusan (point 1 on
224 Fig.3), the highest mountain in the Cusco valley and considered sacred by the Incas (Silva
225 Gonzales and Loza García, 2007). The animal continued westward along the ridge crest that
226 borders Cusco to the north. It crossed “Yuncay Pampa” known currently as Yuncaypata (point
227 2 on Fig.3), a small locality 4 km north of Cusco, and then passed through “Sinca” that
228 corresponds to the Sinqa Mountain (point 3 on Fig.3). It finally vanished in the Quibipay
229 lagoon (point 4 on Fig.3).

230 The exact location of the latter remains unknown, up to now. Mentioned a second time in the
231 book by Pachacuti Yamqui, the place was defined as a flat area where Atahualpa gathered the
232 main ethnic leaders of Cusco after the final battle against the Huascar’s army (Pachacuti
233 Yamqui Salcamaygua, 1993, p. 178 f.42). Others placed it one league, i.e. approximately 5
234 km, from Cusco (Mendiburu, 1902, p. 74), west of Cusco behind the Sinqa Mountain
235 (Zuidema, 1974, p. 215), or north-east of Cusco (Gentile, 2017, p. 310).

236

4.2. Geomorphological analysis

We combined the analysis of the historical source with a geomorphological and neotectonic investigation. Topographical data from the Cusco Basin were processed using two Digital Elevation Models (DEM). The creation of a high-resolution DEM (1.5m) based on Pleiades images and covering the western part of the Cusco Basin allows us to relate the location of the Quibipay lake with a classic feature of tectonic geomorphology. To this end, topographic features were studied thanks to basic GIS analysis including a slope map, hill shadings, and topographic profiles.

Based on a larger ASTER DEM (30m) we executed a “visibility analysis” from the archaeological site of Amaru Marka Wasi, settled on a calcareous plateau above Cusco (AMW on Fig.3). Composed mainly of rocky outcrops containing carvings this site was the seventh shrine of the first *ceque* of the Antisuyu (An 1:7 in Bauer, 1998, p. 76). Considered to be the former residence of the eldest son of the sovereign Pachacuti Inca Yupanqui, the site most probably was dedicated to ceremonial activities. Due to its sacred character, its geographic proximity with the localities mentioned in the story, and its direct relation with Amaru Tupa Yupanqui, we considered it worth questioning the link that may have existed between the outcrop and the Amaru story. The “visibility analysis” realized thanks to Global Mapper software allows us to display the area visible from the summit of the outcrop. This particular GIS analysis highlights the main features of the environment visible from the site and provides some indications of its ceremonial purpose. We fixed as initial parameters an observer of 1.65m tall and, a visibility radius from 20 km, and we kept the standard value of atmospheric correction (1.333 - Brunner, 1984). Field reconnaissance carried out around the archaeological site allowed to validate the region visible from the site. Finally, the GIS platform enabled us to cross check the results with places mentioned in the text and distribution of the main faults (Benavente Escobar et al., 2013).

5. Results and discussion

5.1. Archaeological places as “geolandmarks”?

The present analysis led us to identify a small community now belonging to the extended agglomeration of Cusco, Cruz Verde de Quehuepay (Point 4 on Fig.3), as the former Quibipay plain and lagoon mentioned in the text of Pachacuti Yamqui. As commented in 4.1., this place seems to have held a special significance for the inhabitants of the Cusco region,

since it is the place chosen by the sovereign Atahualpa and his court to speak to the main kin groups and to request their obedience after he defeated his brother's army.

The etymological similarity of Quehuepay and Quibipay as well as its distance from the Cusco historic centre (less than 4 km westward) strongly support the placement of the Quibipay lagoon in Cruz Verde de Quehuepay. In spite of the present dense urbanization, the new high-resolution DEM clearly highlights two important facts. First, Cruz Verde de Quehuepay occupies the flattest part of the area (~2% of declivity) and lies against the Cusco fault scarp (CVQ on Fig.4). Second, the small lagoon seems to have formed as a sag pond, a classic feature of tectonic geomorphology (Burbank and Anderson, 2011) that develops where ruptures bend or where fault segments are offset from one another; in either case the floor of the pond drops with respect to surroundings during recurrent seismic rupturing (Fig.5).

Hence, the Quibipay plain, as well as the other toponyms mentioned in the legend, can be associated directly with active tectonic structures and supports a seismic interpretation of the Pachacuti Yamqui's extract. Three large fault segments run through the region where the legend takes place (the Cusco, Tambomachay and Pachatusan faults) and match with the Amaru's route (Fig.3).

The "visibility analysis" computed from the high-resolution DEM at Amaru Marka Wasi enhanced the observation that standing atop the rocky promontory it is possible to see each of the places mentioned by Pachacuti Yamqui (Fig.3). Instead of providing an overview on the Cusco valley bottom and the Inca city, the archaeological site offers a wide panorama of the mountain ridges bordering the northern part of the Cusco Basin. The Tambomachay fault, which runs all along the mountainside, marks a clear topographic anomaly and forms the most salient element of the landscape (Fig.6).

It is even more striking that all the sites mentioned in the legend and settled along the fault segments contain important venerated places. Pachatusan, Picol and Sinqa were three of the six most important sacred mountains in the Cusco region and hosted places of worship. Not only was Paukarcancha (Pa in Fig.3), an important ceremonial and pilgrimage site displaying Inca material, built on the top of Pachatusan (Bauer, 1998, p. 94; Silva Gonzales and Loza García, 2007), but the Picol summit (Pi in Fig.3) and the Sinqa *waka* located on the southern flank of the Sinqa Mountain (Si in Fig.3) were also significant places of offerings. We suggest that just as ceremonial sites in the southern part of the Inca Empire are associated with volcanoes (Chávez Chávez, 2001; Reinhard, 1983), the sacred dimension of some Inca shrines of the Cusco Basin are related to this tectonic landform resulting from active faults.

5.2. A wavy fault scarp

Based on anthropological studies, Zuidema (1974, p. 215) interpreted the snake described in the Pachacuti Yamqui story as a metaphor of a rainbow. Unable to verify the veracity of this association, however, he simply offered a conceptual discussion about Andean mythological representations. Nonetheless, Bandelier (1906) and Gentile (2017) have noticed the geological interest of the passage, and postulated yet, without providing convincing arguments, the hypothesis of a volcanic eruption or seismic event.

In the landscape above Cusco, anywhere fault scarps cut moraines as in Tambomachay, Pachatusan or many other localities, a peculiar feature stands out: a serpent-like form of the scarp (Fig.7). Moreover, in some interviews in the Huancavelica province (Zuidema, 1967, p. 49) as well as in our conversations in the southern part of the Cusco region (Sicuani), local people have described openings in the ground or cracks as “amaru”. Cristóbal de Albornoz (Duviols, 1967, p. 23) corroborates the frequent association of snakes and geological features in the Andean mythology. The reader may notice that the little *quebrada* north of Picol summit and driven by one Pachatusan fault segment is currently called Amaro (Fig.3). We can easily suppose that pre-Hispanic populations observed the undulating form of the fault trace in the landscape and tried to relate it to something familiar. It is noteworthy that the size of the creature could be consistent with a segment of a surface rupture approximately 2.5 kilometres long and an opening of several meters in width. Relying on rupture of such dimension and considering the seismic disaster of 1950 only associated with small-scale surface rupturing (Cabrera, 1988; Ericksen et al., 1954), we postulate that this “prehistorical” earthquake generated its highest intensities within the Cusco Basin.

Normal faults, which mark the fronts of many of the ridges in the Cusco region (Benavente Escobar et al., 2013) differ from strike-slip faults, like the San Andreas Fault in California, whose traces at the earth's surface are straight for tens of kilometres. Instead, normal faults, commonly consist of short segments – a few kilometres long – that, when linked together, form an escarpment that undulates across the landscape. Thus, whereas the trace of a strike-slip fault bears little resemblance to a snake, linked normal-fault segments can easily engender such an image, especially during trauma induced by severe ground shaking. Moreover, when an earthquake occurs, slip does not suddenly, and simultaneously, occur on all of the linked fault segments; rather, slip initiates at the epicentre, and the locus of slip propagates away from it at a speed of ~1-3 km/s. Thus, for a fault that is, say, 30 km long and visible to a single observer, approximately 10 to 30 seconds will elapse as the locus of slip

wriggles across the landscape from start to finish. As slip on faults during earthquakes commonly occurs at ~1 m/s (Bizzarri, 2012; Brune, 1970), and total amounts of slip during earthquakes of the magnitude that have caused damage in the Cusco region are commonly 1-2 m, slip at any point on the fault will last ~1-2 seconds. Thus, slip within a segment of the rupture will occur concurrently, but segments several kilometres apart will not slip simultaneously, enhancing the undulating and emerging serpent-like aspect of the landform (Fig.7).

As explained in 2.2., the emergence of a chthonian creature within the world of the living was understood in the Andean worldview as a *pachacuti*, a time and space upheaval, disturbing the entire course of action (Bouysse-Cassagne and Bouysse, 1984, p. 57; Huaman Poma de Ayala, 1979, p. 68). The *amaru* in Quechua and its rough translation *yauirca* in Aymara (Bertonio, 1879, p. 396), correspond to one of these subterranean entities that may surge in the context of destructive events such as landslides and earthquakes. The monstrous creature remains then petrified and turns one landscape feature into the remnant of a geological phenomenon (Hocquenghem, 1989, pp. 212–213). The landmark is thus the sign and metonymy of the *pachacuti* and the restoration of order. A document from the *quipucamayocs* seems to confirm the occurrence of a *pachacuti* in the region during Inca times and its close relation with the Quibipay place, identified in this work. That document, indeed, quotes the following words of the Atahualpa generals addressed to the ethnic leader in Quibipay after the fratricidal war between Atahualpa and Huáscar: “**once again** should begin (a new world) of Ticcicapac Inga” (Randall, 1987, p. 92). The Atahualpa generals consider their victory over Huáscar as a new upheaval and seem to refer to a previous one that would have taken place in Quibipay. Despite the less devastating impact of a tectonic event, we can easily consider a large fault rupture affecting the capital of the Inca Empire as a tremendous turmoil.

5.3. “And so, two sacacas of fire came out...”

The second part of the extract from Pachacuti Yamqui Salcamaygua’s chronicle deals with the simultaneous appearance of two balls of fire (*sacacas*). The meaning of this Aymara word is not entirely clear, but could be defined as a fire emanating visibly in the sky, and different from comets, which are called *wara-wara hali* by Aymara speakers (Bertonio, 1879, p. 304). Previous studies did not establish a direct link between this celestial event and the occurrence of the snake. These “fire exhalations” were understood as merely simple falling stars or indirect evidences of the eruption of El Misti (hundreds of kilometres to the west near

Arequipa) dated between 1440 and 1470 CE (Bandelier, 1906; Thouret et al., 2001). We suggest two new possible interpretations of this phenomenon.

During colonial times tremors in Cusco were frequently symbolically associated with celestial events (Anónimo, 1819; Esquivel y Navia, 1980). Although we are not able to explain why both phenomena are commonly linked, the appearance of a comet could be mentioned as a divine sign after a catastrophe. The great influence of Christianity in the writings of Juan de Santa Cruz (Duviols, 2017) would support that hypothesis. The second explanation is based on the still poorly explained, but sometimes observed “earthquake lights” (EQL) that have been reported before or during the ground shaking from major earthquakes (Fidani, 2010; Stothers, 2004; Whitehead and Ulusoy, 2015). The *sacacas* could be an expression of fireball-like lights described in various places such as in Lima during the 2007 Pisco earthquake (Heraud and Lira, 2011) as well as in L’Aquila in 2009 (Fidani, 2010). Theriault *et al.* (2014) noted that reports of earthquake lights seem to be more common in tectonic environments with crustal extension such as the Cusco Basin.

6. Conclusions

In ancient and modern Peru, earthquakes frequently shook the ground, modified the landscape, and devastated human settlements. In Cusco, time after time, people built and rebuilt monumental architecture in the vicinity or even along seismically active faults. Ongoing research indeed demonstrates the resilience of Inca buildings affected by past earthquakes (Hinzen and Montabert, 2017; Rodríguez-Pascua et al., 2019).

How much the Incas knew about earthquakes and faults is unclear. Described as a small piece of land where ground motions occurred, *Guaracince* (Ch. 2:1 - Cobo, 1979, p. 16) constitutes a unique direct reference to an Inca worship site related to earthquakes. Our interpretation of the latter myth suggests nonetheless that the relationship between ceremonial Inca sites and regional faults may be much closer and that modern archaeology and anthropology may have underappreciated the cultural significance of earthquakes for the Inca culture. This situation echoes the well-established influence of the tectonic environment on the development of sanctuaries in the Aegean area (De Boer and Hale, 2000; Partida, 2017; Stewart and Piccardi, 2017).

Historical and “prehistoric” seismicity must deal with large earthquakes that predate instrumental seismology. Without an instrumental record, the identification and characterization of ground-shaking episodes require a multi-proxy approach, combining

analyses not only of paleoseismological trenches and sediment cores, archaeological and neotectonic observations but also interpretations of (ethno)historical sources.

Given that first generation accounts from Spanish chroniclers did not mention any major ground-shaking episodes in the Cusco region during pre-Columbian times, the reader may legitimately wonder why we have based our discussion on a later indigenous chronicler. Although descendants of Inca people do not seem to have referred directly to such violent natural phenomena, we argue that earthquake stories may still be “hidden” in mythological episodes told to the first *conquistadores*. We consider thus the Amaru tale extracted from Pachacuti Yamqui’s chronicle as a relevant example of a disastrous event preserved indirectly in a legendary story and transmitted over several generations. The “seemingly mythological” content of the *Relación de antigüedades deste reyno del Piru* does not preclude its analysis as a valuable source of information. Moreover, it suggests that an earth science-based approach can offer relevant insights regarding the nature and origin of myths in a given geodynamic and cultural setting.

Thus, despite the metaphorical dimension, various elements make the seismological interpretation of the legend plausible and worthy of consideration. We summarize again the arguments, enounced above, in favour of our hypothesis:

- the similarity of the Amaru’s route to the layout of the main Cusco fault complex;
- in the south-eastern part of the Cusco region, indigenous people describe faults scarps as “amaru”.
- the lake where the snake vanished might be interpreted as having been a sag pond. Quibipay, known currently as Cruz Verde de Quehuepay, lies at the foot of the Cusco fault scarp; the snake diving into the water would be therefore a metaphor for the rupture ending in the lake.
- bright lights likened to fire described in the same extract by Pachacuti Yamqui might be linked with earthquakes, given the recurrent association of comets with earthquakes in colonial texts or as the occurrence of “earthquake lights”.

Following the traditional chronology of the Inca emperors made by John Rowe (1945, p. 277), we date the potential earthquake, which occurred apparently around the December solstice (*Qhapaq Raymi*), between approximately 1438 CE (the beginning of Pachacuti’s reign) and 1463 CE (when the second son of Pachacuti took command – note E).

Finally, this study highlights the relevant contribution that legends and myths in past risk perception and management may bring. Due to the mythological content, inherent to this type

of source, geologic phenomena remain roughly constrained in terms of chronology. However, folk tales and testimonies have yet proved their worth for describing pre-instrumental earthquakes, in particular, in the San Andreas Fault region (MacLean, 1979; Meltzner and Rockwell, 2004). A renewed paleoseismological and archaeoseismological effort is needed to confirm the occurrence of such large seismic event during Inca times and affecting the Cusco Basin. Improved characterization and mapping of the destructive evidence affecting the LIP and LH settlements would provide useful complementary data.

According to the World Bank's Independent Evaluation Group, the number of events considered as natural disasters grew by 200% between 1975 and 2015, which demonstrates the increased threat for our modern societies (CRED, 2015; IEG, 2006). Increasing resilience to future earthquakes in the Cusco area will require fostering innovative approaches to address past human coping strategies. Cross-disciplinary interactions are shown here to be necessary to study such an historic area, ranging from human and social sciences (e.g. archaeology, history, anthropology, sociology...) to physical and natural disciplines (e.g. geology, seismology, hydrology, and geography) and engineering (e.g. architecture), with each, from its own perspective, providing new interpretations for improving hazard assessment.

Footnotes

A) We are not claiming in any way that the earthquake occurrence may explain all the evidence of destruction registered during the Killke (LIP) and Inca (LH) periods. Bearing in mind the absence of consideration of earthquakes in almost all the investigation interpretations, we may nonetheless wonder to what extent the current lack of awareness of the seismic risk might have affected interpretations of the archaeological records. We thus stress the need for future investigations to take into account the impact of this natural hazard.

B) Juan de Santa Cruz Pachacuti Yamqui Salcamaygua came from an Aymara-speaking area, but in process of "Quechuaisation" during Inca and colonial times (Itier, pers.comm.). This particular situation explains the combined use of those two languages in his chronicle.

C) "En este tiempo dizen que llegó la nueba como en el **Cuzco** ubo un milagro que como un **yauirca** o **amaro** abía salido del serro de **Pachatusan** muy fieria bestia, media legua de largo y grueso de dos bragas y medio de ancho, y con orejas y colmillos <y barbas>¹. Y viene por **Yuncay Pampa** y **Sinca**, y de allí entra a la laguna de **Quibipay**, y entonges salen de **Aosancata** dos **sacacas** de fuego, y passa a **Potina** <de **Ariquipa**>, y otro viene para más abaxo de **Guamanca**, que está y tres o quatro serros muy altos cubierto de niebes, los quales dizen que eran animales con alas y orejas y colas y quatro pies, y ençima de las espaldas muchas espinas como de pescado, y desde lejos dizen que les parecían todo fuego." (Pachacuti Yamqui Salcamaygua, 1993, p. 157-f.21–21v)

¹ *Por caussa deste amaro puso por nombre a su hijo Amaro Yupangui* (A III).

- D) We consider 1 league = ~ 5.5km and 1 fathom = ~ 1.6718m (Bauer, 2018, p. 47)
- E) We base our chronological interpretation on the traditional Inca's chronology elaborated by John Rowe. He considered that Pachacuti Inca Yupanqui ruled between approximately 1438 CE and 1471 CE, based on colonial texts and calculations of the number of years remaining until the Spanish Conquest. Since he died quite old (~70-80) according to chronicles, it seems probable that Amaru Tupa was born around 1440 CE. Our assumed dating is, for sure, tentative due to the questions that still surround Inca genealogy and succession (Duviols, 1979; Marsh et al., 2017; Meyers, 2019; Ogburn, 2012), but should be regarded as a baseline for future paleo-and archaeoseismological investigations. The assumed relation between the Amaru legend and the name of the eldest son of the emperor Pachacuti justifies the dating attempt.

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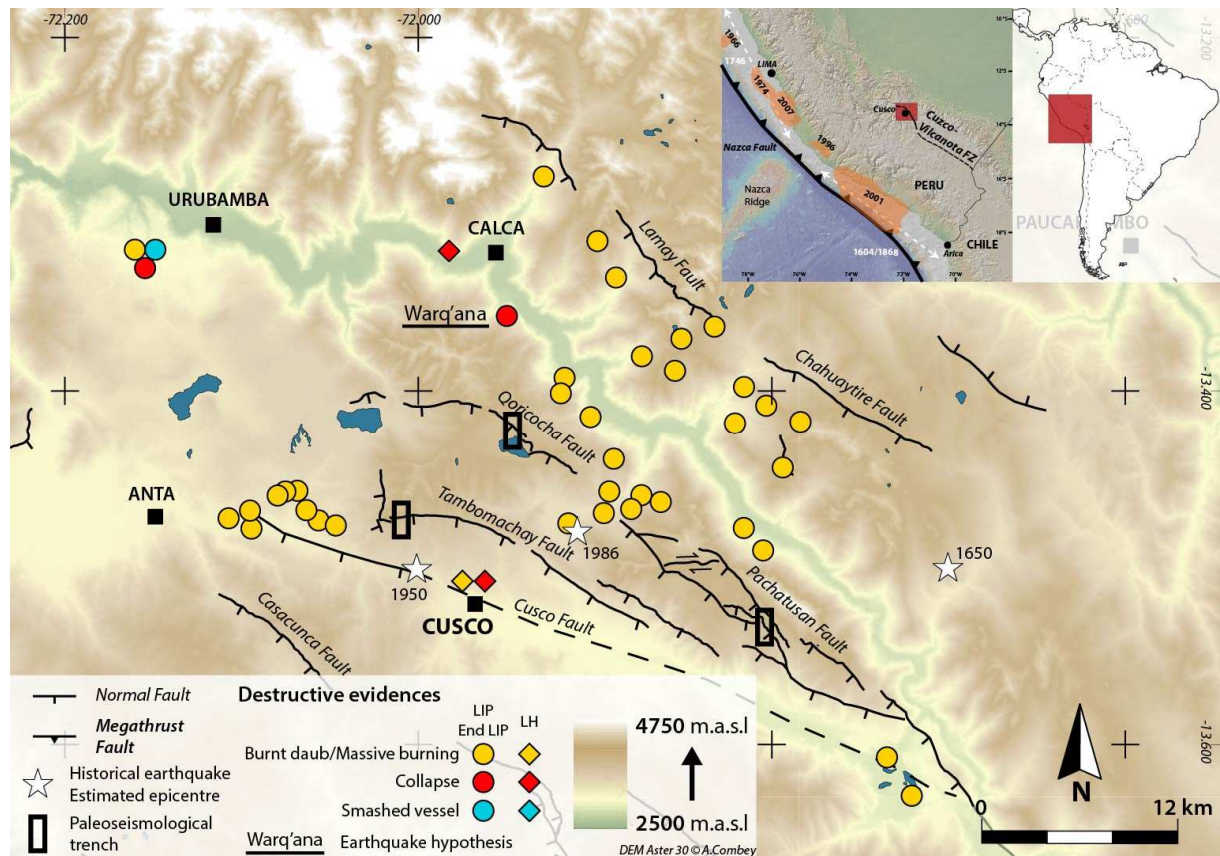


Fig.1. Map listing the archaeological evidence of destructive events (without a determined origin) dated from the Late Intermediate Period and the Late Horizon in the Cusco area (Covey, 2006; Kendall et al., 1992; McEwan et al., 2005; Quave et al., 2018; Vargas P., 2007). The earthquake hypothesis was only alleged in one case.

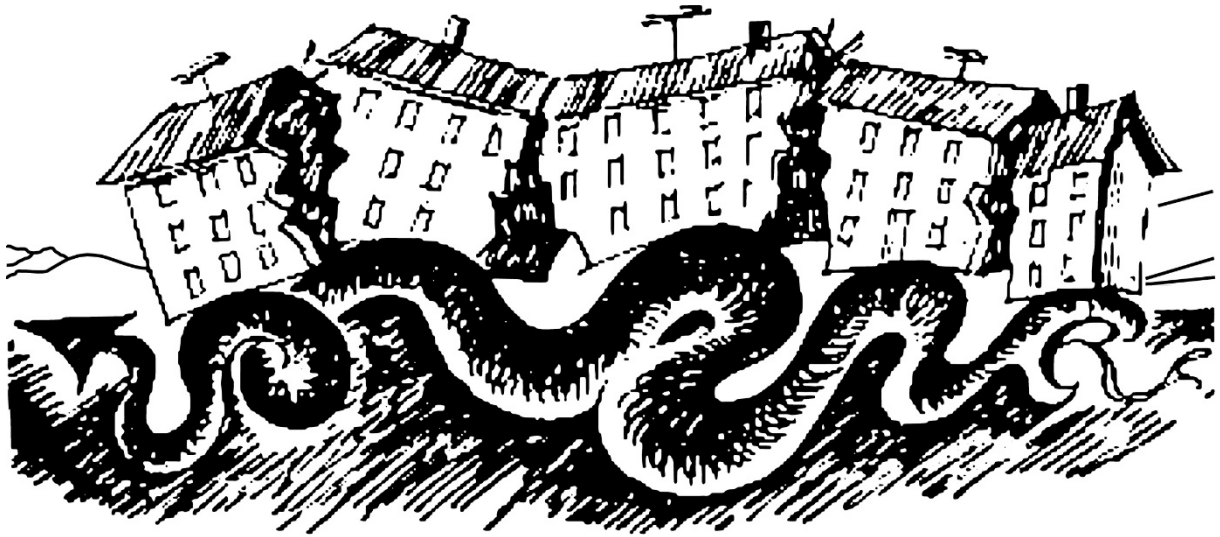


Fig.2. Wiggling of a Dragon-like creature as a metaphor of the ground motion during an earthquake: “let us resort to some imagination to fancy the picture of ground motion under a structure during an earthquake. In my opinion, it can be best illustrated by an image of a gigantic snake-like dragon moving under the building by throwing its body into vertical loops” (Kirikov, 1992, p. 11).

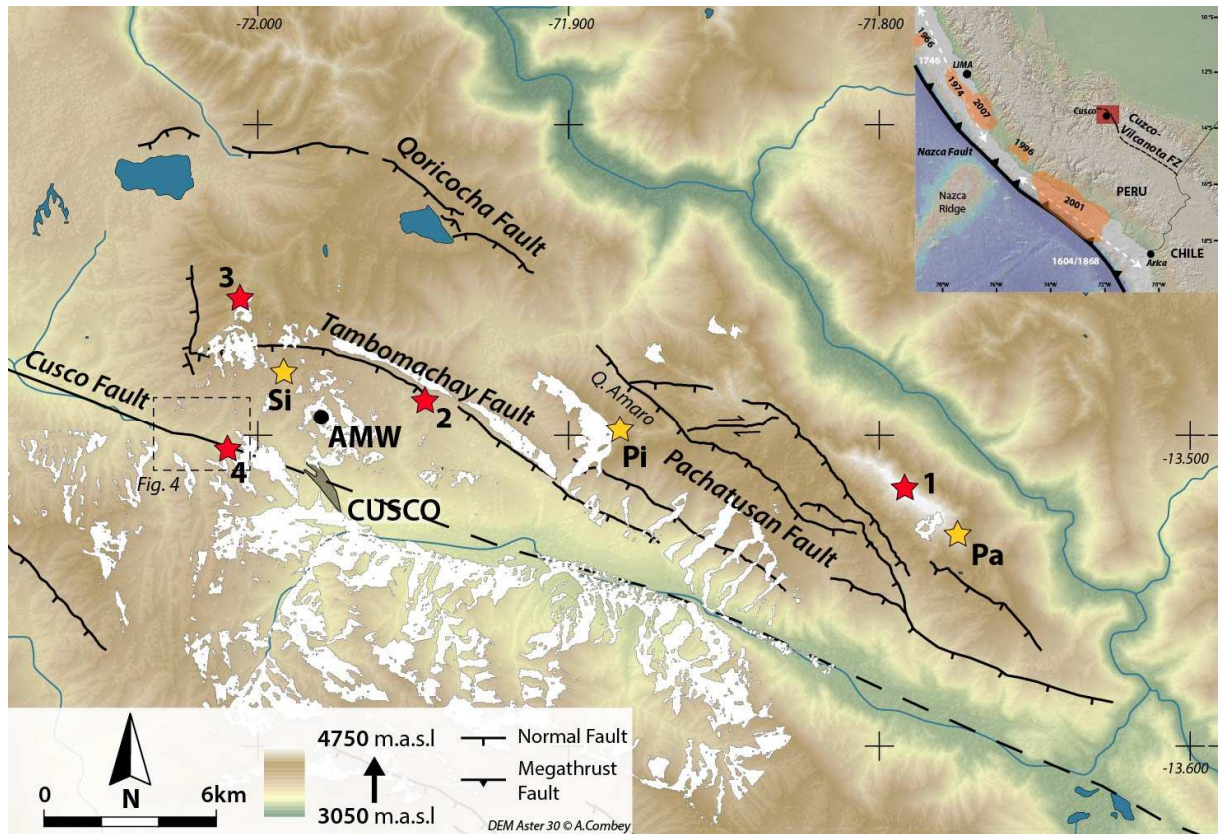


Fig.3. Map of the Cusco valley showing the layout of the Pachatusan-Tambomachay-Cusco Fault System as well as the geographical places (red stars) mentioned in the Pachacuti Yamqui's text. 1- Pachatusan; 2- Yuncaypata; 3- Sinqa summit 4- Cruz Verde de Quehuepay. "Pa" refers to the Paukarancha site, "Pi" to the Picol summit and "Si" to the Sinca huaca. White areas show what can be seen from the Amaru Marca Wasi site (black point, AMW) and therefore highlight that large segments of the fault system are visible from that spot.

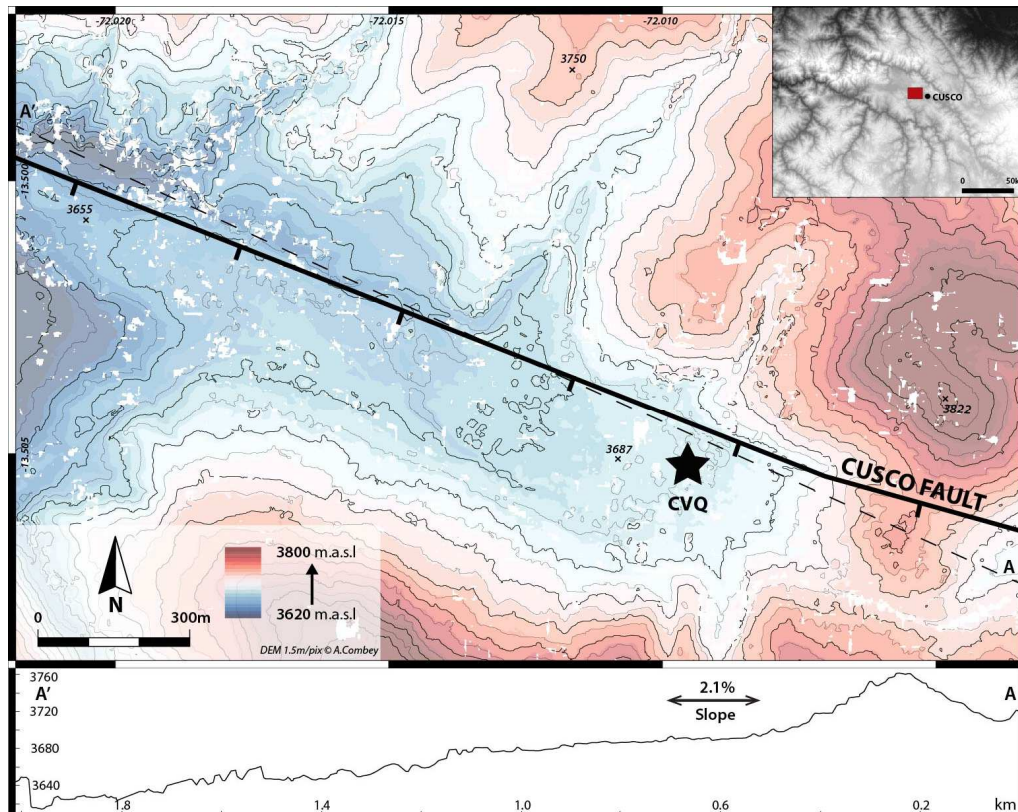


Fig.4. Topographic map of the Quehupay area. The black star marks the location of Cruz Verde de Quehupay (CVQ). The gentle slope illustrated in the topographic profile (AA') explains easily the former name Quibipay *pampa* and its ability to retain water.

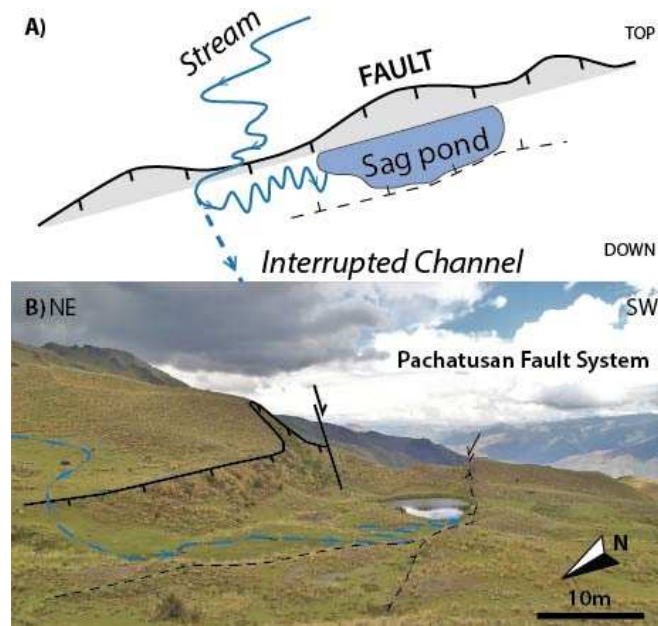


Fig.5. A) Sketch of a “sag pond”. A depression develops in the shear zone of the fault and interrupts the drainage. The subsequent lakes accommodate along this tectonic landform and highlight the fault trace even in steep landscapes. B) Example of sag pond at the foot of a Pachatusan fault segment.

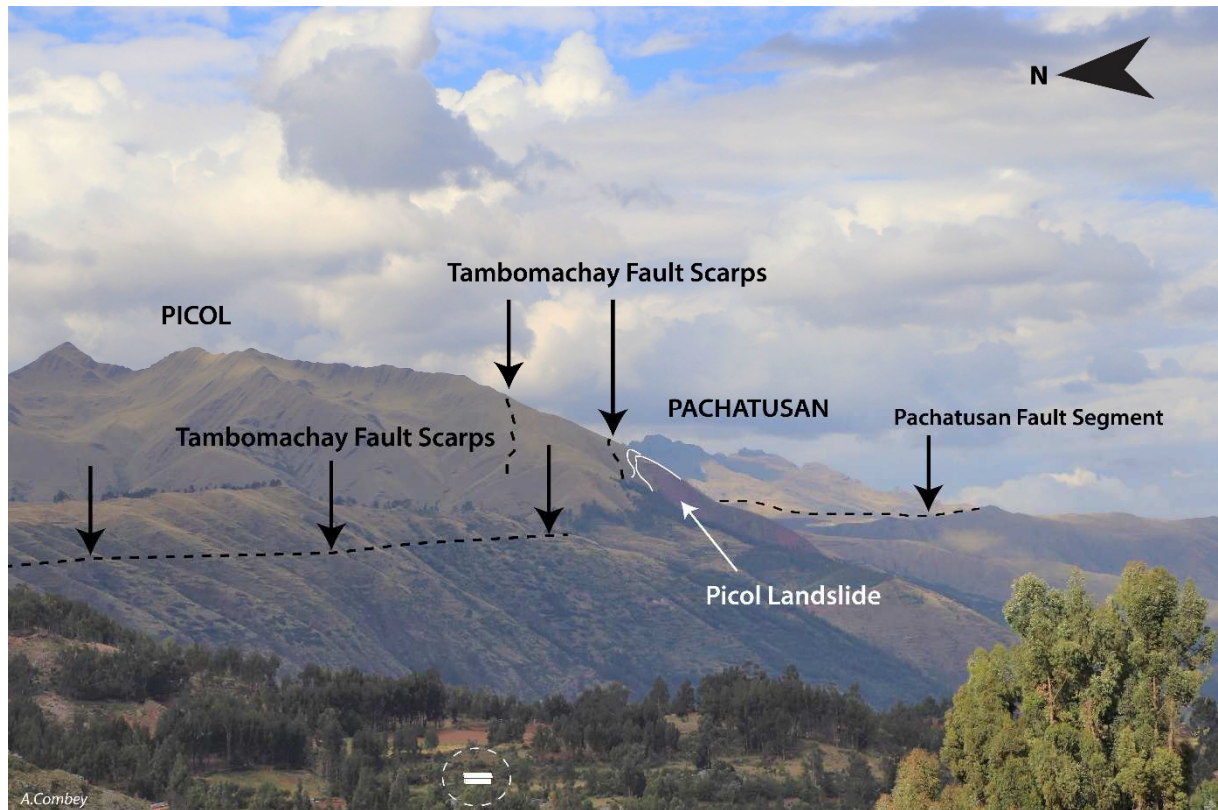


Fig.6. Panorama from the Amaru Marca Wasi archaeological site. The Tambomachay Fault Segment and the Picol landslide represent the most salient features in the landscape visible from that location. Note that the Pachatusan Fault segment is also visible in the background, forming a comprehensive panorama of the “snake like” scarps.

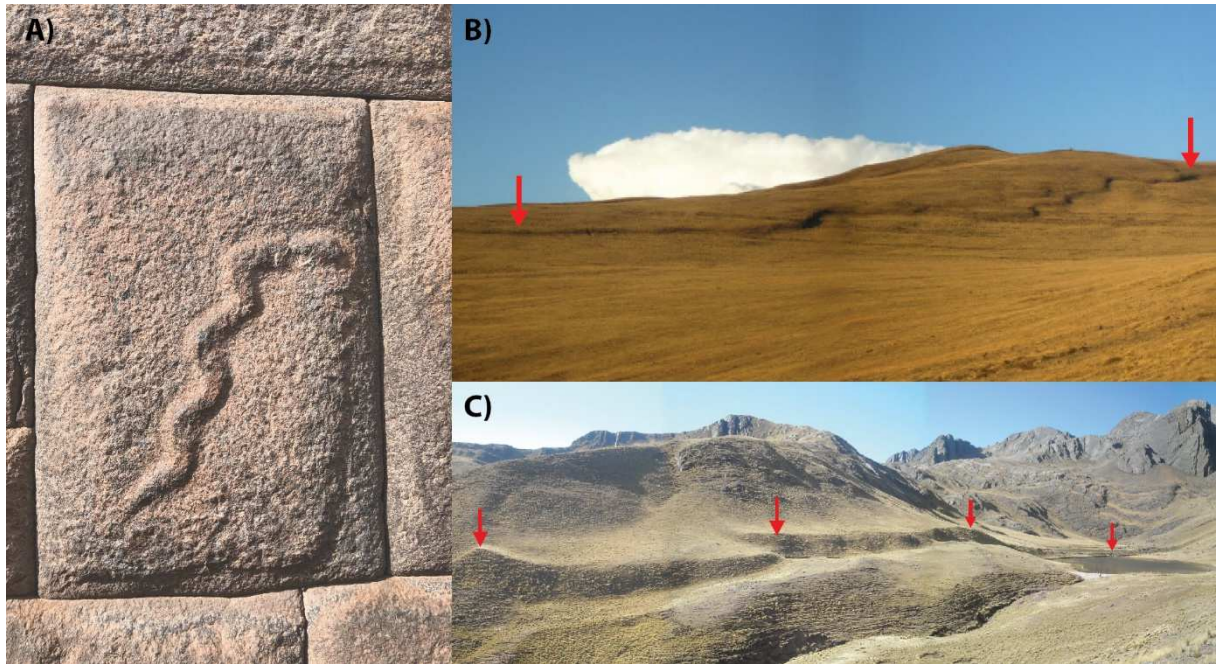


Fig.7. A) Apotropaic figure in architectural elements, the serpent carved motif is a common representation in Inca/colonial walls of Cusco (photograph: Beaterio de las Nazarenas – Siete Culebras). B) Qoricocha fault scarp and C) Langui Layo fault segment. In a similar fashion to modern observers, people during pre-Columbian times might have easily perceived these landforms as a serpent making its way underground.

