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"THE VALUE OF HISTORICAL DOCUMENTS FOR RISK REDUCTION: THE 1600 HUAYNAPUTINA ERUPTION (PERU)"

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ABSTRACT

On the 14th of February of 1600, one of the most explosive eruptions occurred in historical times in South America (VEI 6) plunged the city of Arequipa (Peru) and surrounding villages into a severe crisis, with long lasting dramatic economic consequences. The eruption was produced by the Huaynaputina dacitic stratovolcano (16°37'S-70°51'W), although many historical sources attribute the activity to the volcano of Arequipa or Omate, among others. This eruption also produced alterations in the global climate, between 1601 and 1603. The aim of this research is to demonstrate how historical documents and an adequate working methodology, may aid to reduce disasters.

1. INTRODUCTION

The reduction of natural risks is a social research objective whose interest has significantly increased through time. Undoubtedly, to know more details about explosive eruptions that caused severe damage to population and infrastructures is a topic of great interest. This type of research also has relevance when we try to assess the planetary aftermaths of these catastrophic events, such as climatic changes that may altered the daily life of societies also far away from the place where the eruption occurred. This is the case of the 1600 AD eruption of the Huaynaputina volcano that is considered the most explosive eruption recorded in the Andes, in the last five hundred years of history [Thouret et al., 2002].

This research is based exclusively on the analysis of historical documentation and is complementary with the studies based on archaeology, volcanology and historical climatology [de Silva and Zielinski, 1998; Thouret et al., 2002; Labazuy et al., 2018].

When analysing the effects of an explosive eruption, it is necessary to take into account the reaction of the population that was affected, since their actions and behaviours will serve as elements to calibrate the criteria to be adopted to interpret the historical descriptions. Following this methodology, data will not only validate aspects related to the eruptive phenomenon, but also will provide information on the behaviour and mentality of the affected society.

Bouysse and Bouysse-Cassagne [1984] were the first historians to recognise the importance of this eruption, and to analyse the behaviour of Spanish and indigenous people. They stated that the Huaynaputina activity was interpreted by the Hispanics as a punishment for their sins, and by the natives as a powerful act of their ancient gods aimed to destroy the Spanish. In a previous study, I referred to this eruption and its regional impact [Petit-Breuilh, 2004a], whereas details were discussed in a successive work [Petit-Breuilh, 2016]. Lavallé [2011] discussed the reactions of the inhabitants and religious authorities of Arequipa at the beginning of the 17th century, including some details

of the Huaynaputina eruption, but associating their behaviour with previous catastrophic earthquakes experienced in the area.

Petit-Breuilh [2016] suggested that the idea that the Spanish and indigenous population of Arequipa had about the origin of the disaster produced a series of behaviours on the society. Some personages had to assume the organization of their respective groups and to take charge of the material and economic reconstruction of the city in a moment of generalized crisis. On the other hand, the fear felt by the people and how they expressed it leads to suggest that the providentialism of the time is the answer that helps to understand the celebration of various rituals and ceremonies to appease the "wrath of God" [Petit-Breuilh, 2001]. The Indians also had reactions adjusted to their beliefs, because for them as for the Spanish, the ruin that caused the Huaynaputina eruption was a "divine punishment", by their ancestral gods such as Tice-Viracocha or Tunupa [Bouysse Cassagne, 1987]. They believed that all disasters were a punishment because the Andean communities had abandoned their ancestral beliefs and no longer fulfilled their cults, as required by the tradition through the shamans, generally called "sorcerers" in the documentation.

This information is relevant for the study of extreme disasters since the analysis of the worst possible scenarios is considered from an empirical point of view and not from a theoretical one, as for mathematical models. In our case, the possibility of an explosive eruption is not studied but a real fact is considered, that can be verified through the historical documentation translated into a current scientific language [Petit-Breuilh, 2013].

The sources used to identify the characteristics of Huaynaputina's 1600 eruptive phases and the behaviour of the society of the time are documents of the Archivo General de Indias (Seville), of the Vatican Apostolic Library, as well as chronicles, reviews and reports of missionaries who lived in the affected area. All these documents allowed to reconstruct the facts and to check the available information. Sketches of the time, historical cartography and toponyms of the region were also used, in order to define exactly the ge-

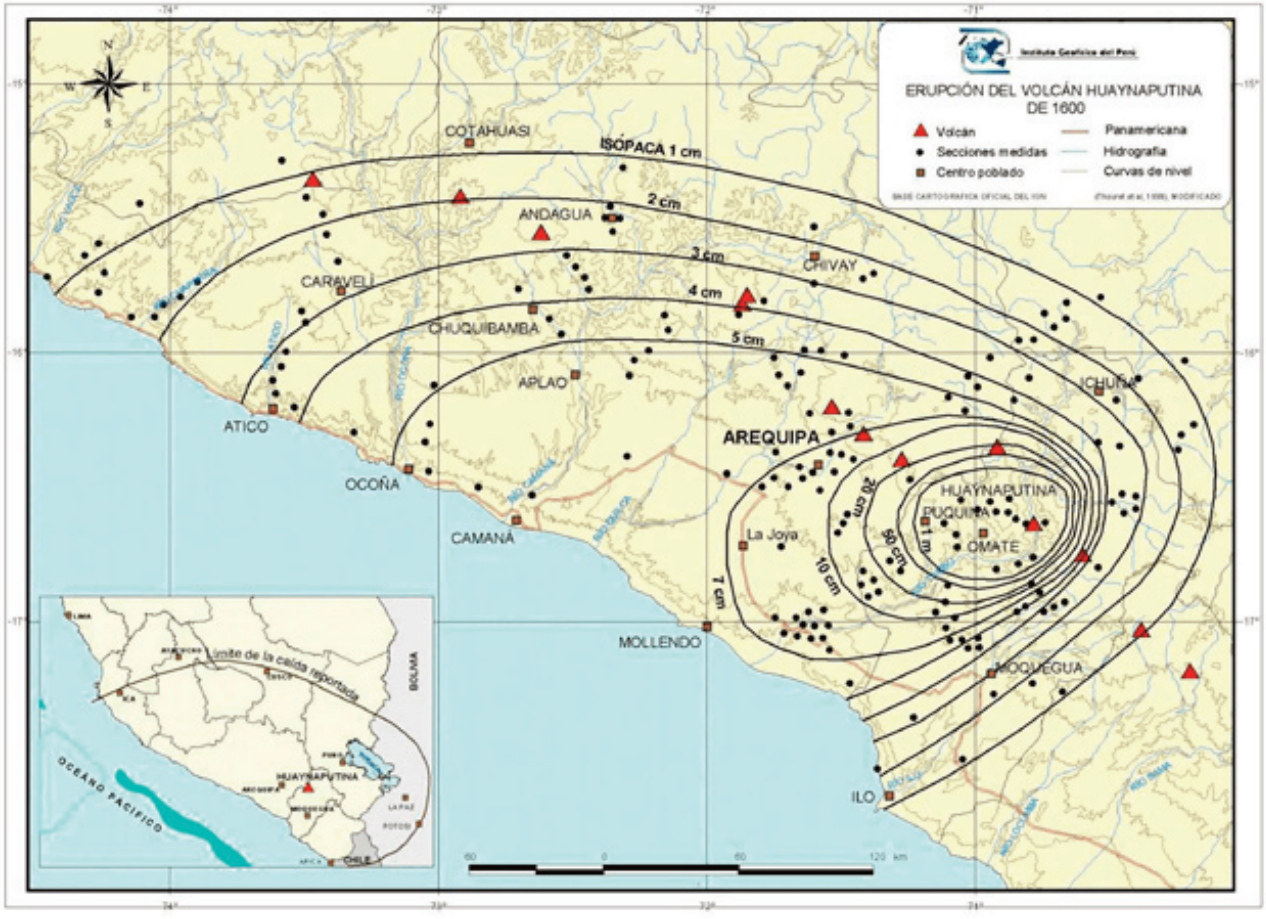

FIGURE 1. Isopac map of the eruption of the Huaynaputina volcano of 1600 (Sinpad- indeci. gob.pe).

ographical details of what was described in the sources. To constrain historical data more carefully, multidisciplinary researches were carried out. Volcanologists and regional geologists evaluated this extraordinary natural event to recognize the local and planetary effects of this eruption; architects and art historians evaluated better the characteristics of the damaged infrastructure.

Data used for this research were obtained from the quoted documentary sources (handwritten and printed). It must be considered that the majority of researchers who have studied this eruption have only used the information obtained from chronicles and printouts that are contemporary with the event, whereas this work presents details of the eruption cycle, the caused damages and the identification of the disaster managers of that time, obtained from the manuscripts of several repositories, especially the General Archive of the Indies of Seville (that preserves the official material of the Spanish Monarchy in America between the 16th and 19th centuries), the Royal Academy of the History of Madrid and the Secret Vatican Archive.

2. HUAYNAPUTINA ERUPTION IN THE SOURCES

In the first records, that also include the historical cartography, the region was also identified with the name of Omate or volcano of the Ubinas, Quinistaquillas or Chequeputina, that mean volcano of bad luck or *agüero* [Amanqui, 2006]. This is the reason why there is some historical confusion over time to determine exactly the vent of this eruption. The town most affected by the catastrophic event was Arequipa together with several Indian villages in its surroundings. For this reason and because a volcano with the same name is very close, in some contemporary chronicles the activity was erroneously attributed to the volcano of Arequipa or Misti and this mistake was transferred in later records (XIX and XX centuries). From this urban nucleus, the most shocking stories were written due to the proximity to the active crater and to fact that many survivors of the neighbouring villages moved to Arequipa in search of refuge.

The 1600 AD Plinian eruption generated by a dacitic stratovolcano, lasted for more than one month in its most explosive phase and the worst moments were experienced from February 19 to February 21 (Plinian phase), from February 26 to March 4, and ending with a fine ash fall on March 15. During this time, at least three pyroclastic flows were generated, and at least seven Indian villages of the surrounding area were buried by them.

This eruption is comparable in its general climatic impact to those of Laki, Iceland in 1783, Tambora, Indonesia in 1815 and Krakatoa, Indonesia in 1883, much better known and studied. The ash of the eruption reached Europe, causing global climate changes [Génova, 2012], and its effects were felt in the low temperatures recorded in 1601 in China and Korea [Fei et al., 2016]. More than 500,000 casualties in Russia are attributed to this eruption [Verosub and Lippman, 2008].

By analysing these data obtained from historical sources, it is possible to identify at least four main explosive phases during the 1600 AD eruption:

1. February 19-20: which corresponds to the Plinian phase with generation of ash fallout and pyroclastic flows.

2. February 21-22: new explosions with generation of pyroclastic flows.

3. February 25-28: explosions with generation of pyroclastic flows. It is specified in the documents that on 25 February the banded pumice emission were identified for the first time during the eruption. Possible onset of phreatomagmatic activity [Thouret et al., 2002].

4. March 4-5: new explosions with generation of pyroclastic flows.

3. THE PHOTOGRAPHY OF THE TIME

The only image of the time is a sketch of the Plaza Mayor of Arequipa (Figure 2) where most rituals and religious ceremonies were held to placate the “wrath of God” in February and March 1600. It highlights the profile of the old Major Church of Arequipa (1558) destroyed during this eruption and rebuilt in the middle of the XVII century.

This sketch tells us how this eruption was perceived in the city of Arequipa, as in its caption it is clearly expressed that the darkness was caused by dust in suspension due to the pumice and ash emitted by the Plinian explosion and by several pyroclastic flows: “The city of Ariquipa: the volcano burst and covered the city and its jurisdiction and districts with ash and sand; in thirty days the sun was not seen, nor the moon, nor the stars” [Guamán Poma de Ayala, 1615].

Date	Description
Feb. 14-15	Precursory earthquakes were felt in the villages near Arequipa.
Feb. 18	At 19:00 tremors began. Near 21:00 the earthquake magnitude and frequency increased; some walls fell and the inhabitants of the city evacuated their houses. There were loud noises and rumblings during the night.
Feb. 19	The tremors continued, some of great intensity, with thunderous noises. Starting at 5:00 p.m., the city became dark and an abundant fall of pumice with "the size of a mustard" began in Arequipa and surrounding areas. The population remained outside their homes. Some houses fell by the earthquakes and by the weight of the ashes that accumulated throughout the afternoon-night. Pyroclastic flows buried some Indian villages. Lightning and "falling stars" were observed in the eruptive column. "Fireballs" on the city.
Feb. 20	Darkness due to the tephra suspension in air. The inhabitants of Arequipa had to quickly discharge ash from the roofs of their houses to prevent roof collapses. At 14:00 the situation worsened: "it was a so dark night that no one could recognize the encountered persons". At 16:00 sky somewhat clarified, but then pyroclastic fallout began lasting for three hours. No water supply to the city because of the accumulated and still falling ash. The thickness of the pumice was estimated that afternoon to about 7-8 centimetres.
Feb. 21	Because of darkness every think appeared as "closed in a colour between red and pale, which made it look horrible". Ash fell for three hours.
Feb. 22	Pale red dawn and continuous fallout of fine pumice from 9:00 a.m. to 3:00 p.m. There were many tremors. In Arequipa, thickness of accumulated ash was estimated to about 21 cm. The roofs of some houses collapsed.
Feb. 23	Some clarity, persistence of fine ash fall and tremors. In the whole city the weight of the fallen ash caused the collapse of some roofs and those still standing had to be unloaded.
Feb. 24	More clarity, no ash fall; tremors continued.
Feb. 25	The cloudy day was so dark that they needed light to see. At 20:00 it rained with "fine earth", probably ash mixed with rainwater. Banded pumice was firstly described. Part of the structure of the cathedral of Arequipa collapsed.
Feb. 26	Dawn was very dark and they had to bring lights to see each other. Surely on this day pyroclastic flows were emitted from Huaynaputina. A lot of fine ash fell in Arequipa and there were tremors and loud noises of volcanic explosions. In some parts of the city the ash reached the people waist. Inhabitants had to unload ash from rooftops to avoid collapses.
Feb. 27	Some clarity by the day and finally it was learned that the origin of the disaster was an eruption of Huaynaputina volcano. Fine ash fallout and tremors continued. At 16:00 explosive activity increased again.
Feb. 28	Some clarity. At 3:00 p.m., the day became darker due to ash suspension in air. At 17:00 the air was clearer but ash fallout continued. There was a strong earthquake and a new explosion.
Feb. 29	The sun was seen. Fine ash fallout continued.
Mar. 1-3	somewhat clearer days. Fine ash fallout continued.
Mar. 4	Clear at dawn, but no visible sun. There was a lot of ash. A new pyroclastic flow buried Indian peoples.
Mar. 5	Deep darkness for ash suspension in air. Tremors.
Mar. 6	Fallout of fine ash and tremors.
Mar. 7-15	Fine ash fallout.

TABLE 1. Chronology of the 1600 AD eruption from historical data collected in Arequipa (56 km from the volcano).

FIGURE 2. An historical drawings, which allows us to reconstruct an event from the past and clarify what actually happened.

4. DAMAGES IN THE REGIONAL ECONOMY

The most important economic activity in the region prior to the 1600 eruption was agriculture, especially vineyard farms and livestock production, with native animals such as llamas and alpacas and those brought from Europe such as cows, sheep, horses, mules and donkeys that were also used to carry different goods from the Audiencia de Charcas to Lima or to the coast of Arica. The first chronicler of the area, Pedro Cieza de León (1540-1550) wrote: "In this area an excellent wheat is produced, of which they make very good and tasty bread" [Cieza de León, 1984].

Martín de Murúa also pointed out that at the begin-

ning of the 17th century in this Andean region there were "many ranches of Castile, sheep and cattle. "It fell in great measure from its prosperity with the ruin of Arequipa, which was a business of many rich men that became very poor" [Murúa, 1987]. It is evident that one of the main consequences of the explosive activity of the Huaynaputina was the damage in the harvests and the death of the cattles; especially considering that the ash is highly harmful to animals because of its abrasiveness and high content of silica.

5. PROCESSES ASSOCIATED WITH VOLCANIC DISASTERS

One of the most dangerous phenomena occurred after the eruption were the lahars generated by rain mobilization of loose tephra in the valleys and ravines that, enabled the possibility of short term economic recovery of the region. The chronicler Bernabé Cobo said: "It highlights the remarkable fury with which these large

FIGURE 2. Fragment of the map of Peru by Nicolas Sanson d'Abbeville (Ca. 1645). Of particular note are the cities of Lima or Ciudad de los Reyes, Callao and Cusco to the northeast, and the port of Arica southern in the Pacific coast. Huaynaputina volcano is located in the mountain area between Arequipa and Lake Titicaca.

floods were produced, composed of ash and a very subtle and soft dust. They devastated many productive lands that now are no longer useful" [Cobo, 1964].

There were also several reservoirs of stagnant water with volcanic materials, tree trunks and organic matter that with the passage of time broke and surprised the neighbours causing again damages and even the death of some people. Cobo [1964] described these processes as follows: "another wave or flood snatched a man, and rammed him with his rapid current into a deep, though narrow, lagoon".

Moreover, due to the large number of dead animals a great pestilence was produced and the real threat of an epidemy arose; in fact, many people became ill due to the environmental conditions to which they were exposed after the volcanic eruption. In a letter preserved by the Jesuits it is written: "Cows have died by the five hundreds. What I fear and what some doctors believe is that it may be the effect of some plague or of the ingestion of ash. We are all like asthmatic. In addition, the large number of dead animals makes us fear worse effects" [Egaña and Fernández, 1986]. After months and years of misery in Arequipa, because of the consequences of the eruption, many neighbours died of hunger; facing this reality some decided to emigrate to other regions losing all faith in recovering their crops, livestock and material goods. Most of them were getting sick without any comfort. Thus a member of the Society of Jesus reflected in 1602: "For all these evils many are losing faith and hardening their hearts" [Fernández, 1981].

6. REACTION OF THE INDIGENOUS PEOPLE

In the Indians community there must have been much concern during the explosive eruption of the Huaynaputina, as several of its villages were in the vicinity of the volcano and some were literally buried by pyroclastic flows and by pumice and ash fallout. The disappearance of at least six villages of Indians: "Omate, Lloque, Tarata, Colaña, Chec and Quinistaca" had certainly severe mental and behavioural consequences that have been little explained in the sources that are almost all Spanish. One of the few information is that of Vazquez de Espinoza, who points out that "los indios al principio de la tempestad se retiraron a un alto cerro, muchos de los cuales se decían idolatraban en él y le hacían sacrificios en él al demonio, ofreciéndole en tiempos indios que echaban en el volcán para que los tragase" [Vázquez de Espinoza, 1992]. This information confirms the maintenance of altitude worship and the practice of human sacrifices in the Andes, especially in active volcanoes at the end of the 16th century [Petit-Breuilh, 2006].

According to the sources, it is estimated that more than two hundred people were killed by the pyroclastic flows of the Huaynaputina eruption. Some survivor Indians came to Arequipa a few days later and related their experiences [Cobo, 1964]. This theme is of high interest in Arequipa; on August 30, 2015 it was reported in the local press that "the people of 17 villages of Indians were buried by the ashes of Huaynaputina in 1600". The project "Huayruro: Peruvian Pompeii" has just begun and aims to recover the remnants from the villages of: Quinistacas, Omate, Coporaque, Quinistaquillas, Tassata, Escobaya, Hanvasi, Cupilaque, Coalaque, Yamana, Acambaya, Jurama, Laji, Chica, Lloque, Colona and Checa, "where more than fifteen hundred people died" [Labazuy et al., 2018].

7. CONCLUSIONS

At present it is necessary that interdisciplinary studies on volcanic eruptions become a reality and not just a good wish. Especially the volcanology would deserve this dialogue between different disciplines as the results could have a great utility, since they can contribute to save lives and to improve territorial planning in areas prone to volcanic risk.

For more than twenty years I have been able to verify that the study of toponymy, historical cartography and the critical analysis of historical sources, allow improving the historical eruptive chronology of active volcanoes and with this the knowledge of the risk of a vulnerable region is broadened.

Through the historical analysis it has been corroborated that the Plinian eruption of the Huaynaputina volcano that began in February 1600 has been the most explosive in the last four hundred years (VEI 6), at least in South America, and that it would be necessary to use the available information for the territorial planning of the region. At present, the traces of this extreme event are still evident and the data of several scientific disciplines confirm that it had important effects on the global climate between 1601 and 1603.

Finally, the historical documentation provides rele-

vant information to understand the volcanic processes and the effects that they produce on the exposed population and infrastructures. History can not be overlooked for the study of this type of natural processes which, as in the case of the Huaynaputina eruption in 1600 AD, have a global impact, altering the climate in vast regions of the Planet.

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REFERENCES

Alcedo, A. de (1789). Diccionario Geográfico-Histórico de la Indias Occidentales o América. 5 tomos, Madrid, Imprenta de Manuel González.

Adams, N., S. De Silva, S. Self, G. Salas, S. Schubring, J. Permenter, and K. Arberman (2001). The physical volcanology of the 1600 eruption of Huaynaputina, southern Peru, Bull. Volcanol., 62, 493-518. doi.org/10.1007/s0044500000105.

Amanqui, Y. (2006). Mentalidad ante los terremotos en la Arequipa colonial, Arequipa, Universidad Nacional de San Agustín. http://www.bvirtual-unsa.edu.pe/edicion 7/9-historia-7-amanqui-pdf.

Bouysse, P. and T. Bouysse-Cassagne (1984). Volcan indien, volcan chrétien á propos de l`éruption du Huaynaputina en l`an 1600 (Pérou Méridional). Journal de la Société des Américanistes, 70, 43-68.

Bouysse Cassagne, T. (1987). De Empédocles a Tunupa: evangelización, hagiografía y mitos. Saberes y memoriasen los Andes, Paris, Édition de L'IHEAL, 157-212.

Calancha, A. and B. de Torres (1972). Crónicas agustinianas del Perú (primera mitad del siglo XVII), vol. 1. Madrid, Consejo Superior de Investigaciones Científicas.

Cieza de León, P. (1984). La crónica del Perú (1540-1550). Crónicas de América, Núm. 4, Madrid, Historia 16.

Cobo, B. (1964). Historia del Nuevo Mundo en Obras del Padre Bernabé Cobo de la Compañía de Jesús. Biblioteca de Autores Españoles, vol. 1, Madrid.

De Silva, S. and G. Zielinski (1998). Global influence of the AD 1600 eruption of Huaynaputina, Peru. Nature, 393, 455-458. doi.org/10.1038/30948.

Egaña, A. de and E. Fernández (1986). Monumenta Peruana, vol. VII (1600-1602). Apud Institutum Historicum Societatis Iesu, Romae, 1986. Signatura: Ordini Rel. II, Gesniti 6, nº 128.

Fei, J., D. Zhang, and H. Lee (2016). 1600 AD Huaynaputina Eruption (Peru), Abrupt Cooling, and Epidemics in China and Korea. Hindawi Publishing Corporation, Advances in Meteorology, Article ID 3217038, 1-12. doi.org/10.1155/2016/3217038.

Fernández, E. (1981). Monumenta Peruana, vol. VIII (1603-1604). Apud Institutum Historicum Societatis Iesu, Romae. Signature: Ordini Rel. II, Gesniti 6, nº 120.

Génova, M. (2012). Extreme pointer years in tree-ring records of Central Spain as evidence of climatic events and the eruption of the Huaynaputina Volcano (Peru, 1600 AD). Climate of the Past, 8, 751-764.

Guamán Poma de Ayala, Ph. (1615). Nueva corónica y buen gobierno. 597 foja. Manuscrito http://www.kb.dk/permalink/2006/poma/info/es/frontpge.htm.

Jiménez de la Espada, M. (1888). Una ascensión á el Pichincha. Primer semestre, tomo XXIV, Boletín de la Sociedad Geográfica de Madrid.

Lavallé, B. (2011). Miedos terrenales, angustias escatológicas y pánicos en tiempos de terremotos en el Perú a comienzos del siglo XVII, e-Spania. 1-16. http://e-spania.revues.org/20822.

Labazuy, P., F. Donnadieu, J.C. Thouret, D. Ramos, J. Marino, N. Sánchez, I. Lazarte, and S. Japura (2018). Physical impacts of the AD 1600 Huaynaputina VEI 6 eruption on hábitat and infraestructure, southern Peru: Geophysical insights from the Huayruro proyect. Cities on Volcanoes 10, IAVCEI, Napoli Italy.

Martí, J. and G. Ernst (2005). Volcanoes and the Environment. Cambridge University Press.

Murillo Velarde, P. (1990). Geografía histórica de la América y de las Islas Adyacentes, y de las Tierras del Norte y del Sur. Tomo IX, edición facsímil (1752), Granada, Universidad de Granada.

Murúa, M. de (1987). Historia General del Perú (1613). 35, Madrid, Historia 16.

Ocaña, D. de (1987). A través de la América del Sur. 33, Madrid, Historia 16.

Petit-Breuilh, M.E. (2001). Conjuros y exorcismos ante

los desastres naturales en Hispanoamérica (siglos XVI-XVIII). González Cruz, D. (ed.) Ritos y ceremonias en el mundo hispano durante la Edad Moderna. Huelva, Universidad de Huelva, 331-351.

Petit-Breuilh, M.E. (2004a). La historia eruptiva de los volcanes hispanoamericanos (siglos XVI al XX). El modelo chileno. Serie Casa de los Volcanes, Islas Canarias, Servicio de Publicaciones del Exmo. Ayuntamiento de Lanzarote.

Petit-Breuilh, M.E. (2004b). Desastres naturales y ocupación del territorio en Hispanoamérica. Huelva, Servicio de Publicaciones de la Universidad de Huelva.

Petit-Breuilh, M.E. (2006). Naturaleza y desastres en Hispanoamérica. La visión de los indígenas, Madrid, Sílex ediciones.

Petit-Breuilh, M.E. (2007). La concepción científica de la dinámica terrestre en los cronistas de Indias en Orbis Incognitvs. Avisos y Legajos del Nuevo Mundo, Universidad de Huelva, 405-420.

Petit-Breuilh, M.E. (2013). La investigación histórica sobre la actividad volcánica de la Edad Moderna en Hispanoamérica en Alberola. Armando (Coord.) Clima, Naturaleza y Desastre. España e Hispanoamérica durante la Edad Moderna, Universidad de Valencia, 169-191.

Petit-Breuilh, M.E. (2016). Miedo y respuesta social en Arequipa: la erupción de 1600 del volcán Huaynaputina (Perú). Obradoiro de Historia Moderna, 25, 67-94. doi.org/10.15304/ohm25.3154.

Simkin, T. and L. Siebert (1994). Volcanoes of the World. Geociences Press, Tucson, Smithsonian Institution.

Sinpad-indeci (2016) Sistema de Información Nacional para la respuesta y Rehabilitación. Lima, Instituto Nacional de Defensa Civil.

Thouret, J.C., E. Juvigné, A. Gourgaud, P. Boivin, and J. Dávila (2002). Reconstruction of the AD 1600 Huaynaputina eruption base on the correlation of geologic evidence with early Spanish chonicles. J. Volcanol. Geotherm. Res., 115, 529-570.

Vázquez de Espinoza, A. (1992). Compendio y descripción de las Indias Occidentales (segunda parte). Madrid, tomo 68b, Historia 16.

Verosub, K. and J. Lippman (2008). Global Impacts of the 1600 Eruption of Peru's Huaynaputina Volcano. EOS, Trans. Am. Geophys. Union, 89(15), 141-148.

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