Study of EQLs in Lima, during the 2007 Pisco, Peru earthquake and possible explanations.

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SUMMARY

Introduction

The subduction of the Nazca Plate under the South American Plate is responsible for intense seismic activity along the west coast of South America. It is one of the most active areas in the world and has produced some of the strongest earthquakes known in history. The epicenter of the Mw8.0 earthquake of 15 August 2007 was located near the port of Pisco, about 150km south of the capital city of Peru, Lima. As described by Tavera et al. (2007), this event was the strongest shallow earthquake in Central Peru in the last 250 years, according to Tavera H. and Bernal I. (2008). Extensive damage occurred in the port and city of Pisco as well as in Chincha, El Carmen, Ica, Cañete, and smaller towns, leaving thousands of homeless people and producing hundreds of deaths. The seismic activity was felt along hundreds of kilometers on the Peruvian coast and very strongly in the capital city of Lima, where people were leaving work at 6:40 pm, already dark in the southern hemisphere´s winter time. This explains why thousands of people along the coast, as described by Ocola L. & Torres U. (2007), and specially in the city of Lima, where only day time earthquakes had occurred at least for the last 70 years, have reported strong coseismic luminescence in the skies, and specially on the top of hills and islands on the ocean. No pre-seismic luminous activity has been reported.

Photographic and video evidence of the lights had been accumulated and published but no consistent study had been performed, as to the simultaneous direction of occurrence, intensities and colors recorded in video evidences. This work presents such a study based on videos and complemented with qualified witness descriptions, including reconstructed images of the luminescence observed and an analysis of time correlation with accelerometer data and a discussion of possible explanations.

Previous Work

In a short summary, luminous or EQL activity has been observed since ancient times, reported since the latter half of last century, studied theoretically and experimentally for some years. Earth Quake Lights or EQLs are secondary luminous effects of a seismic event taking place in the atmosphere, as described by Richter (1958) and reported by Terada (1930, 1931), by Yasui (1968), reviewed by Derr (1973), studied by Tsukuda (1997). In the Mediterranean region, EQLs have been reported since ancient times and researched by Papadopoulos (1999) in connection with 30 events

978-1-4244-6051-9/11/$26.00 ©2011 IEEE

and he concluded that EQLs were associated with strong (M≥6) shallow earthquakes at epicentral distances up to 140 km. Stothers (2004) reported EQLs in NW Turkey and St-Laurent (2000) reported EQLS associated with earthquake as small as M=4.8 in Quebec, Canada. Reports of association of radon gas emissions with electromagnetic phenomena related with large earthquakes have been published by Omori Y. et al. (2007) and Liperovsky et al. (2005, 2008) have explored models in which radon gas and aerosols are injected into the atmosphere that lead to enhanced electromagnetic activity and EQLs. Other theories by Mizutani et al., 1976, Lockner et al., 1983, St-Laurent et al., 2006 have been proposed to explain EQLS and recently Freund (2010) describes a solid state theory to explain pre-seismic signals which could explain electric charge transportation mechanisms associated with EQLs. We should also mention that on the experimental side, Brady and Rowell (1986) conducted laboratory experiments which produced light emissions when subjected to high pressure an more recently Bleier et al. (2010) performed rock fracturing on the field confirming the production of electromagnetic activity prior to the actual fracturing.

In direct connection with the eyewitness observation described here, it is interesting to point out that Perez Mallaina (2001) refers to a chronicle archived in Madrid´s National Library describing the flame-like lights observed near the prison at San Lorenzo Island 21 days prior to the very strong earthquake in Lima on 28 October 1746. The earthquake was the largest ever registered in the city, when a large Tsunami hit the coast and waters reached 5 km inland. The chronicle refers that Captain Manuel Romero, in charge of the island prison, temporarily allowed the prisons to walk out and testify about the flame-like lights on the San Lorenzo island, which is part of the scenario described in this presentation.

The Lima Scenario

The security cameras at the PUCP campus were one of the main sources of our data. Made available to us almost three years after the seismic event, they contain valuable video information, so other sources of video information were searched and found at the Larcomar Shopping Center and at the Lima International Airport. Two short videos clips will be shown during the presentation, a complete video from the PUCP campus camera, looking west towards the ocean and a shorter one from one the Larcomar cameras.

In order to complement the observation, four highly qualified witnesses were interviewed and their observations during the earthquake interactively registered by art students in a Google Earth image. Mr Giancarlo Crapesi, a professional pilot, was on his landing approach at the Lima International Airport. He described his view from 1500 ft as unusual as he saw rapidly moving flashes of light on the rocky hills around the city. He specially described lights on top of La Regla hill on the left of the runway, Morro Solar, 274 m high, at the south end of the city and San Lorenzo Island, 398m above the ocean and about 5 km offshore, to the right. Mr. Jorge Merino, air traffic controller at the Lima airport control tower was on duty and maintained radio contact with our first witness informing him of the severe earthquake at the time. Mr. Merino referred to us that he saw a round shaped luminescence on top of the ocean portion slightly beyond and south of the island. Our third witness was the chief security officer at the airport, who was at the airport ramp at the moment and saw the luminescence

reflected on a large glass window at the airport tower that points towards the ocean. Finally our fourth witness, a Peruvian navy second lieutenant at the San Lorenzo Island base was on duty and he described two columns of light rising from the ocean, about half way between the island and the coast, with a slight spiral structure. Later we associated these lights with pointed rock islets outcropping from the ocean at about the position he described. All of these observations and a general view of angles and directions involved is depicted in one of the figures shown.

Discussion

The PUCP video was analyzed frame by frame, areas were measured for each color in order to infer intensities, angle of arrival and precise timing in the relative time frame available through the computer digital clock. Unfortunately we had no record of the clock calibration so no absolute time reference was assumed. A time correlation was performed with data obtained from the seismological station on campus, a 3-axis accelerometer and the total ground acceleration computed from it, obtaining a good correlation with the distinct light flashes. The results are shown in the presentation.

The images were processed with an area measuring software by colors, establishing a scale from 0 to 13 in order to analyze intensities for each flash. Five main flashes were recognized, taking into account the angle of arrival of the lights. The color scale and the morphology of the areas as well as the morphology of the light pulses is shown. The computed intensities of the light pulses is also shown with the time intervals measured in order to perform the time correlation analysis previously described.

There is little doubt that lights observed and here described are a natural phenomena, occurring on top of hills and islands where no electrical open lines exist. The PUCP video shows the complete event from a single, fixed, automatically recording camera and registered coincidental information with that described by the witnesses. The Larcomar camera shows information arriving directly from the ocean, overlooking the whole Lima bay scenario from the Morro Solar hill to the San Lorenzo island and the small islets in between. The witnesses accounts, show coherence and also support the assumption that real coseismic luminosity in Lima was produced during the Pisco earthquake with an epicenter 150 km away. We assume that seismic energy carried by seismic waves was responsible for the luminous phenomena, which had to be generated locally due to the highly improbable possibility that charges migrate long distances. Two main mechanisms have been explored, the first connected with charge migration of electrons and/or p-holes through stress by rock compression mechanisms described by St-Laurent F., Derr, J. & Freund, F. (2006), Freund F. (2010) and experimented in the laboratory by Brady and Rowell (1986) and in the field by Bleier et al. (2010). The second involves the activation of charges by enhanced electric fields produced by emanations of radon gas and aerosols into the atmosphere by fractures in the rocks during shallow and strong earthquakes and described by Liperovsky et al. (2005, 2008), Omori Y. et al. (2007) and others.

Conclusions and Future Work

We can conclude that the lights observed in the city of Lima, Peru during the Mw8.0 earthquake of 15 August 2007 near Pisco, Peru should be considered real, natural phenomena. They are highly correlated with ground acceleration measured at the same site where recorded by a video camera and coincidental with qualified eyewitness reports. Our hypothesis is that their occurrence is related with locally produced charges migrating from rocks compressed by seismic waves travelling from the rupture area, about 150 km away. Because of lack of radon gas observations in Peru, there is no way we can incorporate the possibility of radon gas enhancement in the production of luminosity but that possibility remains open for the incorporation of new experimental evidence from future work. Correlation with the appearance of unusual pulse activity in local magnetic field records obtained with QF series magnetometers, already operating in southern Peru, is also considered for future work.