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Images of the Benioff Zone in the Lithosphere using Electromagnetic Energy released from Stress in Tectonic Plates

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Abstract

Different manifestations of electromagnetic phenomena have been reported in the scientific literature for many years, linking them with seismic events, from large to even 3.0 Ml earthquakes. Examples are pre-seismic and co-seismic luminescence, various forms of electric charge displacement and magnetic fields, stress generated electromagnetic pulses, radio wave generation by accelerated charges at different frequencies and even strange animal behavior. In this paper, we report several events of electromagnetic pulses associated with seismic events and registered by magnetometers and analyze several cases of EM phenomena leading to the determination of the physical morphology and other physical aspects of the lithosphere from passive reception of pulses associated with earthquakes.

1. Introduction

During the 8.2 Ml earthquake off the coast of the city of Pisco in central-southern Peru at 6:43 pm August 15, 2007, co-seismic luminescence, commonly reported as "Earthquake Lights" or EQLs was observed by probably tens or hundreds of thousand people along more than 300 km. A very precise video with a known bearing and a digital clock installed at the PUCP campus, allowed us to perform a time correlation between the brief (0.5s to 2 s) flashes of light in the sky and the resultant of the ground acceleration from an accelerometer only 200m from the camera. The result was a precise time correlation between the advent of the S-wave and the lights observed through the video. Further meetings with selected technically oriented eye witnesses (an airline pilot, a navy lieutenant, an airport traffic controller) and historic publications of the "Great Lima Earthquake" of October 28, 1746 that produced a 5 km ocean incursion in Callao and Lima from the Tsunami, lead us to conclude that electromagnetic phenomena are most probably involved in this EQL occurrence where local positive and negative charges were produced, as mentioned by Heraud and Lira [1]. The origin and release mechanisms for these charges in rocks has been studied in the laboratory by Friedemann Freund [2] and found to originate in the stress to which rocks are subjected in the tectonic plate displacements in the lithosphere.

For the first time, the generation of such EM pulses has been shown to occur two weeks previously to an earthquake, in several areas of central and southern Peru and we have also used such data to produce images of various physical parameters at the subduction or Benioff zone.

2. ULF pulses associated with seismicity

The use of magnetometers in several locations along the coast of Peru has led to the determination of the source of ULF pulses that originate at and propagate through the lithosphere and the ocean all the way to the surface, conveying information about the stresses originated at tectonic interfaces.

At the Institute for Radio Astronomy of the Pontificia Universidad Catolica del Peru, a network of ten magnetometers has been deployed in central and southern Peru since 2009 through a donation from Quakefinder Inc. of California and Telefonica S.A. of Peru. The data is being collected and analyzed continuously in order to determine the origin, timing, location, direction of arrival and other characteristics of the ultra low frequency EM pulses, correlated with seismic activity in the area. Through physical models and appropriate processing, the results of such study has led to the use of this information in order to find out more about the occurrence of earthquakes with several days in advance, plotting the possible area of the epicenter, studying the morphology of the lithospheric structures and leading to imaging the Benioff zone for the first time, using passive EM methods. Additionally, the distribution of the tectonic plates has been compared to measurements obtained by strictly seismic methods with precise coincidence.

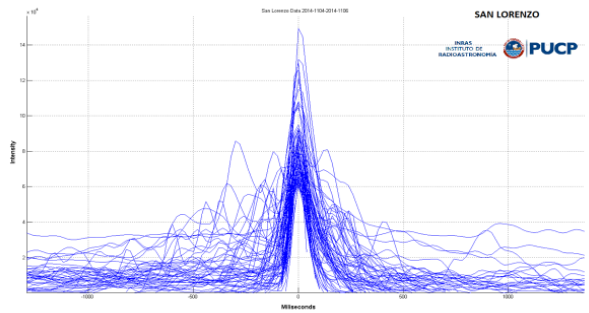


Figure 1. EM pulses as recorded by our San Lorenzo site magnetometers, correlated with seismic activity in Peru.

The propagation of ULF EM pulses in the lithosphere and sea water was studied by A. Chave at al [3] and found as not convenient for submarine communications due to its low bandwidth, up to 1 Hz and short useful distance (<100 km). It is clear that even at low data rates and short distances, appropriate frequencies can convey useful data on geophysical phenomena. It is obvious that before we talk about the feasibility of sea water propagation, lithospheric propagation has to occur, especially for the scenario used in the typical 20-60 km depth hypocenters in the subduction zone along the Peruvian coast. We have found that this fully coincides with our 0.01 Hz to 1Hz frequency pulses and earthquake alerts obtained up to 75 km in distance in 2010, both parameters fully fitting within the paper's conclusion. Starting in April-May 2010, the second corroboration of the 15- day lead time between the appearance of the first pulses and the occurrence of the earthquake was discovered and in October 2010 an alert was issued in a reserved way a week ahead of the actual earthquake, also in southern Peru. The earthquake occurred 75 km offshore of our station, on October 22, 2010 as predicted.

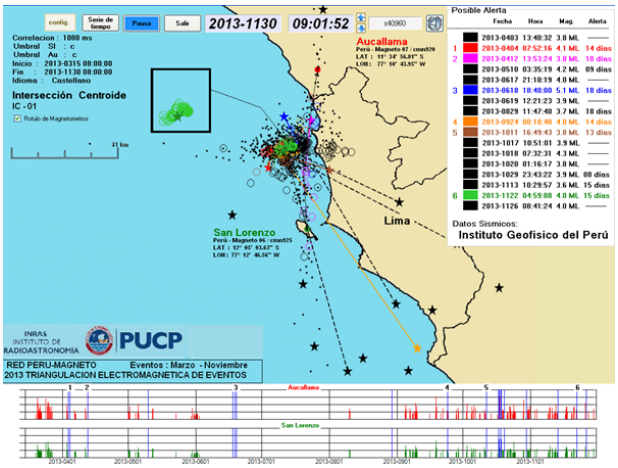


Figure 2. Triangulation of pulses in central Peru, associated with small earthquakes and determination of future epicenters.

3. Imaging the Benioff zone using ULF pulses

A two-dimensional geometry was originally used, showing the precision of this technique to find out the origin of the electromagnetic pulses. Compelling evidence that the pressure points could be located along an inclined surface with the same angle as the subduction zone, a three-dimensional imaging process was implemented leading to the discovery that the surface obtained was indeed a plane with the correct inclination in the West to East direction and the slight tilt in the North-South direction that corresponds to geophysical images of the Benioff zone. All of the pulse source points of the EM activity are associated with earthquakes that range from 3.1 ML to 5.8 ML and have occurred in the area of this research. Thus, an image of the subduction zone or interface between the Nazca plate and the continental plate in the northern area of Lima, Peru, has been obtained, in correct coincidence with the location and angle of the subduction zone, as obtained by traditional seismic methods.

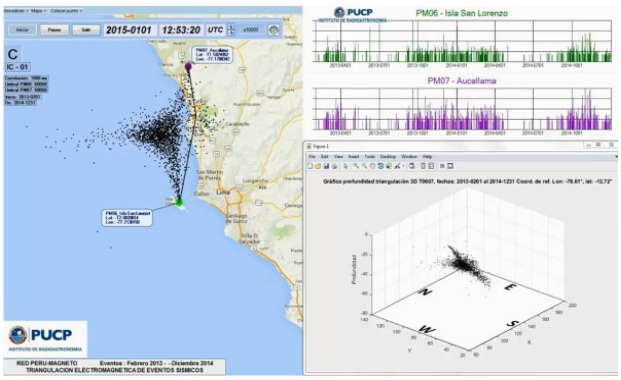


Figure 3. Benioff zone obtained from the 3D triangulation of 2,300 EM pulses approximately, all of them related to earthquakes that occurred in the area.

Additional work has conducted to the imaging of energy density of the radiated electromagnetic pulses as well as other characteristics of the activity in a portion of the referred area of the Benioff zone. All of the mentioned results have been sequenced in a vivid video presentation consisting of lapsed time data points that illustrate the dynamics of such phenomena as it occurs during a period of two years, 2013 and 2014.

The result is shown in Figure 3, where the individual pulses are shown as red crosses and a best fit surface has been included. A very clear image arises, showing the Benioff zone as a slightly warped plane with the right 24 degrees inclination in the West-East direction and a slight North-South inclination as the Benioff plane dips south with the massive altiplano Andean formation in southern Peru and western Bolivia.

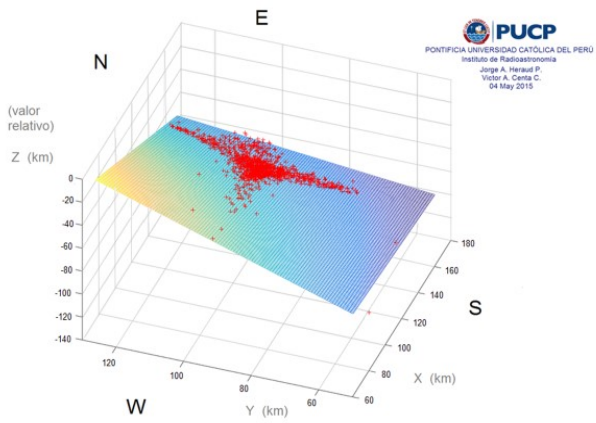


Figure 4. The subduction plane interface between the Nazca plate as it dips beneath the South American plate in the West-East direction imaged from about 2,300

electromagnetic pulses associated with small earthquakes in a 2 year period.

The image of the subduction zone as obtained from sources associated with earthquakes, is a sufficient condition to deduce that the stress points in the rock that give rise to those pulses are the seismic stresses themselves. Furthermore, a direct comparison of the angle of the imaged plane in the West-East direction as obtained by the EM method was made with the plane formed by the locus of the seismic events recorded over a century and as published by Bernal and Tavera of the Geophysical Institute of Peru, IGP [4]

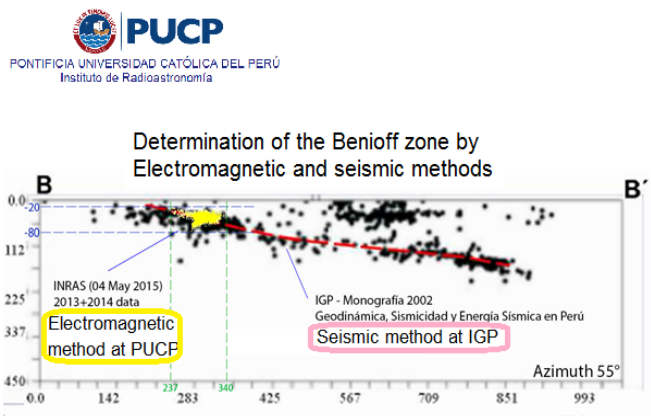


Figure 5. Comparison of the EM imaged subduction zone obtained at PUCP with the seismic activity plotted subduction zone, published by the Geophysical Institute of Peru in 2002.

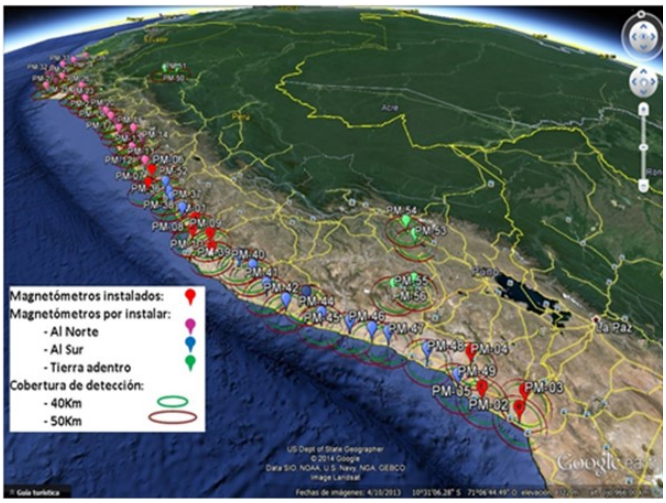
We can hardly have any doubts that the EM pulses that we receive at the magnetometers deployed in the Peruvian coast are related to stress points arising in the subduction zone. In these points, charged particles are released that in turn give rise to electromagnetic radiation of ultra low frequency capable of propagating through the lithosphere from depths of at least 65 km and sea water.

6. Future Work

With the purpose of establishing new imaging and alert points, a larger network of magnetometers is being planned. With appropriate spacing and a more robust communications system, the expanded network is shown in Figure 6.

7. Acknowledgements

We wish to express our thanks to Quakefinder Inc. in California, USA for providing us with nine magnetometers and Telefonica del Peru S.A. for providing us with funds for the purchase of the San Lorenzo magnetometer, as well as free internet access through their cellular network for the transport of the data



. We are also grateful for the effective cooperation of INRAS-PUCP engineers in the operation and maintenance of our network and our student research assistants for their help. Increased data processing capability was made possible by the support of the Peruvian Government Program FINCyT (Innovate Peru) *Equipment for Laboratory Equipment: Radio Science*, No: 127-ECL-2014

7. References

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