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Electrostatic Theory on the Generation of Seismic Lights

In the last years, not only have videos of seismic lights been recorded in various countries – Mexico (September 7, 2021), Ecuador (April 16, 2016), Mexico (September 8, 2017) and Peru (August 15, 2007) –, but also clear evidence of a temporal correlation between seismic lights and earthquake accelerations has been found. Likewise, theories have been developed that have tried to explain the origin of seismic lights; however, they have had inconsistencies with the observed experimental data. In this work, an electrostatic theory is presented that is based on the separation of electric charge during the fracturing of the rock in the earth's crust and the induction of surface charges prior to the electric discharge in the atmosphere. Likewise, based on the theory presented here, a calculation is made of the underlying electric charge in the crust, necessary for the generation of seismic lights. The charge found is of the order of magnitude of the electrostatic charges that form in clouds before a lightning strike.

Keywords: *seismic lights, earthquake accelerations, electrostatic theory*

Introduction

Although luminous phenomena in nature have always caused the admiration of human beings, many of these occur only in certain places and are possible to observe under well-defined physical conditions. Thus the northern lights are a phenomenon well known to the Eskimos; however, they are difficult to conceive for people who live in the equatorial region. Something similar happens with earthquakes, which are well-known phenomena in the Mediterranean area, but constitute an unusual phenomenon in central Europe. Even more so, the combination of both phenomena: earthquakes plus seismic lights at the same time is something unusual for most human beings. Although they have occurred throughout history and have been written in chronicles, few people have been able to conceive them and even less believe them. However, the situation has changed radically in recent years with the massive use of cell phones. Natural event that occurs is immediately recorded and published through videos on the internet. This is the case of seismic lights, which have been easy to find since 2007 on the internet. This article presents a theory that explains seismic lights. This theory is based in part on experiments done in the laboratory in order to simulate the conditions that occur in nature during an earthquake. This paper is organized by the following parts: introduction, literature review, methodology and discussion, results and conclusions.

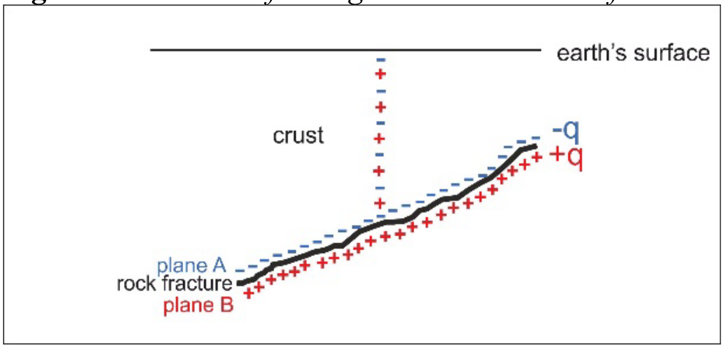
Literature Review

Although seismic lights have never been faithfully reproduced in the laboratory, it has been possible to study the causes that produce them, propose models from their origin in the interior of the Earth to the luminous phenomenon itself and verify their viability through experiments. Various models have been proposed, but a physical battery model is perhaps one of the most published in the specialized literature [1]. In this model, the earth's crust would function as a semiconductor diode and the physical battery would be pressure-driven. Positive holes and electrons would be the charge carriers, and would be activated when the rocks were under stress. The main weakness of this model is that the flow of positive holes, thus generated, would also occur through uncompressed rock beyond the volume under tension and would flow by diffusion even through gravel and sand. Another type of model, the hydromechanical model, has also been proposed to explain the Matsushiro seismic lights [2]. According to this model, the transport of electrical charge through the earth's crust would have occurred through a mixture of water and carbon dioxide and would have reached the surface through the pores of the earth's crust. In the laboratory experiments carried out to support this model, 0.3 to 0.5 MPa carbon dioxide was used. At this pressure, it is expected that the water mixed with the gas will come out through the cracks in the earth's surface, reaching tens of meters in height. The surprising thing is that this would be easily audible, which is in contrast to Matsushiro's lights which were silent. Another surprising point is that if water mixed with carbon dioxide reaches the earth's surface, it should come out through the cracks in the form of jets and therefore the seismic lights would also have a similar morphology; however, photographic evidence of the Matsushiro seismic lights does not show this. One of the recent models that attempts to explain seismic lights is that of dipole currents [3]. The authors assume electrical dipole currents through the earth's crust. These currents would be directed perpendicular to the earth's surface and there would also be a sequence of dipole currents moving along the earth's surface with the speed of seismic waves. The lack of quantitative information on the region of electrical charge separation within the Earth that would generate dipole currents is mentioned; however, this does not prevent an analysis of the situation. Considering the separation of the electric charge at two points forming an electric dipole, the authors do not explain why the current generated does not flow between these two points making a short circuit. In recent years, evidence about seismic lights has been strengthened with film recordings, which have a great advantage in being more objective in relation to witness accounts. In this work, a theory is presented that allows us to explain the origin of seismic lights in a simple and coherent way.

Methodology and Discussion

Seismic ground accelerations are related to stresses acting on the underlying earth's crust; if these stresses are several hundred MPa, they can fracture intact rocks producing electric charge separation. The amount of electric charge that can be separated depends on the type of rock. When the rock fractures inside the Earth, an empty space is generated in the fracture zone that the rock previously occupied. This vacuum does not allow an electric discharge due to Paschen's law. At the same time, the resistivity in the rock is large enough to prevent current from passing through it. The generation of electric charge on the earth's surface is easy to understand by considering electrostatic induction (Fig. 1). The electric charge in plane A could induce charge separation in the adjacent rock material. The induction effect of plane A is much greater than that of plane B due to its shorter distance, which is why, in a first approximation, only the induction effect of the charge of plane A will be considered. The induced electric dipoles will be reproduced through the crust causing the appearance of charges on the earth's surface. The generation of surface charges has been observed in analogous laboratory experiments using various materials (granite, wood, water and dry soil). The electric charges +q and -q have been simulated using the electrodes of a high voltage generator. The induced surface charge has been detected with a surface charge detector. Operating with 20 kV, it has been possible to detect charge induction in dry soil up to a distance of 5 m. Charge generation on the earth's surface would also occur even if there were insulating layers in the earth's crust. Having a sufficiently large induced charge at a point on the earth's surface we will have the electric field necessary to initiate the electric discharge in the atmosphere accompanied by a luminous phenomenon - excitation of the air atoms - which will be spherically symmetrical, as can be seen in the videos of seismic lights. This diffuse discharge, with spherical symmetry, is what determines that seismic lights are silent. On the other hand, when the discharge is carried out through a single path, the current density increases and becomes audible.

Figure 1. *Induction of Charge on the Earth's Surface due to Rock Fracture*



Results

Let us consider that the electric field necessary to initiate the electric discharge in the atmosphere is 3 x 10^6 Vm^{-1} (this value depends on the pressure and relative humidity). Considering the earth's surface as a sheet of charge and using Gauss's law we have that

$$E = \sigma/\varepsilon_0, \qquad (1)$$

where σ represents the charge density on the earth's surface and ε_0 is the permittivity of free space and approximately that of the atmosphere, and is given by 8.85 x 10^{-12} C^2 N^{-1} m^{-2}, from here we obtain

$$\sigma = 5.31(10)^{-5} Cm^{-2}. \qquad (2)$$

The charge density on the earth's surface at point P (Figure 2) is related to the charge q through the equation

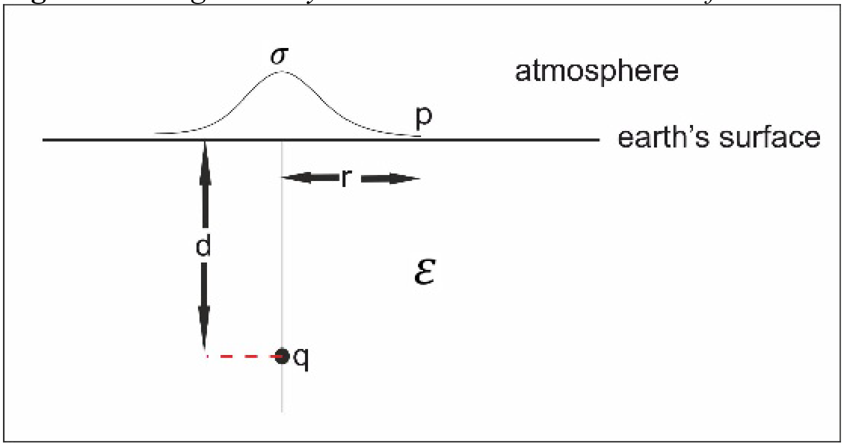
$$\sigma = q\varepsilon_0(\varepsilon - \varepsilon_0)\, d/2\pi\varepsilon(\varepsilon + \varepsilon_0)\,(d^2 + r^2)^{1.5}, \qquad (3)$$

where ε is the permittivity of the constituent material of the earth's crust above the electric charge, d is the depth at which the charge q is found and r is the distance from point P to the vertical axis. Considering the point P directly above the electric charge and using the dielectric constant κ (= ε / ε_0) we obtain

$$\sigma = q(k - 1)/2\pi k(k + 1)d^2. \qquad (4)$$

Let us consider that the charge q is at a depth of 100 m and that the earth's crust above the electric charge is made up of dry soil (κ = 2.8), this would give rise to an induction charge of 20 C on the earth's surface, a similar amount to that found in clouds before lightning: 15-350 C depending on the sign.

Figure 2. *Charge Density Distribution on the Earth's Surface due to a Charge q*



In the film recordings of the seismic lights, it can be seen that the lights are generated only at certain points on the earth's surface, which would correspond to the points where the electric discharges ionize the surrounding air, generating an avalanche of electrons that will expand in the atmosphere. These points where the seismic lights are generated would be just above the points in the earth's crust where there has been rock fracture. Since the induced polarization relaxation could be neglected, this would explain the time-difference correlation between the lights and the maximum seismic ground accelerations. It is worth mentioning that the electric field generated at a point on the earth's surface will not only depend on the energy released in the earthquake but also on its distance from the point in the earth's crust where there has been rock fracture, as well as the dielectric, geological characteristics and dynamic behavior of the soils. Therefore, it is not possible to directly compare the energy released by an earthquake and the change in the local electric field due to fracture of rocks in the underlying earth's crust. However, if measurements are made in the area close to the epicenter, electrical methods could be used to monitor the state of the crust, leading to effective seismic risk mitigation measures.

Conclusions

In general, the amplitudes of the signals recorded at a point on the earth's surface, as a result of the occurrence of an earthquake, are due to the geological characteristics and dynamic behavior of the soils: compact soils attenuate the waves, soft soils amplify them due to the reflection and refraction of seismic waves trapped in the surface layers. They are amplified by the reflection and refraction of seismic waves trapped in the surface layers. This amplification of seismic waves could cause rocks in the earth's crust to fracture, and this would trigger seismic lights higher up on the earth's surface. This would explain the difference-time correlation between the seismic lights and the maximum accelerations of the nearby stations and not with those of the distant stations. The induction theory proposed here is new and can explain the formation of seismic lights, even if the earth's crust had layers of high electric resistivity. This theory also successfully addresses the case of water-filled failures. In the same way, it explains the formation of seismic lights without the need for special conditions in the earth's crust nor on the earth's surface or in the atmosphere.

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