Investigating a Temperature Increase before and During a Magnitude 8 Earthquake Affecting the Portuguese Territory

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Abstract

Historical and registered earthquakes of great magnitude have caused destruction with injuries and deaths in mainland Portugal. This work uses data not yet used to investigate a possible increase of the temperature of the water in the region and possible consequences when materials with different thermal properties are in physical contact. A temporal link between geomagnetic anomalies recorded by *Permanent Geomagnetic Observatories and earthquakes detected in the Iberian Peninsula and adjacent regions during the month of February in 1969 was found using data from 3 Observatories located in the Iberian Peninsula. The anomaly recorded on February 27,1969 is due to large alterations in the direction (inclination) of the geomagnetic field and associated variations in the electric field of the atmosphere recorded in Lisbon. The source of the first earthquake filled and registered in the early morning of February 28 was in the Atlantic Ocean. The variations in the geomagnetic inclination, detected in the records, may have led to rotations of the water molecules to align their electric dipoles with the electric field in the region, originating heat release. As consequence, an increase of temperature occurred. The analysis of the arrival times of the first seismic waves at the seismic stations located in Lisbon, Coimbra and Porto (cities located near the Atlantic Ocean at different latitude values) combined with the distances of the cities to the earthquake source, shows different values of the average speed of propagation of the seismic waves. The values found decrease from Porto to Lisbon. Seismic velocity values change with temperature and pressure. As we are talking about the same earthquake, different temperature values found in the last part of the wave paths seems to be responsible for this fact. This means that temperature values at lower latitude values (Lisbon city and earthquake source) are higher. The increase of the temperature values of water contributes to the opening of cracks and faults in the region with the entry of hot water that can reach great depths, increasing the temperature, the volume, and the pressure of the materials. When materials with different values of thermodynamic properties like specific heat, thermal conductivity and thermal expansion coefficient are in physical contact, the heat received from the water can originate perturbations like pressure gradients of thermal origin whose value can increase causing rupture of the materials. The presence of water with elevated temperatures in deep regions can also change the velocity of chemical reactions with heat release, increasing the* described effect.

Keywords: *Earthquakes, temperature, geomagnetic variations, average seismic velocity, thermal properties, earthquake duration*

1. Introduction

The first earthquake with source in the Horseshoe Basin, registered in the early morning of February 28 in 1969, had magnitude 8 and was felt by people in Portugal, Northern Morocco and some regions of Spain, causing destruction with injuries and deaths. The seismic catalogue [1] includes 29 earthquakes in the region during that day. Many earthquakes with source in the region were registered for several months, including the magnitude 5.4 earthquake on May 5 and the magnitude 5.0 earthquake on December 24 of that year [1]. The time interval of the earthquake duration (more than 1 minute) is very large, and there are no complete records of the earthquake at the seismic stations in mainland Portugal. There are many studies about this earthquake but , until now, it was not possible to identify the fault where it occurred as well as the location of its source.

A link between thermal phenomena, including short-lived transient anomalies occurring before, during and after major earthquakes has been object of several studies[2][3]and [4]. This work uses geomagnetic anomalies obtained from data registered by "Permanent Magnetic Observatories" located in the Iberian Peninsula (in the Western border of Europe) and in the Canary Islands located in the Atlantic Ocean. When similar amounts of heat are introduced in regions with materials having different thermal properties it is possible to show that the temperature increase may be very different in close formations with additional pressure gradients of thermal origin near contact zones of different materials [5] increasing the deformation in the region and possible rupture of materials. The average velocity of the first seismic wave movement obtained in seismic Portuguese observatories and variations of the electric field registered in Lisbon are also analysed to complete the work.

2. Data

This work uses magnetic data registered and published by "permanent Magnetic Observatories" located in Coimbra [6], Toledo[7] and San Fernando, in the Iberian Peninsula and Santa Cruz de Tenerife in Canary Islands [7]. The data used are hourly average values of the magnetic declination and the horizontal and vertical components of the magnetic field [6][7] registered during the year 1969. This means that the anomalies studied are verified in average hourly values and must be seen as "possible minimum anomaly values".

The Portuguese seismic stations did not make the registration of the earthquake due to saturation and failure but they registered very well the first arrival of the seismic waves before failure. The location and time of the earthquake in the source was obtained from the Seismic Catalogue [1] to obtain the average seismic wave velocity of the first arrival at three cities in Portugal, located near the Atlantic coast at three different latitudes.

2.1 Geomagnetic anomalies

The data available were used to calculate the average intensity and the average inclination of the magnetic field at every hour in February 1969. Differences between the maximum and minimum values for each day were calculated. The results obtained can be seen on "Fig 1". The lowest value of magnetic intensity variation is 0.41 nT (day 12) and the highest is 42.40 nT (day 2).

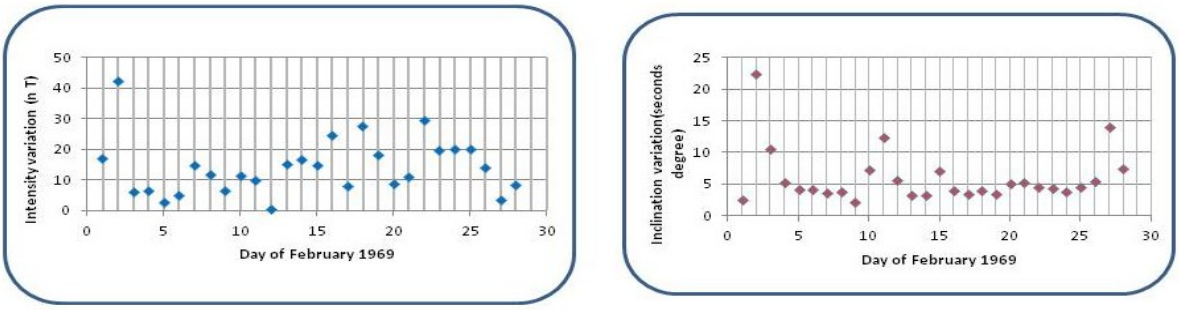

Fig. 1. Differences between maximum and minimum values of magnetic intensity and magnetic inclination

Variations from 20 to 30 nT were recorded on the days 16,18,22,23,24 and 25. On that days small difference values between the maximum and the minimum of the inclination were found. Two small values in Intensity differences were found on day 12 (0.41 nT) and day 27 (3.50 nT). In these days the inclination variation values are 5.71(degree seconds) at day 12 and 13.97 (degree seconds) at day 27.

To understand the consequences of the variations of the electromagnetic field we must use the Faraday's law of the electromagnetism [8] and to introduce the concept of magnetic flux through a flat surface [8] of area A. Faraday's law says that a changing magnetic field can induce an electromotive force (EMF) in a conductor. Mathematically speaking the Faraday's law can be expressed by equation (1).

$$\boldsymbol{\varepsilon} = -\frac{d\,\boldsymbol{\Phi_B}}{d\,t} \quad (1)$$

ε is the electromotive force and Φ_B is the magnetic flux. Basically the electromotive force is originated when the magnetic flux changes over time. How can the magnetic flux change? The flux of a uniform magnetic field through a flat surface of area A may de defined by the equation (2).

$$\boldsymbol{\Phi_B} = \vec{\boldsymbol{B}}\,.\vec{\boldsymbol{A}} = \boldsymbol{B}\,\boldsymbol{A}\cos\boldsymbol{\Theta} \quad (2)$$

$\vec{A}$ is a vector whose intensity is the area of the surface and direction normal to the surface, θ is the angle formed by the two vectors $\vec{A}$ and $\vec{B}$. Considering a surface of area A, the magnetic flux can change due to variation of magnetic intensity or variations in magnetic direction or both variations.

Looking again to "Fig. 1", it is possible to see magnetic flux variations due mainly to intensity changes of the magnetic field in days 16, 18, 22, 23, 24 and 25. Flux changes at days 11 and 27 are mainly related to change directions of the field. In both cases the change in the magnetic flux will originate additional electric currents in the region and subsequent heating due to Joule effect [9].

When an electric current is found in a region an electric field is associated to the current. When the magnetic flux changes due to variations in the direction of the magnetic field the angle between the vector $\vec{B}$ and the vector $\vec{A}$ have different values and the induced currents must change its direction and the direction of the electric fields associated. The earthquake source is located under the Atlantic Ocean. We must think about a very high value of water molecules in regions where electric field lines are changing due to changes of the magnetic flux. Water molecules are dipolar with the centre of negative charge not coincident with the centre of positive charge. In the presence of the described situation water molecules tend to align its dipole axis with the electric field lines and will rotate to obtain an equilibrium state. This rotation is associated to energy release as heat. The amount of heat released is related with the number of molecules involved and the number of rotations associated to magnetic alterations.

2.2 Average velocity of seismic waves

The average velocity of the seismic waves was obtained using the time of the first arrival of the waves in three cities of Portugal. The earthquake source location used is 35.953N latitude and -10.839W longitude [1]. The results are summarized in Table 1.

Tab. 1. Time intervals and average seismic velocity using the first arrival of the seismic waves

City	Distance to the source (Km)	Time interval Δt (s)	Average velocity (Km/s)
Lisbon	342.44	46.7	7.33
Coimbra	518.00	68.0	7.62
Porto	610.39	78.5	7.78

The average velocity increases with the distance to the earthquake source. As the cities are located near the Atlantic coast, the increase of the distance is due to an increase in latitude values. The velocity of the seismic waves varies with pressure and temperature [10]. It increases with pressure and decreases with temperature. As we are talking about the same point of departure (the earthquake source) we think that these different values of seismic velocity are related with different temperature values in the last part of the trajectory. This higher temperature values are obtained in regions with lower latitudes such as Lisbon and the source of the earthquake.

2.3 Structures with different thermal properties

Contact zones between structures with different thermal properties can be identified using results from seismic tomography and gravity data [11][12] and also the radiometric chart of natural radioactivity of rocks from Mainland Portugal [13]. Depths of the contact zones may be found from seismic velocities and boundaries between "warm" and "cold" regions with contrast of thermal properties can be obtained from the ratio between V_P and V_S waves [12].

3. Some comments

There are only one Permanent Magnetic Observatory on mainland Portugal. Its location is in the city of Coimbra (40 13.3N latitude and -8 25.3W Longitude)..Geomagnetic anomalies in Lisbon and Southern part of the country were not registered. The decrease of the average velocity values of the first arrivals of the seismic waves is very important to understand the spatial temperature variation. The heating effect occurred throughout the month and reached the highest value on the 27th with changes in the direction of the magnetic field. Information about magnetic anomalies near the earthquake source are not available. Information related with the structure of the region [11] and the location of the earthquakes registered on days 27th and 28th in the Horseshoe region clearly indicates different materials in the region forming a boundary between regions with and without earthquakes.

The maximum value of seismic intensity in mainland Portugal (Grade VIII of the Mercalli scale) was found in the southwestern region, near the village of Vila do Bispo. This is a region with Atlantic Ocean water in the western and southern coast. Some contrast between magmatic and metamorphic formations, with different values of radioactivity may be found [13]. V_P/V_S ratio values at 1,4 and 8 km depths suggest cold regions, rigid, and without fractures, but at 12 and 16 km depth the situation is different and warm values (indicating water or fractured regions) are present [12]. At the surface, near the places with more destruction, a negative anomaly of radioactivity is present [13].

4. Conclusion

Geomagnetic anomalies found with data from Geomagnetic Observatories may be connected with water temperature increase. Different anomalies may originate different levels of heating. Anomalies related with changes in geomagnetic field direction may be very important in regions with water.

Different temperature values were deduced from the average velocity of the first seismic wave arrival time at three seismic observatories located in three cities of mainland Portugal.

The heating effect of materials with different thermal properties can originate/increase pressure gradients of thermal origin and possible rupture of the material. This effect may have occurred in some places (southwestern part of Portugal) and be overlapped with the main earthquake causing a high level of destruction.

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