ENERGY-RELEASED APPROACH: ON THE SEISMIC BEHAVIOR CHARACTERISTICS OF ECUADOR.

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ABSTRACT

The scope of this paper is to define the characteristics of the seismic behavior using the energy-released concept. The historic energy released pattern is used for defining seismic periods and seismic stages (different seismic behavior instants) during the last century. The analysis has been extended to understand these characteristics for large and small earthquakes separately. The historical data have been used to corroborate the tendencies, although the principal analysis takes into account 2400 events from twentieth century.

Introduction

The coast of Ecuador is 200 km from the boundary of the Nazca and the South American plates. This is one of the most active subduction zones in the world, which is why this region has very high seismic activity. There are several big earthquakes reported in Ecuador since the sixteenth century. The historical data before 1900 are only estimated by references existing in historic documentation. After 1900 the magnitudes and epicenters become reliable because they are the result of a conventional calculation. The Ritcher magnitude is an estimation of the destructive power of an earthquake and could be used to calculate the energy released by an event (3). Guttenberg and Ritcher gave the relation for these two concepts in 1956:

$$\text{Log}\,(E_S) = 1.5\ M_s + 11.8\ \ (\text{Ergs}) \tag{1}$$

This paper resumes the analysis of the variation of the energy released for the area of Ecuador. Additionally relate the energy released concept with the number of events in order to define some parameters for the seismic behavior of the area. Ecuador was divided into three areas depending on the geological origin.

Studied Area

The Area between latitude 3N to 7S and between longitude 84W to 73W is studied in this paper. This area comprehends the boundaries of Ecuador and 200 km around them, the additional area contains important sources of seismic events that affect the seismic behavior of the region.

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The area has been divided in three zones, depending on the geological origins (Fig 1). The zone 1 correspond to the coast region which is 200 km from the subduction trench, it has a relative new origin and has important actives faults (2). The zone 2 corresponds to the highland which are crossed by Los Andes chain. The zone 3 corresponds to the Amazonian region.

Seismicity and Seismic Data

More than 2400 events, taken from the Geological Survey of United States (USGS) catalogue, has been analyzed in this paper. The area is crossed by the boundary between Nazca and South American plates, this trench is the principal source of high magnitude earthquakes for the region. The area has several active faults parallel to the subduction trench (2). The faults are constantly producing earthquakes and releasing energy but in minor quantity than the subductive trench.

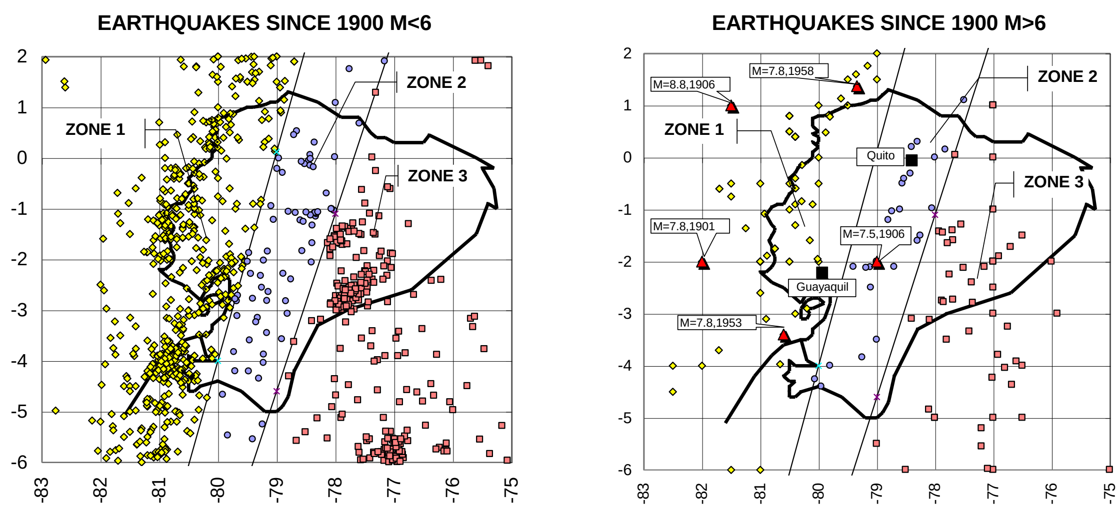

Figure 1.

The Great Ecuadorian Earthquake of 1906

The first big earthquake of the century occurred on January 7th of 1901 it was Ms=7.8, occurred in zone 1, 100 km from Guayaquil, the biggest city in Ecuador, with more than 3 millions of inhabitants (Fig.1).

The Great Ecuadorian Earthquake occurred on January 31st of 1906 with Ms=8.8 and depth = 25 km, this earthquake struck the northern coast of Ecuador in zone 1, 100 km from the shore line in front of the coast of Esmeraldas. This event produced a Tsunami wave with a range of oscillation of 3.6 meters during 30 minutes in Hawaii, killing more than 1500 persons (5). This event is considered the 4th biggest earthquake in the world and the second in Latin America by the US Geological Survey.

The third major earthquake was on September 28th of 1906 with Ms=7.5 and depth of 150 km, this was an event of the zone 2 (Fig.1). These three earthquakes are part of a seismic instant where high levels of energy were released.

Historical Events

In this region there are references of earthquakes since the sixteenth century. The magnitudes and epicenters of the events before 1900, are estimated from the information obtained in historic documents for that reason this values are not reliable, but these data can be analyzed to observe the historic seismic activity pattern as is shown in fig. 2. This graphic shows the events (Ms>7).

The envelope curve of the historic pattern shows the close relation that exist between the reliable data recorded after 1900 and the estimated data before 1900.

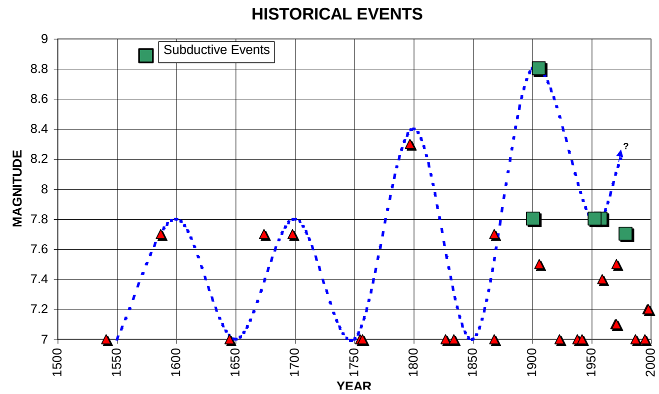

Figure 2.

The events shown with a square are events of zone 1. They are the biggest events in this region they give the shape to the enveloped curve.

The Law of 95% on Energy Released

For this area the analysis shows that the 95% of the events are Ms<6, and they release 5% of the energy stored and the 5% of the events are Ms>6 and they release 95% of the energy stored. This is called the law of the 95% on energy released.

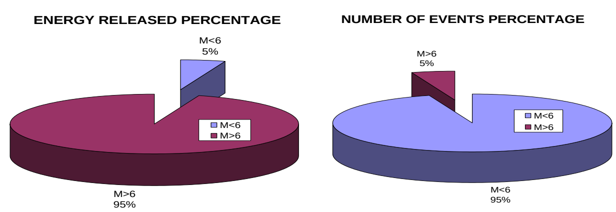

Figure 3.

Stored Energy and Energy Released

The energy is defined as the capacity to do work, when a work is done on a material the energy is stored as strain energy (1). If there is not absorption or dissipation of energy then:

Strain Energy = Work Done. (2)

The theorem of Castigliano declares that: "If the total strain energy expressed in terms of external load is differentiated with respect to one load, the result is the deflection in the point of application of that load and in the direction of the load".

$$\delta = \frac{\partial U}{\partial F} \qquad (3)$$

Where δ is displacement, U is the energy stored and F the force. The relation between stress and energy is express by the following expressions:

$$U = \frac{\sigma^2}{2E} \quad ; \quad U = \frac{\tau^2}{2G} \qquad (4)$$

The movement of plates generates an increment on the energy stored, this fact creates an increment of the stress on the rock Eq. 4. The theorem of Castigliano can be used to relate the energy and displacement.

The number of events and energy released by minor earthquakes (Ms<6) is governed by areas of low capacity to store energy. When the energy stored increases, these areas begin releasing more energy and the number of event increases because those areas have not enough capacity to store it, then an increment in the number of minor events is a sign that the energy stored is increasing.

The number of event and the energy released by major earthquakes (Ms>6) is governed by areas of high capacity to store energy, in these areas the energy released not necessarily increase with the energy stored, because the areas continue storing energy.

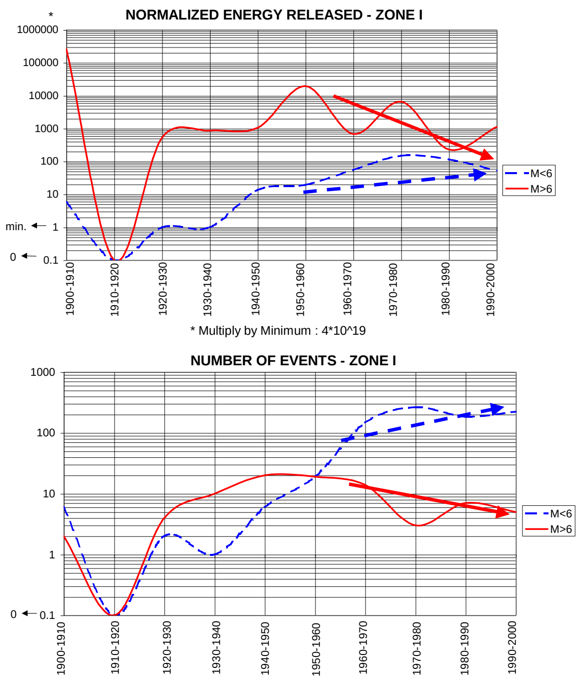

Figure 4.

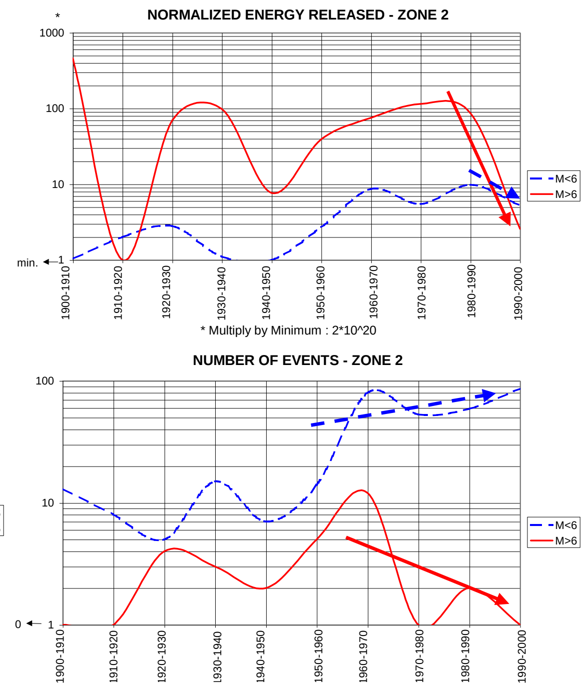

Figure 5.

The strain energy released potency theory (SERPT) declares that: " If the probability of occurrence of several damage mechanism is the same, the mechanism most likely to occur first will be the one which has the highest potential for releasing stored strain energy"(4). Then the event expected to occur will have the higher magnitude but this fact is limited by the characteristic of the material in the fault because the rupture occur when the stress in the material overcomes its maximum resistance, after this, the material collapse and liberate the energy stored.

Seismic Stages

A stage is a specific instant in the historic seismic behavior (Fig. 7), each stage counts with two phases; the first one is an instant of high liberation of energy and the second is the process of recharging the stored energy for the next stage.

One of the factors for the increment in number of events registered during the analyzed period are the improvements in the sensors in the region. . We have analyzed the information trying not to be affected by this factor.

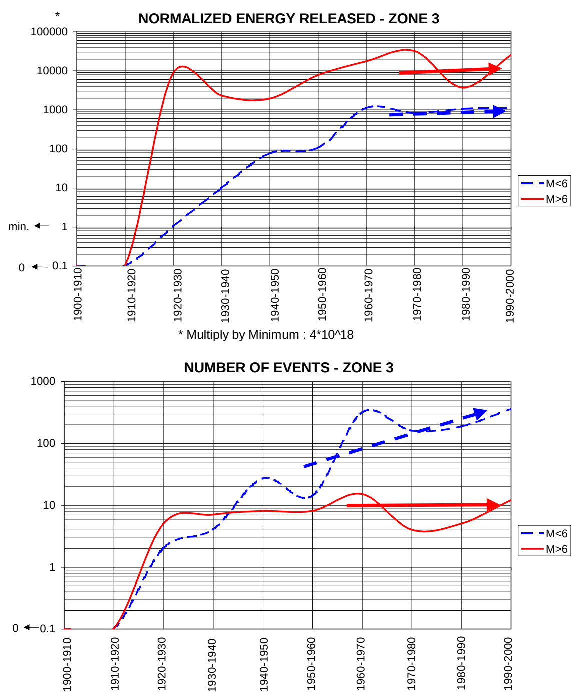

Figure 6.

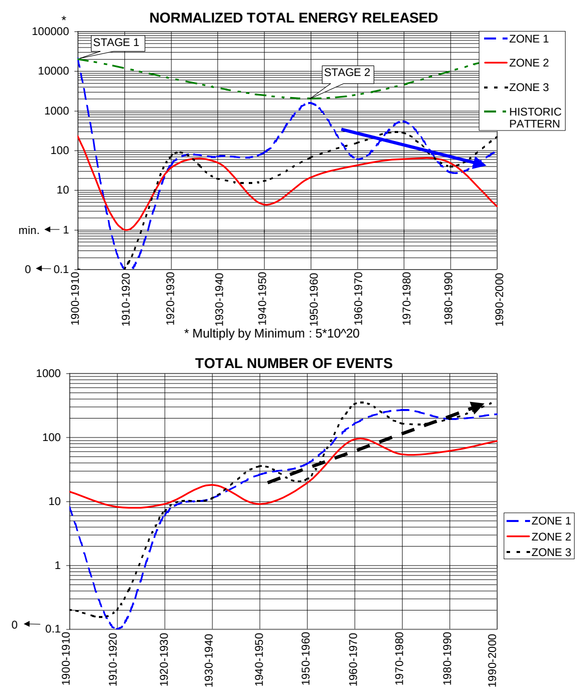

Figure 7.

Stage 1

Occur at the beginning of each century, is compound by 10 years of high energy released. Three major earthquakes occur during this stage in zone 1 and 2; one in 1901 and two in 1906 (Fig 1,2). This decade was succeed with 10 years of distension, where almost no seismic activity occurred, due to the high levels of energy released in the former decade. After this, 30 years of releasing a middle level of energy, in this time the energy stored is recovered for the next stage.

Stage 2

Occur at the decade of 50's in each century (Fig. 2), the energy released is high but 100 times less than stage 1. This stage has 10 years of high energy released and until now, 40 years of storing energy for the next stage. From the historic seismic pattern (Fig. 2) is possible to infer that a new stage 1 will happen at the beginning of the century.

Conclusions

Guayaquil city has more than 3 millions of inhabitants, it is the biggest city in Ecuador. The location of this city (Fig. 1) is critical in stage 1 and 2 because there have been 3 major earthquakes of Ms>7.5 at 100 and 200 km of distance.

The zone 1 releases more energy than the other regions, it had 4 earthquakes of Ms>7.8 in this century (Fig.1). The Fig. 4 shows that the energy released by events Ms>6 is $8*10^{24}$ ergs and $8*10^{23}$ ergs at stage 1 and 2 respectively. This zone is storing energy for that reason the graphic of energy released has a tendency to decrease in the last decades. The number of events Ms>6 is decreasing and the number of events Ms<6 is increasing. All these clues indicate that the stage is in the second phase and storing energy for the next stage.

The zone 2 shows a minor level of energy-released, Fig. 5 shows that $8*10^{22}$ ergs and $2*10^{22}$ ergs were liberated in Stage 1 and 2 respectively. This zone is storing energy too, because the graphic of energy released has a tendency to decrease. The number of events Ms>6 is decreasing and the number of events Ms<6 is increasing. This indicates that the stage is in the second phase too and storing energy for the next stage.

The Fig. 6 shows the behavior of zone 3. It has no events in stage 1 but this value is clearly affected by the lack of sensors for this area at that time. The energy liberated for stage 2 was $1*10^{23}$ ergs. The curves of energy released and number of events are increasing.

The Fig. 7 shows the energy released by all the events in the different zones, all the zones are storing energy for that reason all the curves are decreasing. The number of events is increasing in all the zones, this indicates that the complete area is recharging the energy stored that is going to be released in the next stage. The maximum levels of energy released occur at zone 1 and was $1*10^{25}$ ergs and $1*10^{24}$ ergs for Stage 1 and 2 respectively.

Two Stages has happened in this century. The same stages appear in the graphic of historical events (Fig.2) which indicates that important earthquakes occur at the beginning and in 50's of each century. This seems to be the periodical pattern for this region.

References

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