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ON THE VOLCANIC ACTIVITY AND LARGE EARTHQUAKES IN COLIMA AREA, MEXICO

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RESUMEN

Se analiza la relación entre eventos volcánicos y eventos sísmicos grandes en la región de Colima, México. El comportamiento entre ambos parámetros concuerda con el reportado por Carr (1977) en el estudio de áreas similares. Se reportan dos posibles relaciones entre estos parámetros, una de ellas es similar a la reportada por Acharya (1982) en el estudio de áreas sismovolcánicas.

ABSTRACT

The relationship between volcanic events and large earthquakes is analyzed in the Colima area of Mexico. The patterns between these parameters are in agreement with those reported by Carr (1977) in a study of similar areas. Two possible relations are found between these parameters, one of them is similar to the one reported by Acharya (1982) for other seismovolcanic areas.

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INTRODUCTION

Recently, several authors have reported an apparent relation between volcanic activity and large earthquakes (Carr, 1977; Kimura, 1978; Acharya, 1982). These studies show that the volcanic activity increases a few years prior to a large earthquake. In many cases, the pattern is well defined and is characterized by a quiescence period in the volcanic activity preceding the earthquake. This pattern established by Carr (1977), consists of three parts: *i)* Precursory increase in volcanic activity, *ii)* quiescence preceding the earthquake and *iii)* increase in volcanic activity near the time of occurrence of the earthquake. The most characteristic part of this pattern is the period of volcanic quiescence called Q by Carr (1977). This author observed that the period of increased volcanic activity after the quiescence (phase *iii*) is usually present but is highly variable in intensity, sometimes presenting only a slight increase in the volcanic activity. The starting time of this phase is also variable and it seems to follow a specific pattern according to the area: In southern Chile the phase *iii* began a few years before the earthquakes, in Central America this phase began, in many cases, a few months after or before the earthquake and in the Antillas, most of the historic volcanic events have occurred in association with large earthquakes.

The seismic and volcanic activity patterns for the Colima area shows a pattern similar to the one established by Carr (1977) for other seismo-volcanic areas. In the Colima Volcano eruptions during the past 200 yr phase *iii* is presented with a duration time of a few months to a few years before a great earthquake (Medina, 1983). The 1806 seismic event (Ms <7.5), was preceded for a few hours by an important volcanic event and the 1818 seismic event (Ms <7.7), was preceded by a volcanic event three months before the earthquake. A rough relation between volcanic and seismic events reported by Medina and Mena (1981), for the past 400 yr, indicates that the periods with more seismic events have more volcanic events.

In an analysis carried out in several different areas, in which two or three events with observed Q period had occurred, Acharya (1982) found that the increase in volcanic activity (phase *i*) begins at a time which depends on the earthquake magnitude, and that the burst of activity of small earthquakes follows the increase in volcanic activity. He also reported the following empirical relation:

$$\log t = 0.54\, M - 0.78$$

with a correlation coefficient of 0.94. In this relation t is the time interval in days

from the beginning of the increase in volcanic activity (phase *i*) to the occurrence of the large earthquake and M is the magnitude of the earthquake, implying that earthquakes of a greater magnitude occur at larger time intervals. A similar analysis has been carried out for the Colima area and is presented in this paper.

COLIMA AREA

Historically Colima is Mexico's most active volcanic complex. It lies at the southern end of the 80 - 90 km long SSW trending Colima Graben. To the north, the Colima Graben intersects with the Chapala Graben, which extends to the east, and with a small volcanic chain of composite volcanoes which extends to the northwest (Fig. 1). This Volcanic Complex is the western end of the Mexican Volcanic Belt, which developed as a result of the subduction of the Cocos Plate into the Middle American Trench.

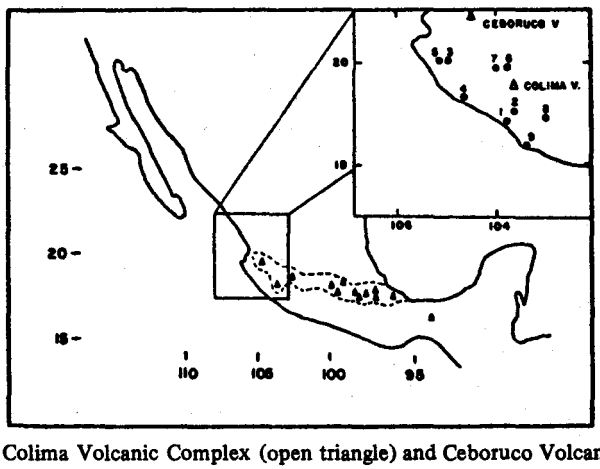


Fig. 1. Location of the Colima Volcanic Complex (open triangle) and Ceboruco Volcano (solid triangle) and its position in the Mexican Volcanic Belt (MVB). The seismic events (dots) are numbered in reference to Figure 2.

The seismicity and historical volcanic activity in the Colima area is known for the past 200 yr. Singh *et al.* (1984) and Singh *et al.* (1981) compiled and relocated the shallow earthquakes that occurred in the area during this period. These authors reported the locations of epicenters with an accuracy of about ± 1(Fig. 1) and the magnitudes to about ± 0.3 unit. On the other hand, Medina (1983) reported a history of the volcanic activity for the same period. The catalog is complete for the majority of the moderate and large eruptions but many small eruptions may be missing. The starting dates of the eruptions at the beginning of the past century are known to within ± 6 months. With this information, an analysis similar to that of Carr (1977) and Acharya (1982) was made for the Colima area.

In his analysis, Carr (1977) defined volcanic activity as the number of volcanoes on the landward side of the rupture zone that were in eruption during a 1 or 2 year time interval. During the past 200 yr, in the Colima area, the Ceboruco has presented activity only during 1870-1876 and the Colima Volcano has presented several activity periods (Fig. 2). The Q period has been observed in more than half of the seismic events for Colima, Figure 2 shows the volcanic and seismic activity in this area. Six events (1, 2, 5, 6, 7 and 9) occurred probably linked with volcanic activity in accordance with the pattern established by Carr (1977), and in all these cases the Q period was observed. Events 3 and 8 occurred without volcanic manifestations, and the Q period was not observed for event 4.

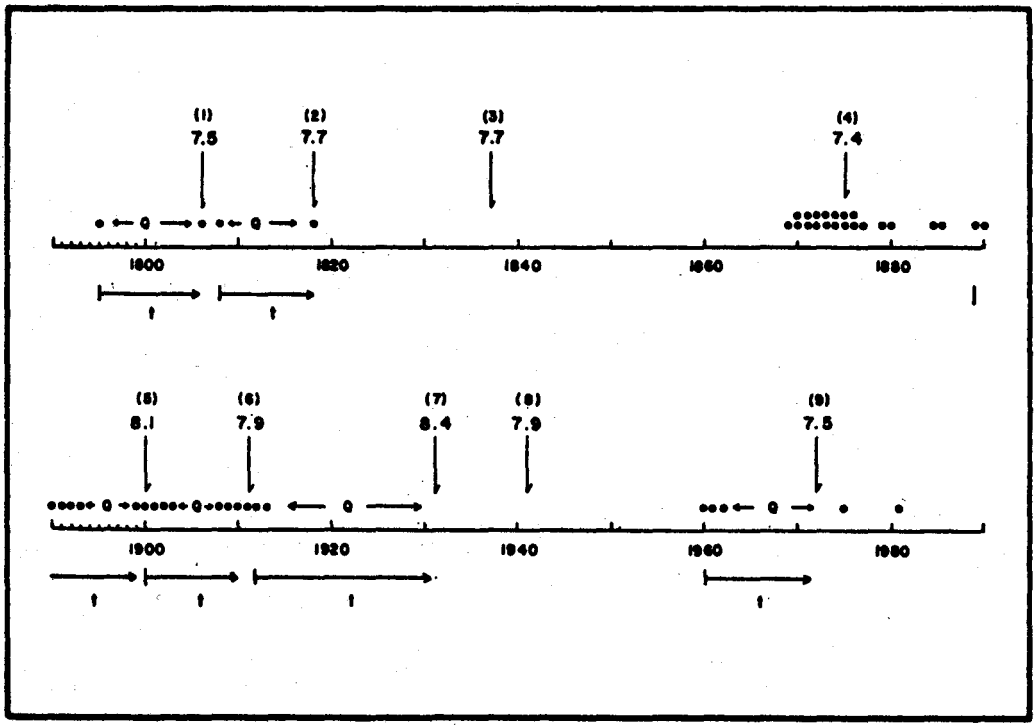


Fig. 2. Volcanic (dots) and seismic events (vertical arrows) for the Colima Area in time. The Ceboruco activity, for the period 1870-1876, is included. The seismic events are numbered according to figures 1 and 3.

DISCUSSION

The data for the magnitudes of the seismic events (Singh *et al.*, 1984) and the time duration between starting phase *i* to the occurrence of the seismic event (Medina,

1983) are shown in Table 1. From this it is possible to find a relationship between these parameters following Acharya (1982). For all the events plotted in Fig. 3 the corresponding regression equation is:

$$\log t = 0.14\ M + 2.51.$$

which is similar to the relation reported by Acharya, but the correlation coefficient is 0.24 (with a probability of correlation less than 35%). If we consider only the events for which the volcano is within the rupture zone (1, 2, 6 and 7), it is possible to find the relation:

$$\log t = 0.28\ M + 1.49.$$

with a correlation coefficient of 0.73 (probability of correlation 63%), which is in agreement with the Acharya's result.

Table 1

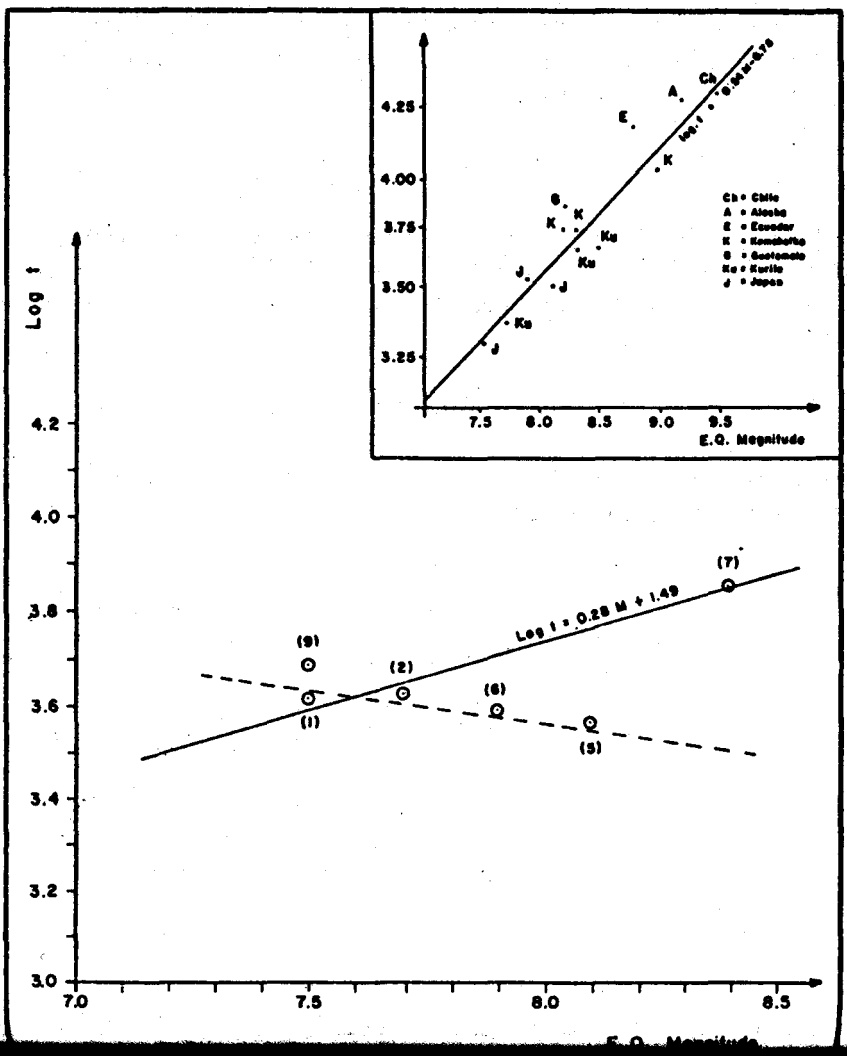
Event	Magnitude (Ms)	Date	Start Phase t^3	log t
1	7.5[1]	March 25 1806	1795	3.61
2	7.7[1]	May 31 1818	1807	3.62
5	8.1[2]	Jan. 20 1900	1890	3.56
6	7.9[2]	June 7 1911	1901	3.58
7	8.4[2]	June 3 1932	1913	3.85
9	7.5[2]	Jan. 30 1973	1960	3.68

[1]Singh, S. K. *et al.* (1981)
[2]Singh, S. K. *et al.* (1984)
[3]Medina, F. (1983)

In Figure 3 it is apparent that the relation could be different with the elimination of the event 7 (dashed line), in this case the equation is:

$$\log t = -\ 0.15\ M + 4.75.$$

with a correlation coefficient of 0.70 (probability of correlation 69%). With the elimination of the events 7 and 1, the correlation coefficient is 0.90. Acharya (1981) interpreted the period of increased volcanic activity followed by quiescence as cor-



ning of increase in volcanic activity (phase 1) to the occurrence of the large earthquake. The continuous line is a relation similar to the one reported by Acharya (1982), the dashed line is a possible different relation between these parameters. Above, data and relation reported by Acharya (1982).

responding to an increase in aseismic subduction followed by stronger coupling between the plates, and suggested that the dependance of t on earthquake magnitude is of longer duration for larger earthquakes. The relation with the elimination of

event 7 implies that great magnitude earthquakes were preceded by small time intervals. The same pattern could be observed in the analysis of other volcanoes such as Izu-Oshima, with the seismic events of 1923 and 1956 and the preceding volcanic activity (Yamashina and Nakamura, 1978) and the Guatemalan volcanoes with the seismic events of 1902 and 1942 (Carr, 1977).

CONCLUSION

These results could be interpreted as supporting the idea of the existence of a relationship between volcanic activity and large earthquakes. The patterns observed in the Colima area are in agreement with those reported by Carr (1977) in other seismo-volcanic areas; two thirds of the seismic events occurred with a quiescence period in the volcanic activity prior to large earthquakes (Q period is presented in all the events in which the volcano is within the rupture zone).

Considering only the seismic events in which the rupture zone includes the volcanic area, the relation found is very similar to the Acharya (1982) results. This relation suggests that great magnitude earthquakes were preceded by great time intervals. However, it is possible to find another apparent relation which implies that great magnitude earthquakes were preceded by small time intervals between start phase *i* and the seismic event. With the limited number of events it is not possible to conclude if the Colima area follows the pattern observed by Acharya.

For his analysis Acharya examined different areas, each one with two or three events with observed Q period (13 events in total and only one is in Central America, Fig. 3), in our case the analysis is carried out only in one area with six events. It is possible that different areas follow different patterns. For the comparative analysis between these and the Acharya results, the separation of events by specific areas is needed, but this work is limited in that the volcanic activity history is not available for many areas.

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