THE JANUARY 25TH, 1999, EARTHQUAKE IN THE COFFEE GROWING REGION OF COLOMBIA

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SUMMARY

At 1:19 PM local time (18:19 GMT) of January 25, 1999, a 5.9 m_b magnitude, ±10 km depth earthquake occurred in the Central-Western region of Colombia. The seismic event occurred in the heart of the coffee-growing region on Colombia, where most of the coffee produced by the country is harvested. Despite the relatively low magnitude of the event, it caused more than 1200 casualties and approximately 3000 injured persons. The earthquake affected the cities of Armenia and Pereira, capitals of the departments of Quindío and Risaralda, respectively, and several smaller towns. The geographical setting of the region is presented. The tectonics of the North-Western corner of South America are discussed. The main faulting systems in Colombia are presented along with the seismology of the country. The current earthquake resistant design regulation seismic hazard maps are discussed. The present article corresponds to a brief general introduction to five additional papers that deal in more detail with the characteristics of this earthquake.

1. GEOGRAPHIC SETTING

Colombia, with an area of 1,138,300 km^2, is located in the North-Western corner of South America. The country has coasts both in the Atlantic (Caribbean) and Pacific Oceans, to the north and west respectively, with bordering Panama between them. To the east borders with Venezuela and Brazil, and to the south with Ecuador and Peru (see Figure 1). As the northern Andes enter into the country from Ecuador, they divide into three cordilleras -- eastern, central, and western -- with the Magdalena River running between the first two with a south-north direction for 1550 km from a place just north of the border with Ecuador to the Caribbean. The Cauca River, a tributary of the Magdalena, runs between the western and the central cordilleras. Geologically the central cordillera is the oldest, and the eastern one the youngest. The active volcanoes in Colombia lie in the central cordillera, and provide through volcanic ash the appropriate topsoil for good quality coffee growing. Since the temperature in the tropics depend on altitude, elevations between 800 and 1500 meters above sea level; provide the climate suitable for this crop. Although coffee is produced in most of the Andean region of Colombia, the departments more affected by the earthquake -- Quindío, Risaralda, Valle, Tolima and Caldas -- account for the greater part of the production.

More than 85 per cent of the population of Colombia lives in the Andean region. The population of the country has increased more than three times since the 1950's (see Figure 1). Presently, sixty-eight per cent of the population lives in urban centers. The combination of these factors makes most Colombian cities especially vulnerable to natural disasters, and especially to seismic events, where the built environment play such a large role with respect to the number of victims. The coffee-growing region has been part of all these processes taking place, and the cities located there grew at the same if not larger rate. Currently the region has a population of the order of 1,500,000 inhabitants. The population of Armenia, capital of the Quindío department, is 320,000 inhabitants and Pereira, capital of the Risaralda department, has 456,000 inhabitants. The region contains also a large number of small to medium size towns.

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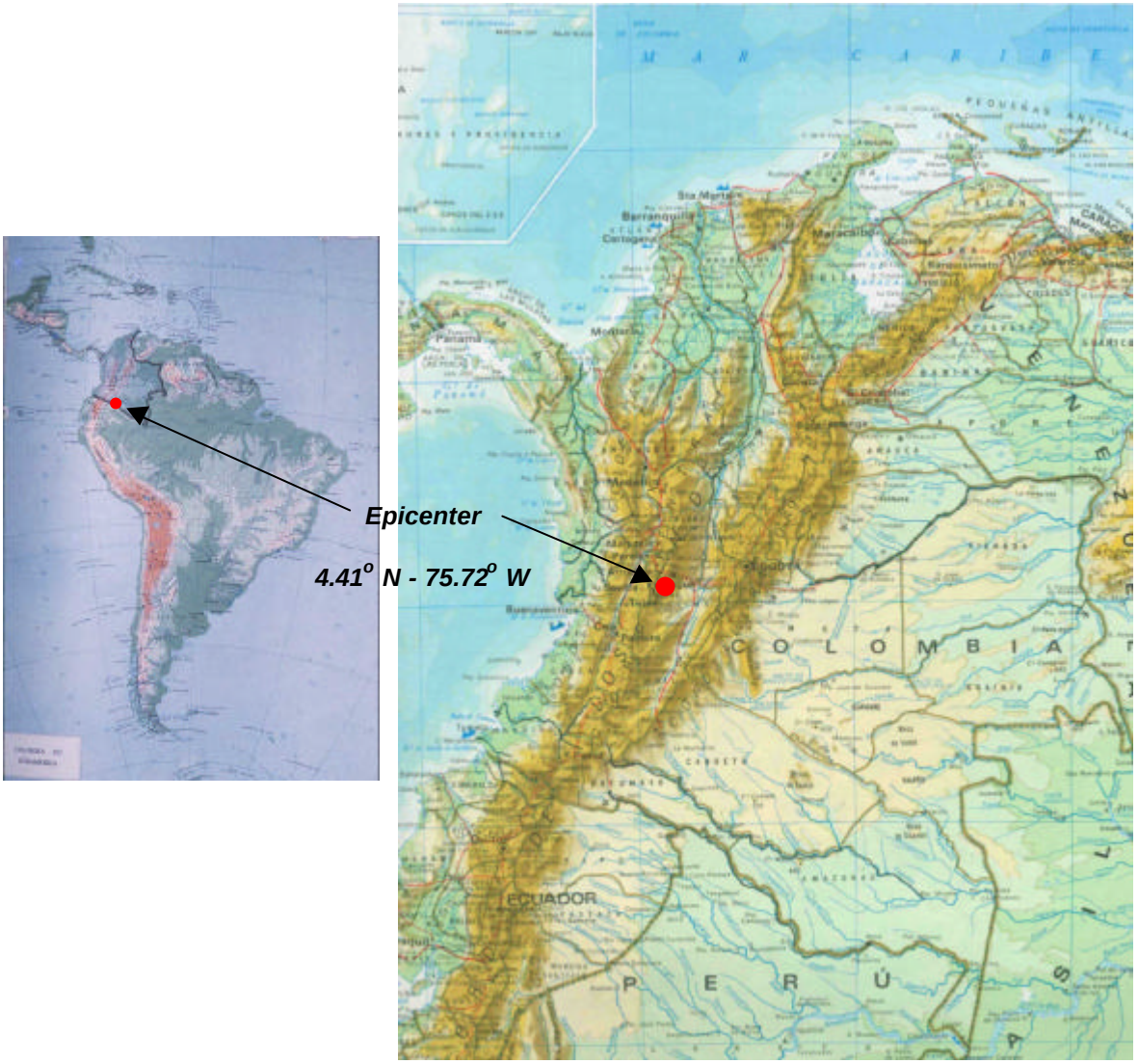

Figure 1 – General location of the January 25th, 1999, earthquake

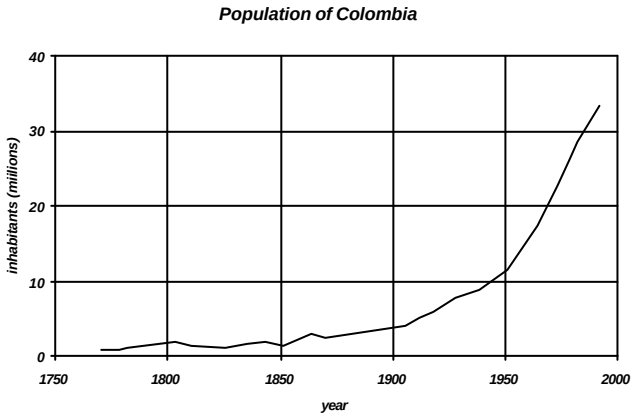

Figure 2 – Increase of population in Colombia in the last 230 years

2. THE JANUARY 25th, 1999, EARTHQUAKE

At 1:19 PM local time (18:19 GMT) of January 25th, 1999, a 5.9 $\mathbf{m_b}$ magnitude, ±10 km depth earthquake occurred in the Central-Western region of Colombia (4.41° N - 75.72° W). The epicenter was located 16 km

south of Armenia and 48 south of Pereira (see Figure 3). The causing fault has been established as the Silvia-Pijao segment of the Romeral faulting system. At 5:40 PM local time of the same day, a 5.4 m_b magnitude aftershock occurred. The towns and cities more affected by the earthquake were (from South to North in Figure 3) in the department of Quindío: Pijao, Buenavista, Córdoba, La Tebaida, Armenia, Calarcá, Montenegro, Circasia, Salento, Filandia; and in the department of Risaralda: Pereira, Dos Quebradas and Santa Rosa de Cabal.

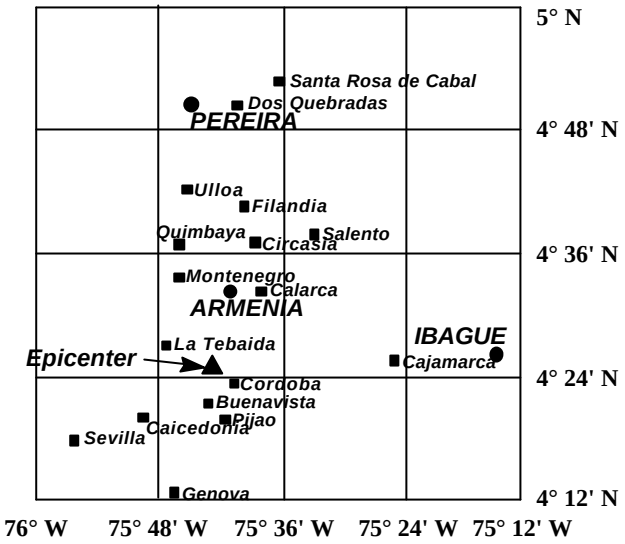

Figure 3 – Cities and towns affected by the January 25th, 1999, earthquake

3. GENERAL TECTONICS OF NORTH-WESTERN SOUTH AMERICA

The tectonics of the northwestern corner of South America is complex, to say the least. The fact that the Nazca, South American and Caribbean Plates converge in Colombian territory makes the tectonics of the region specially challenging (see Figure 4). The border between the Caribbean and South American plates is undefined. The Nazca plate forms a subduction zone under the South American plate in the Pacific Ocean coast. The direction and the convergence rate of the plates is shown in Figure 5 [Kellog and Vega, 1995].

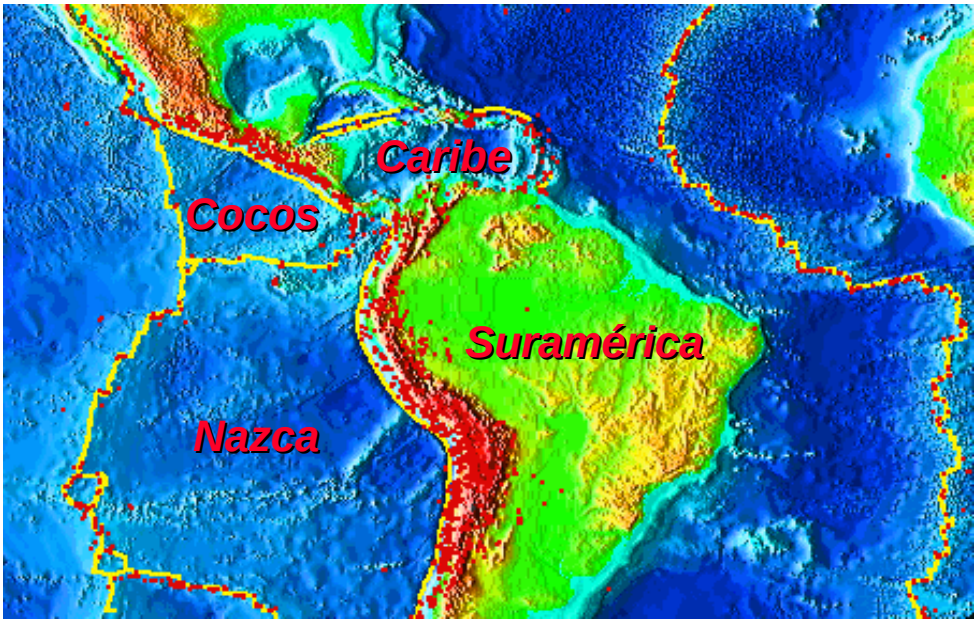

Figure 4 – Tectonic plates that meet in Colombia

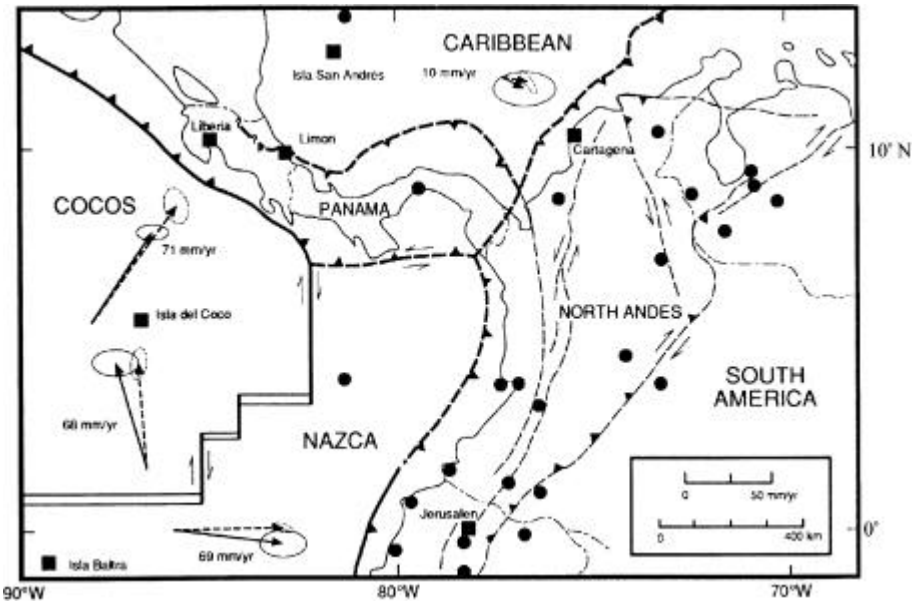

Figure 5 – Direction and convergence rate of the tectonic plates in Colombia [Kellog and Vega, 1995]

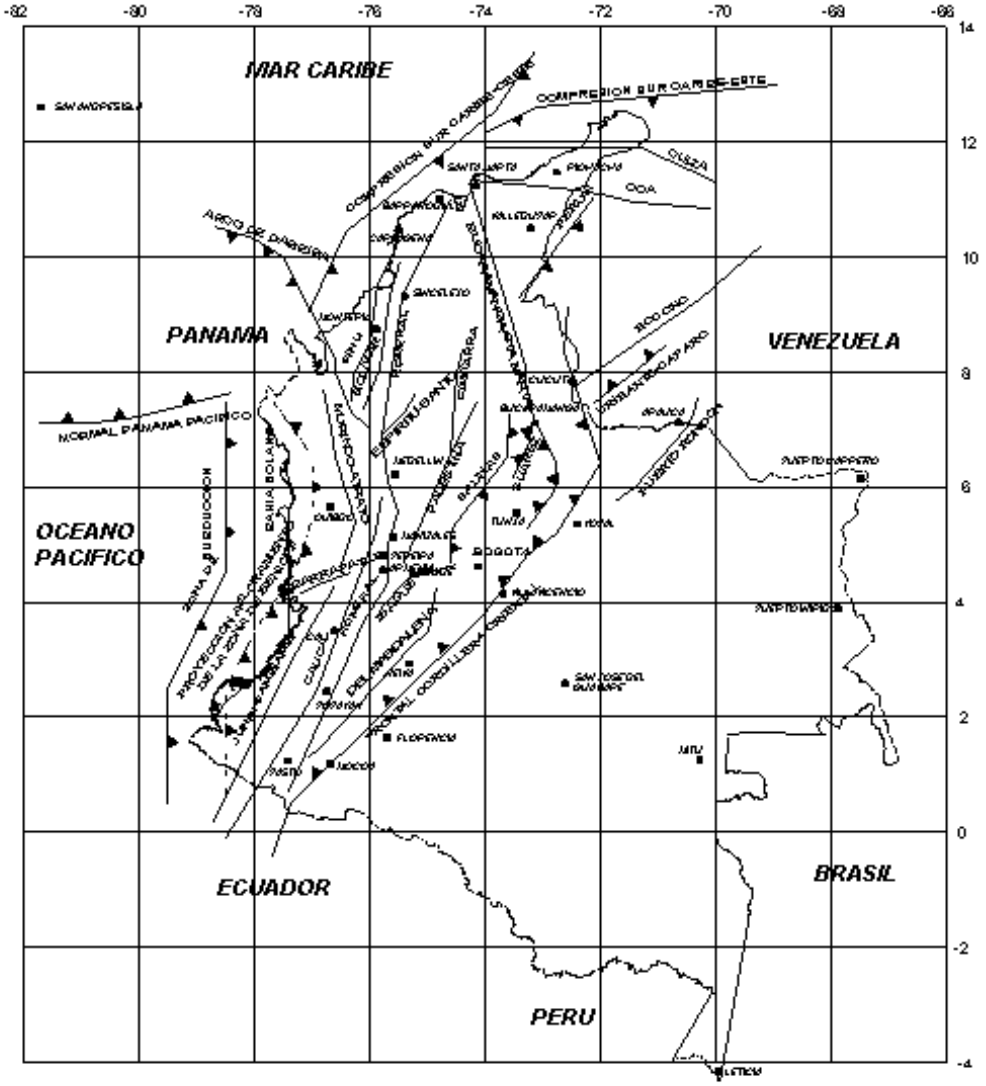

Figure 6 – Main faulting systems in Colombia

The structural geology of the country had been studied with different degrees of detail. In general, a good mapping of large fault systems had been done for mining and petroleum exploration purposes. Special exploration has been done on a routine basis for the large hydroelectric projects with participation of leading world consulting firms. All this information was available for the identification of the main faulting systems [París, 1993]. They are shown in Fig. 6. In general, the faulting in Colombia has a predominant N-S direction in coincidence with the three main cordilleras. The main seismotectonic accident is the Subduction zone in the Pacific Ocean. It is caused by the bending of the Nazca Plate as it subducts under the South American Plate. In the Colombian Pacific Coast, there is evidence of its existence from a point south of the Equatorial Line to 8° north. The ability to produce very large magnitude earthquakes of this subduction zone is known and the December 12, 1979 M_s = 7.9 earthquake certainly was produced by it. A Benioff zone develops with different dip angles that can be obtained from E-W sections of plots of focus of earthquakes. Its activity varies but earthquakes up to 120-130 km of depth can be assigned to it. Besides this, a large number of faults have been identified.

4. SEISMICITY OF COLOMBIA

The first event of which a written record exists occurred in 1566, causing intensive damage in Cali and Popayán in the South West part of the country [Ramírez, 1975]. The instrumental seismicity of Colombia begins with the installation of the first seismographic station in 1922. Seven permanent seismographic stations scattered through the country were operated by the Geophysics Institute of the Javeriana University in Bogotá, from 1957 to 1993. In 1993, the Colombian Seismological Network, administered by Ingeominas, a Colombian government agency, started operation. Currently it has 20 permanent stations, linked via satellite to a main processing center located in Bogotá. Figure 7 shows the spatial distribution of earthquakes, including historical and instrumental events, and covers data from 1566 to January 1995. From this figure, it is evident that the Nazca Plate subduction and the existing faults in the Andean region of produce most of the seismic activity in the country.

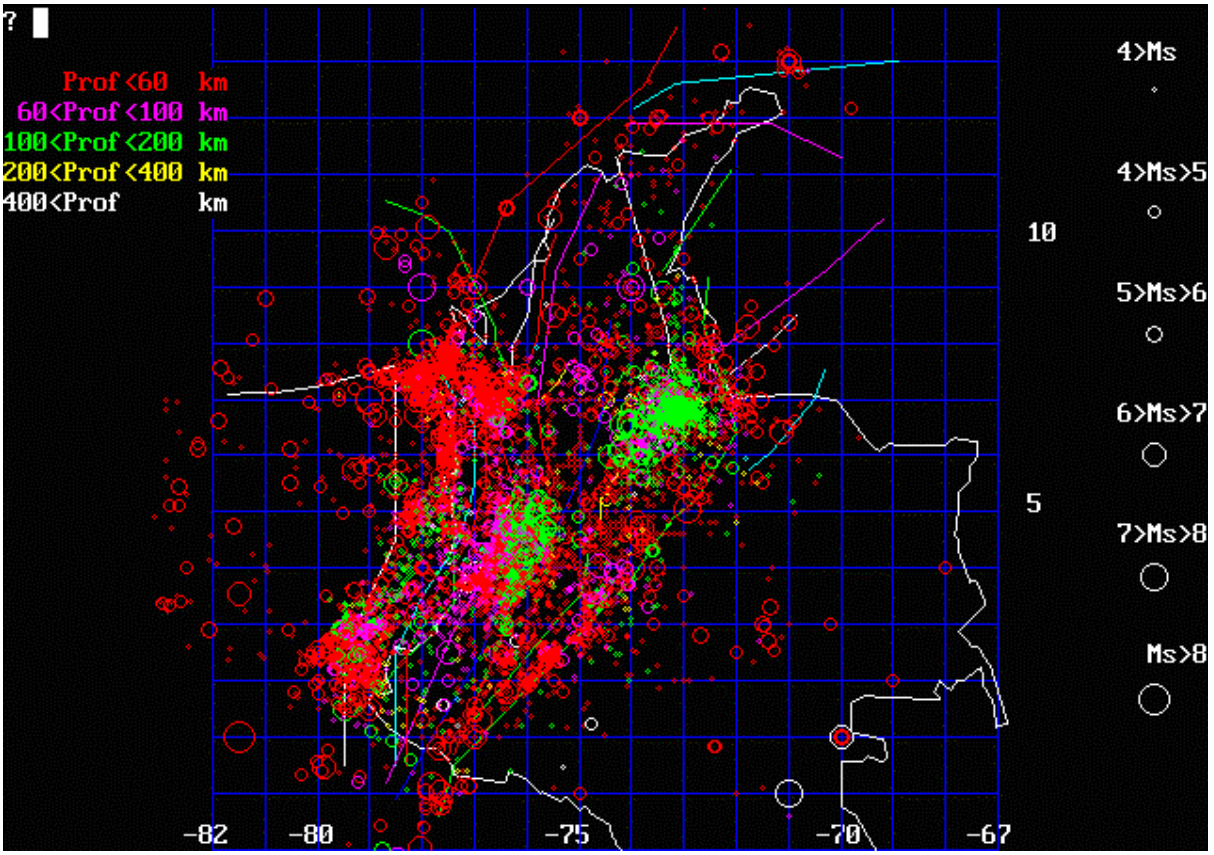

Figure 7 – Earthquake location, depth and magnitude in Colombia 1566-1995

5. SEISMIC ZONING AND PEAK GROUND ACCELERATION

Current seismic design regulations, enacted in January 1998, contain the maps shown in Figures 8 and 9 [AIS, Ingeominas, and Uniandes, 1996]. The map in Figure 8 divides the country into High, Moderate and Low

seismic hazard zones. The map in Figure 9 shows the effective peak ground acceleration in rock for a mean return period of 475 years. The coffee growing region is contained within a high seismic hazard zone, and the effective peak ground acceleration in rock corresponds to zone No. 6, with a value of $\mathbf{A_a}$ = 0.25.

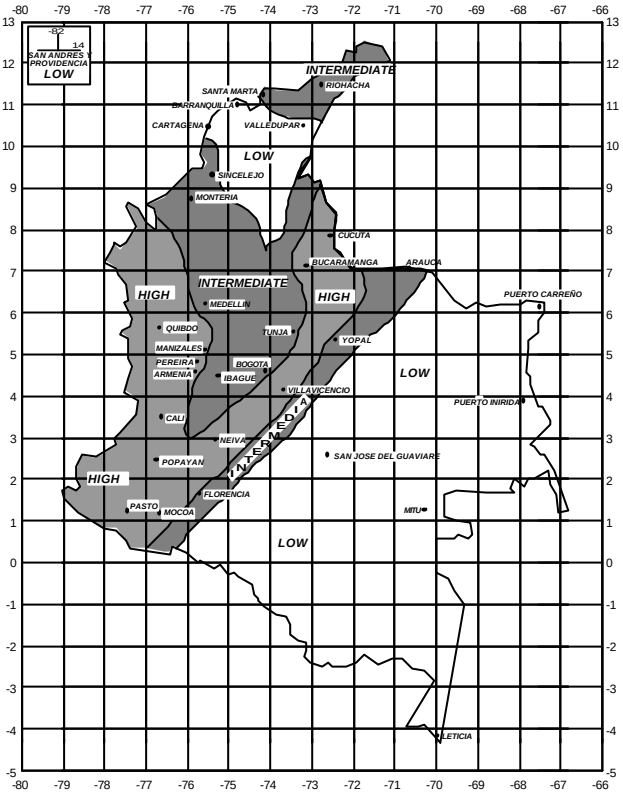

Figure 8 – Seismic hazard zoning in Colombia

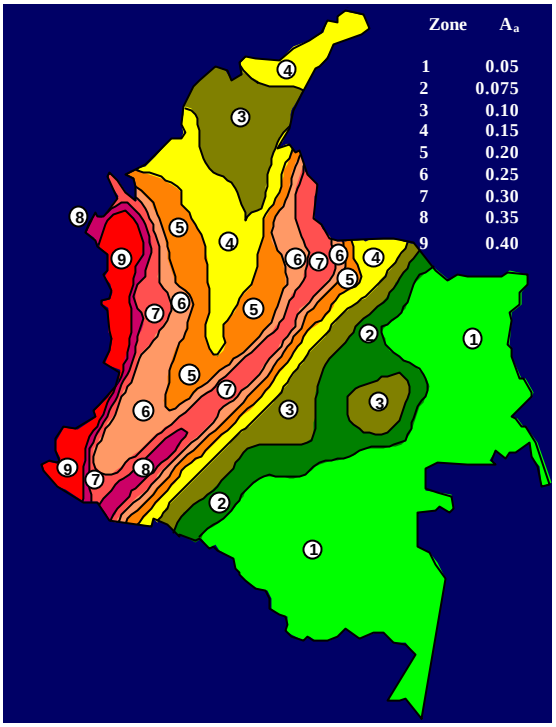

Figure 9 – Effective peak ground acceleration

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