DOI 10.4430/bgo00386

Estimating magnitude and location from macroseismic data of the 1925 Colombian earthquake

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(Received: 10 February 2021; accepted: 17 January 2022; published online: 23 June 2022)

ABSTRACT The earthquake of 7 June 1925, which occurred in south-western Colombia, is one of the most important intraplate seismic events in the region. This earthquake caused damage at several localities along the Cauca valley. The distribution of the intensity data points reveals a trend line in the SW-NE direction, corresponding to the Andean mountain range, which coincides with the strike of the main geological faults existing in the SW of the country. In this work, earthquake parameters are computed from macroseismic data. The moment magnitude obtained is 6.6 ± 0.2. The epicentre is located at the coordinates 3.29° N and 76.91° W, at approximately 50 km SW from the town of Cali.

Key words: earthquake parameters, intensity data points (IDPs), Cali, Colombia.

1. Introduction

The earthquake of 7 June 1925 is possibly one of the most important intraplate seismic events in Colombia, which significantly contributes to the seismic history of Cali, the capital and largest town (population ~ 2.3 millions) of the Valle del Cauca department and main economic growth pole in south-western Colombia.

Earthquake parameters published by Gutenberg and Richter (1949) gave the focal time at 23:41:42 (UTC) and the epicentre located offshore, in the Pacific Ocean, at the coordinates 3.0° N and 78.0° W, with a focal depth of 170 km. Engdahl and Villaseñor (2002) and ISC (2020) proposed the epicentre as onshore, associating it to a crustal source.

In literature, macroseismic studies and relocation of the epicentre have been observed since the 1980s. The seismic risk study by GERSCO (1987) presented some effects, caused by the event, in several localities in Valle del Cauca department, including the town of Cali; however, this report was not officially published. According to some macroseismic data, patterns and trends of other earthquakes with good instrumental locations in the region, Mendoza *et al.* (2004) proposed that the earthquake of 7 June 1925 originated in the Wadati-Benioff area, locating the epicentre as onshore, in the northern Valle del Cauca department. In that study, an isoseismal map is presented with three isolines, and the one indicating the highest intensity, containing Cali, has a value of 7 of the Modified Mercalli (MM) scale.

The knowledge of macroseismic data for the 1925 event has been improved by several historical studies (Espinosa Baquero, 2003; Salcedo-Hurtado *et al.*, 2005; Sarabia and Cifuentes, 2010). Such studies have contributed with new distributions of intensity data points (IDPs) in Valle del Cauca and neighbouring departments and maximum intensities in the Cauca valley. An updated historical seismicity study on Cali reviews primary and secondary sources that enabled us to evaluate the damage and effects caused to buildings of this and other towns of Valle del Cauca department (Salcedo-Hurtado *et al*., 2007; Salcedo-Hurtado *et al.*, 2021a). The maximum intensity is assigned to Cali town (I = 8 EMS-98), 84 km away from the onshore instrumental epicentre proposed by Engdahl and Villaseñor (2002), and 165 km from the epicentre proposed by ISC (2020). These instrumental solutions are located far from the highest macroseismic intensities and cannot be considered reliable. Up to 1941, earthquakes localisation in South America depended heavily on the records acquired by the La Paz station in Bolivia (Gutenberg and Richter, 1949).

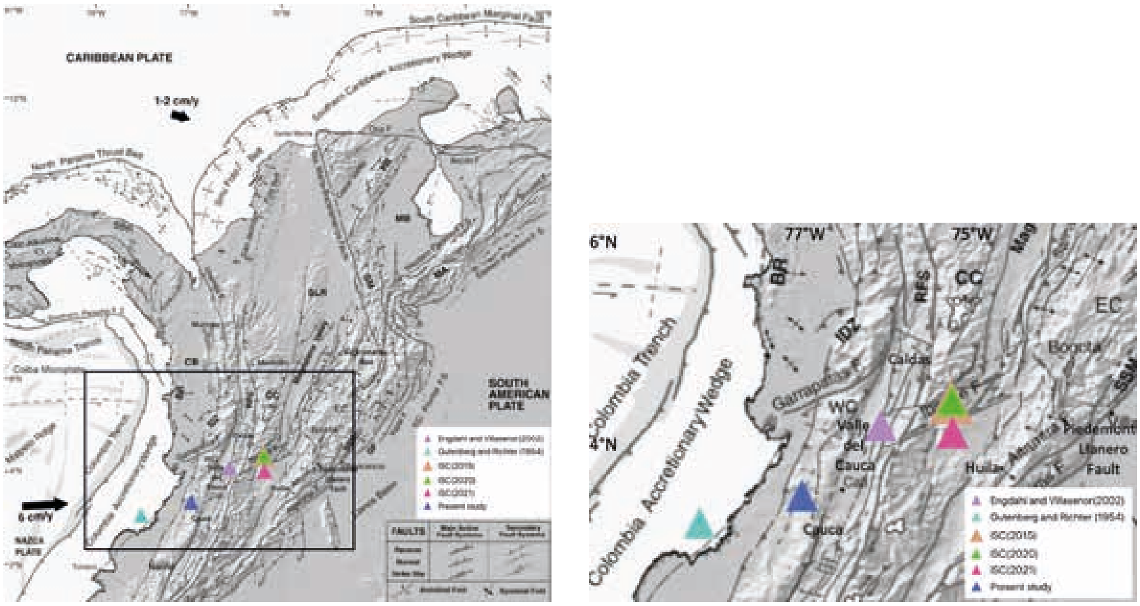
The Colombian historical seismicity (Ramirez, 1975) is based on more than 250 earthquakes with textual description between the 16th century and the beginning of the 1970s (Espinosa Baquero *et al*., 2004). Between the 1940s and 1990s, the instrumental location of seismic sources in the Colombian territory improved thanks to the deployment of the seismological network of the Geophysical Institute of the Colombian Andes, linked to the Pontifical Xavierian University (Vargas-Jiménez *et al.*, 2018). The National Seismological Network of Colombia started its activity in June 1993 (Nieto Echeverry and Escallon Silva, 1996; Pulido, 2003).

Systematic investigations of national and local historical archives have contributed to improve the knowledge on the 1925 earthquake. At that time, the city of Cali [60,350 inhabitants (Jiménez and Bonilla, 2000)] was not the same as it is now. Despite the structural differences and the size of the city at different periods, according to the historical seismicity research carried out in the framework of the seismic microzonation study of the city of Cali (Salcedo-Hurtado *et al*., 2005), there is no evidence that any other earthquake has caused the damage and effects like those produced by the 1925 earthquake. In this paper, we review the initiatives and data that accompanied the construction of the basic knowledge for the 1925 seismic event, that to date was responsible for the maximum macroseismic intensity observed at Cali.

The aim of this work is to evaluate the earthquake parameters of the 7 June 1925 Colombian event according to macroseismic data, published in more recent literature. The Bakun and Wentworth (1997) method is applied using 41 IDPs proposed by Salcedo-Hurtado *et al*. (2021a) as input data (Appendix, Table A1). The method requires macroseismic intensity attenuation relation as a function of the moment magnitude (M_w) and hypocentral distance. For the Colombian Andean territory, the macroseismic attenuation model calibrated on earthquakes with both IDPs and instrumental M_w, proposed by Gomez-Capera *et al.* (2020), is considered. The results obtained are discussed in a preliminary way within the context of the seismic history of Cali.

2. Regional tectonic framework

Colombia is located in the northern Andes where the complex geodynamics is characterised by the subduction of the Caribbean and Nazca plates beneath north-western South America. The area to which the occurrence of the earthquake of 7 June 1925 is attributed corresponds to the Valle del Cauca region, located in south-western Colombia where the Nazca oceanic plate is moving to the east, subducting beneath the South American plate with a relative mean velocity of 6 cm/yr (Pennington, 1981; Kellogg *et al*., 1983; Freymueller *et al*., 1993; Gutscher *et al*., 1999; Trenkamp *et al*., 2002; Trenkamp *et al*., 2004; Monsalve and Mora, 2005). The active limit between the Nazca and South America plates is defined by the Colombia trench that runs parallel to the Pacific coastline, defining the surface limit of the subduction zone. The interaction of these lithospheric plates generates the mountain uplift and active volcanism in this Andean area (Fig. 1). The intracontinental deformation in the northern Andes is characterised by mountain chains associated with large-scale reverse and strike-slip faults (Taboada *et al*., 2000).



a) b)

Fig. 1 - a) Epicentres of the 7 June 1925 Colombian earthquake by different catalogues (Table 1). Neotectonics map of the Colombian Andes indicating the main active fault (after Taboada *et al*., 2000 and Dimaté *et al*., 2003). Plate velocity relative to the South America plate is indicated by solid arrows. WC = Western Cordillera, CC = Central Cordillera, EC = Eastern Cordillera, RFS = Romeral Fault System. b) A zoom on the epicentres (coloured triangles) area.

Various authors proposed a segmentation model of the Nazca plate based on the distribution of seismicity and volcanism, as well as the mechanism of earthquakes and the morphology of the Colombia trench: the existence of three active segments stands out with different characteristics that govern the subduction process in this region (Monsalve, 1998; Corredor, 2003; Collot *et al*., 2004; Arcila and Dimaté, 2005; Pedraza, 2006).

These segments are characterised by Arcila and Dimaté (2005) as follows: 1) the northern segment represents the subduction of the Coiba block under the extreme NW of Colombia, with a trench length of 170 km, oriented at 310° azimuth, with a Benioff's plane dipping 25° to 40°; the maximum estimated M_W is 7.8; 2) the central segment, with a seismogenic source in the trench and one more in the Benioff area defined under Caldas region, with a trench length of 160 km, oriented 20°, and a subduction plane dipping from 40° to 110°; the maximum estimated M_W is also 7.8, and 3) the southern segment, in front of the coast of Valle del Cauca region, Nariño region and north of Ecuador, in a section of trench oriented with a azimuth of 40° and 550 km long, with a Benioff plane dipping from 30° to 130°; the maximum estimated M_W is 8.8.

The third segment incorporates the Valle del Cauca region, where the earthquake of 7 June 1925 occurred, and where three types of seismogenic sources are also to be found: the subduction zone itself, the Benioff zone and the intracontinental faults such as the Romeral fault system (RFS, Fig. 1), and the Cauca fault system (Western Cordillera, WC, Fig. 1). These sources together are responsible for the high seismic activity and for the high seismic hazard in the region (Dimaté and Perez, 2005; Salcedo-Hurtado and Pérez, 2017).

In addition, in the conformation of the tectonic framework of the region a complex faulting system is superimposed, with three main directions [N20-30E, N40-50W and N60-70E (Nivia, 2001)]. Along these faults, the movements have interacted, influencing the deformation of the South American plate, activating the rotation and translation of cortical blocks and the superposition of structural features (Paris and Romero, 1994; Paris *et al*., 2000).

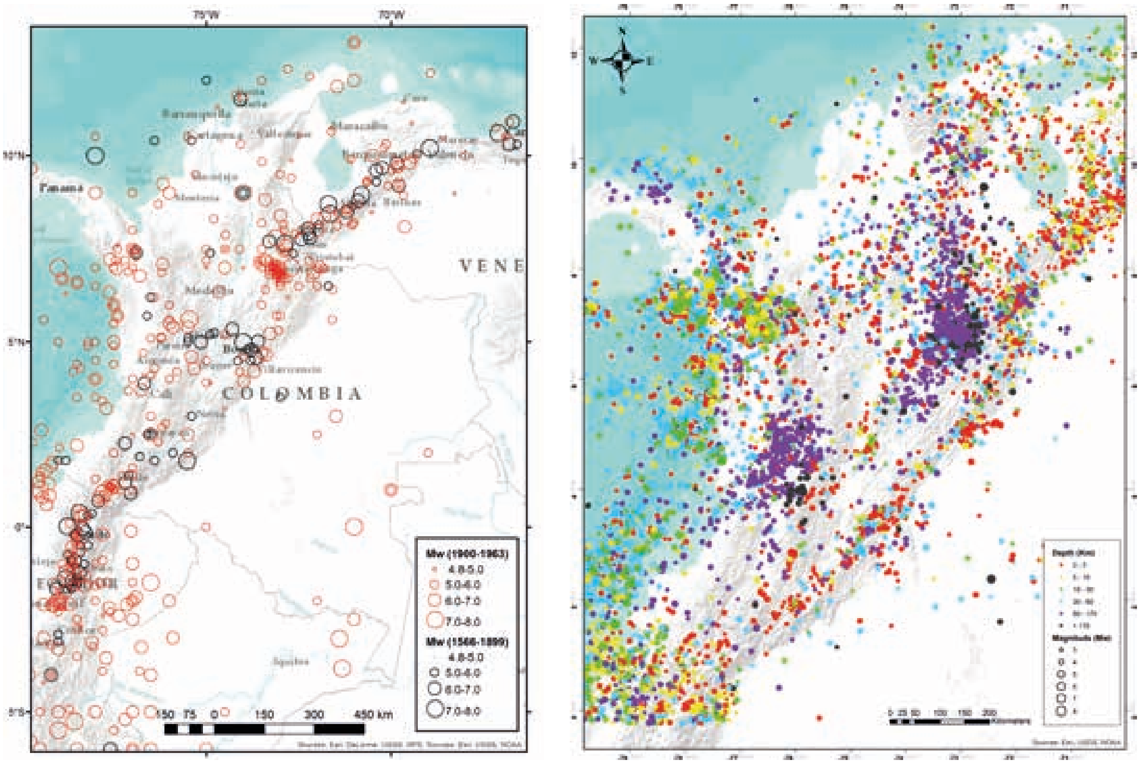
These seismogenic sources are related to various strong, superficial or intermediate, historical (Fig. 2a) and recent (Fig. 2b) earthquakes, responsible for considerable damage and numerous victims in the western and central area of the country (Ramirez, 1975; SGC, 2020):

- 9 July 1766, which severely damaged the cities of Buga and Cali (I_{Max} = 8 EMS-98);
- 31 January 1906 with M_W = 8.45, that heavily damaged the Pacific coastal area of the Cauca and Nariño departments (I_{Max} = 10 EMS-98);
- 24 May 1957, M_W = 6.1 (I_{Max} = 7 EMS-98);
- 30 July 1962, M_W = 6.5 (I_{Max} = 8 EMS-98);
- 12 December 1979, M_W = 8.1 (I_{Max} = 10 EMS-98), which, as the 1906 event, generated a tsunami affecting the coasts of the Cauca and Nariño departments;
- 19 November 1991, M_W = 7.2 (I_{Max} = 8 EMS-98), February 8, 1995, M_W = 6.4 (I_{Max} = 8 EMS-98), and November 15, 2004 with M_W = 7.2 (I_{Max} = 8 EMS-98), events that strongly damaged the infrastructures of the city of Cali;
- 6 June 1994, M_W = 6.8 (I_{Max} = 8 EMS-98), which produced a large number of landslides and distributed damage.

The recent seismicity in the continental part of the Colombian territory, as instrumentally recorded, is characterised by at least four important zones of greater seismic activity. The first of them corresponds to the 'Bucaramanga Nest', located in north-eastern Colombia (between 6.5°-7° N and 73°-73.5° W, Fig. 2b), where a compact and intense concentration of earthquakes, mainly of low magnitude <5.0 M_W and intermediate focal depth [140 ≤ h(km) ≤ 170 (Coral Gomez, 1987; Rivera, 1989; Taboada *et al*., 2000; Prieto *et al*., 2012; Sepulveda-Jaimes and Cabrera-Zambrano, 2018)], are observed.

Another very important zone of seismicity in Colombia is located in the north-western part of the country (between 6°-8° N and 75.5°-78° W, Fig. 2b), where earthquakes that exceed M_W 6.0 occur with shallow depth (<15 km). The main seismogenic source in this area is the Murindó; the 10 October 1992 earthquake occurred in this region with an M_W 7.1 (Li and Toksoz, 1993; Paris *et al*., 2000; Cardona *et al*., 2005; Mosquera-Machado *et al*., 2009; Dionicio and Sánchez, 2012) and I_{Max} = 10 EMS-98 (SGC, 2020). The 1992 earthquake was felt in Cali with I = 5 EMS-98 (SGC, 2020).

The third seismic zone is located in the central western region of the country (Caldas, Fig. 1) between 4° and 6° N and 75.5° and 76.5° W (Fig. 2b) and is characterised by the occurrence of shallow and intermediate depth earthquakes. It is tectonically under the influence of the Benioff zone and some faults belong to the Romeral Fault System (RFS, Fig. 1): the Armenia earthquake, occurring on 20 January 1999 in this region with M_W 6.1 and I_{Max} = 9 EMS-98 (Paris *et al.*, 2000; Taboada *et al*., 2000; Vargas-Jiménez and Monsalve-Jaramillo, 2009; SGC, 2020), is the most significant earthquake with respect to casualties and economic losses in Colombia. The Armenia earthquake killed 1230 people and approximately 200,000 people were made homeless. The economic impact of these earthquakes was a direct financial loss of approximately 1.9 billion US$



a) b)

Fig. 2 - Seismicity of Colombia: a) from 1566 to December 1963, as published for the historical component (pre-1964) of the SARA project (Gomez-Capera *et al*., 2016, 2020); b) from 1964 to December 2017, as published for the instrumental component (1964-2013) of the SARA project (Arcila *et al*., 2016) and ISC (2021) from 2014-2017.

(Restrepo and Cowan, 2000). Despite the destruction in the epicentral area, it seems that the earthquake did not cause important effects of Cali, as there is no data of macroseismic intensity. In some localities of Valle del Cauca department, north of Cali, the event was widely observed [I = 4 EMS-98 (SGC, 2020)].

Finally, we find a seismic zone associated with the so-called Piedemonte Llanero fault system in the Eastern Cordillera [EC in Fig. 1 (Paris *et al*., 2000; Taboada *et al*., 2000)], where historical and recent events have caused damage in cities such as Bogotá and Villavicencio. The most recent earthquake occurred near Bogotá on 24 May 2008 (Salcedo-Hurtado *et al*., 2021b). The Huila earthquake, occurring on 9 February 1967 (M_W = 7; I_{Max} = 10 EMS-98) in the eastern boundary of EC (Dimaté *et al*., 2005), caused damage in Cali [I = 6 EMS-98 (SGC, 2020)] despite the epicentral distance of approximately 200 km.

Crustal shallow earthquakes indicated by red, yellow, green, and blue dots in Fig. 2b are generally located near the foothills of the eastern, central and western Andean Cordilleras, where active and potentially active fault systems are observed at the surface. The cluster of intermediate seismicity observed under Central and Western Cordilleras is related to the oceanic subduction of the Nazca plate under South America (Taboada *et al*., 2000). The 1925 earthquake occurred in the Valle del Cauca region where intermediate-depth events are predominant (Fig. 2b), and shallow seismicity is observed as well.

3. Data

3.1. Earthquake parameters from instrumental data

The earthquake of 7 June 1925 damaged several localities in south-western Colombia. However, there is still great uncertainty about its magnitude and location from instrumental data (Fig. 1). The first seismological station was set up in 1941 in Bogotá (Ramirez, 1948; Espinosa Baquero *et al.*, 2004). The early instrumental earthquake parameters were reported by Gutenberg and Richter (1949), noting that the location of South America earthquakes depends heavily on the reports from La Paz station (Bolivia) since that station was established in 1913 in the Observatory of San Calixto by Jesuits. Despite the poor seismological network, earthquakes were mapped whenever the location was reliable. Many well-recorded shocks were rejected because it was not possible to determine their depth, which is usually one of the most uncertain parameters of the location. Gutenberg and Richter (1949) located the 1925 event as an intermediate offshore earthquake, in the Pacific Ocean, with a depth of 170 km and 6¾ of magnitude (the magnitude scale is not defined in the published catalogue), but with a low-quality location. These earthquake parameters are cited by Ramirez (1975) and CERESIS (1985), but with a magnitude M_S 6.8. Engdahl and Villaseñor (2002), on the other hand, report a new epicentre, located onshore, in Valle del Cauca department.

In the framework of the South America Risk Assessment (SARA) project, a catalogue (pre-1964 earthquakes) has been compiled for South America, in terms of M_W (Gomez-Capera *et al.*, 2016, 2020); in particular, the earthquake parameters of the 1925 event have been compiled from ISC (2015) and it has been located in the northern Valle del Cauca department. For the ISC (2020) catalogue, the epicentre is located in the Central Cordillera (CC, Fig. 1), further north of Valle del Cauca department, at a depth of 15 km, with an M_W 6.08 (Storchak *et al.*, 2013, 2015; Di Giacomo *et al.*, 2018). The Colombian Geological Survey (SGC, 2020) quotes the epicentre by Engdahl and Villaseñor (2002), the magnitude by ISC (2020), and a depth of 120 km, as suggested by Mendoza *et al*. (2004) using the expert judgment method. Table 1 shows a summary of the instrumental information about earthquake parameters, by different catalogues.

Table 1 - Earthquake parameters of the 7 June 1925 Colombian event by different catalogues. Depth q = depth quality [q: A(highest)/B/C)].

Catalogue	**Lat. N**	**Long. W**	**Depth (km)**	**Depth q**	**Magnitude**	**Magnitude type**
Gutenberg and Richter (1949)	3.00	78.00	170	-	6¾	-
Ramirez (1975)	3.00	70.00	170	-	6.75	-
CERESIS (1985)	3.00	78.00	170	-	6.8	M_S
Engdahl and Villaseñor (2002)	4.029	76.079	35	-	6.8	unknown
ISC (2015) (used in SARA project catalogue)	4.279	75.331	15 ± 25	C	6.29 ± 0.67	MW
ISC (2020)	4.295	75.323	15 ± 25	C	6.08 ± 0.30	MW
ISC (2021)	3.957	75.315	120 ± 20.5	C	-	-
SGC (2020): Epicentre from Engdahl and Villaseñor (2002) Depth from Mendoza *et al.* (2004) M_W from ISC (2020)	4.02	76.07	120	-	6.1	MW
Present study	3.29	76.91	-	-	6.6 ± 0.2	MW

Earthquake location is reassessed (ISC, 2021) using macroseismic and updated instrumental data by Di Giacomo and Sarabia (2021).

The lack of resolution of the focal depth for events occurring in the early instrumental years complicates the relocation of the 1925 event. In fact, its instrumental location (ISC, 2020) is obtained in the Central Cordillera (Fig. 1), 165 km away from the highest macroseismic intensities in the Valle del Cauca region. Such a large discrepancy in the depths of the different locations is possible if the initial solution of the instrumental data is poorly constrained and/or the available arrival times are insufficient or of too low quality to provide a robust solution (Di Giacomo and Sarabia, 2021). The uncertainty in the focal depth is highlighted by the poor quality (Q = C; Table 1) given by the different ISC solutions.

3.2. Macroseismic data

The macroseismic intensity is considered a classification of the severity of the ground motion on the basis of observed effects on civil structures, environment, objects, and people in a limited area (Grünthal, 1998). The macroseismic data, despite its non-instrumental nature and the degree of intrinsic subjectivity involved in the assessment of the macroseismic intensity, are considered as the basic information for determining historical earthquake parameters, which, among other aspects, allow us to improve the knowledge for the evaluation of the seismic hazard and risk of a region.

3.2.1 Early macroseismic studies

The earthquake of 7 June 1925 caused damage to several localities in south-western Colombia. However, there is still great uncertainty about the location, magnitude and maximum damage of this event. Ramirez (1975) does not report textual descriptions of the damage. Table 2 shows a summary of studies that reported macroseismic data from historical sources and maximum macroseismic intensity for this earthquake assigned in each study.

Table 2 - Intensity data points (IDPs) of the 7 June 1925 Colombian event by different studies. NIDPs: number of IDPs.

Study	**NIDPs**	I_{Max}	**Localities with** I_{Max}	I_{Scale}
Espinosa Baquero (2003)	33	8	Cali, La Cumbre, Restrepo, Yotoco	MM
Sarabia and Cifuentes (2010)	34	7-8	Cali, Restrepo	EMS-98
Salcedo-Hurtado *et al.* (2021a)	41	8	Cali	EMS-98

A contribution to the macroseismic study of the earthquake of 7 June 1925, is given by Espinosa Baquero (2003), which proposes 33 IDPs in MM scale (Appendix, Table A1), assigning the maximum value of 8 MM to Cali, La Cumbre, Restrepo, and Yotoco localities in Valle del Cauca department; the epicentre is located in the Pacific Ocean on Gorgona Island (Colombia).

Salcedo-Hurtado *et al*. (2007) analysed the effects caused in 18 localities of Caldas, Cauca, Cundinamarca, Nariño, Quindío, Risaralda, Tolima, and Valle del Cauca departments. The maximum macroseismic intensity is evaluated in the city of Cali with a value of 7-8 EMS-98. In this study, it is pointed out that, despite the macroseismic data collected, it is still not possible to specify the earthquake parameters of this event, so complementary investigations should be done to that end.

A study published by the Colombian Geological Survey (Sarabia and Cifuentes, 2010; SGC, 2020) used the sources presented by Mendoza *et al.* (2004) and Salcedo-Hurtado *et al.* (2007) and 34 IDPs are proposed in EMS-98 (Appendix, Table A1). The maximum intensity evaluated was 7-8 EMS-98, assigned to Cali and Restrepo in Valle del Cauca department.

3.2.2 The most recent macroseismic data

As part of a seismic risk project in Cali, Salcedo-Hurtado *et al*. (2021a) updated the study on macroseismic data by Salcedo-Hurtado *et al*. (2007), for the 1925 earthquake, adding historical references to previous studies. These new references are contemporary and primary sources of information on the 1925 earthquake and are not derived from others. The primary sources are press releases, damage reports, illustrative documentation (photographs), and literary material. These sources are considered to be of good quality and are to be found in various central archives in Bogotá and local archives in the Valle del Cauca and Popayán (Appendix, Tables A2 and A3).

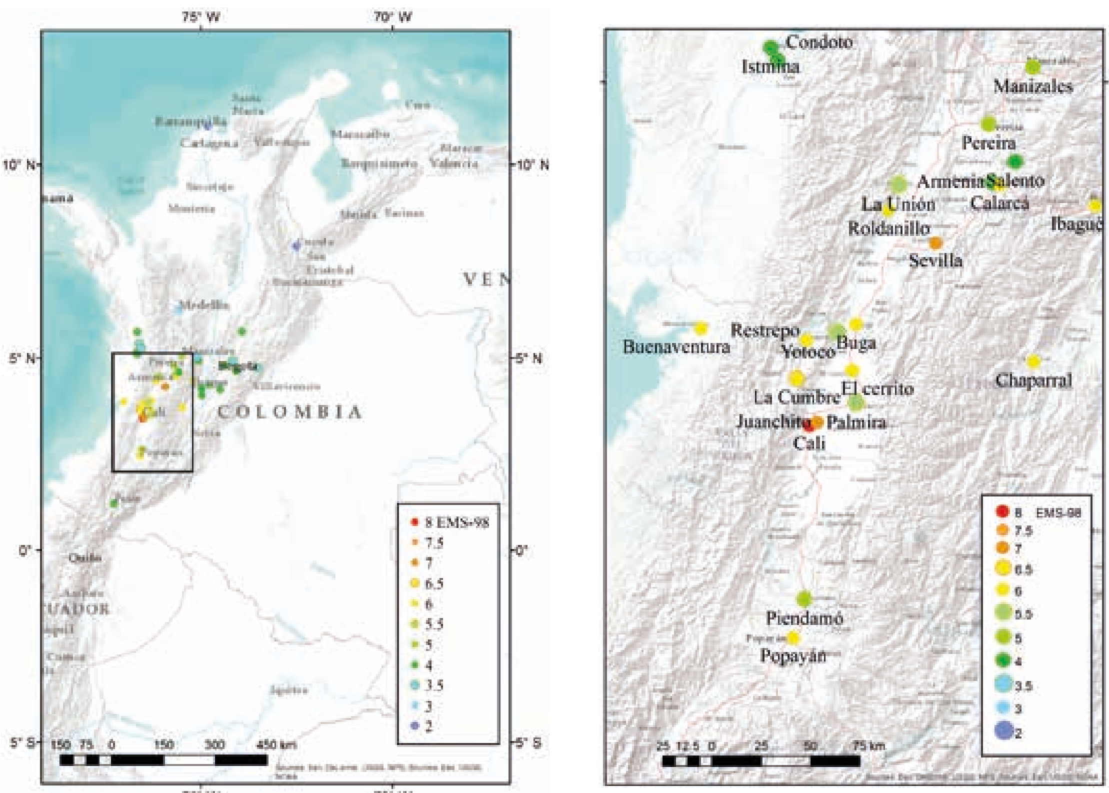
The journalistic sources are local newspapers of Cali (Correo del Cauca, 1925; El Gráfico, 1925; El Relator, 1925), regional newspapers of Armenia (ABC, 1925), national newspapers of Bogotá (El Espectador, 1925; El Tiempo, 1925; Mundo al día, 1925). Among the literary documentation as primary and secondary sources, we drew on Aragón (1930) and Castrillón Arboleda (1986). Some of these sources give a relatively good description of the damage, others only write that the earthquake was felt in distant countries without any information on the damage caused. In Cali, public buildings, churches, and private homes were damaged and a few collapsed, forcing people to camp on the streets. Specific details, such as completely destroyed brick houses, can

Fig. 3 - The ruins of the church ‘Ermita Vieja de Cali’, in Cali, totally destroyed by the 7 June 1925 earthquake (Barth, 1925; Calero Tejada, 1983).

be found in the sources of the Cali city. A summary of the sources, archives and descriptions of the effects of the earthquake in three cities is in the Appendix (Tables A2, A3, and A4).

The discovery of new historical sources is reflected in the growing number of inhabitants affected by this earthquake, as well as in the improvement of information on the damage and effects shown in other cities. The intensity data are expressed in the EMS-98 scale, the quality of the information has improved and allows us to obtain new and more precise macroseismic intensity values, which also fill geographical gaps. The new macroseismic data are 41 IDPs (Appendix, Table A1), distributed along the Andean valleys. The distribution of IDPs shows that, in addition to the damage caused to the localities of the Valle del Cauca department, there were also effects on the municipalities of Antioquia, Atlántico, Boyacá, Caldas, Cundinamarca, Chocó, Nariño, Norte de Santander, Quindío, Risaralda, and Tolima departments. The small town of Juanchito, near Cali, is not present in previous studies such as that of Espinosa Baquero (2003) and is classified with *I* = 7 EMS-98 by Salcedo-Hurtado *et al*. (2021a). The maximum intensity (*IMax* = 8 EMS-98) is again assigned to the Cali city. Fig. 3 shows the ruins of the church Ermita Vieja de Cali, in Cali, totally destroyed by this event.

Fig. 4 shows the distribution of IDPs proposed by Salcedo-Hurtado *et al*. (2021a): the IDPs indicate a trend of damage and effects in SW-NE direction in south-western Colombia on the continuation of the Andean Mountain range (Fig. 5), coinciding with the impact of the main geological faults of the region (Paris and Romero, 1994; Paris *et al*., 2000).



a) b)

Fig. 4 - Left, IDPs distribution map of the 7 June 1925 earthquake in Colombia (Salcedo-Hurtado *et al*., 2021a); right, a zoom on the epicentral area.

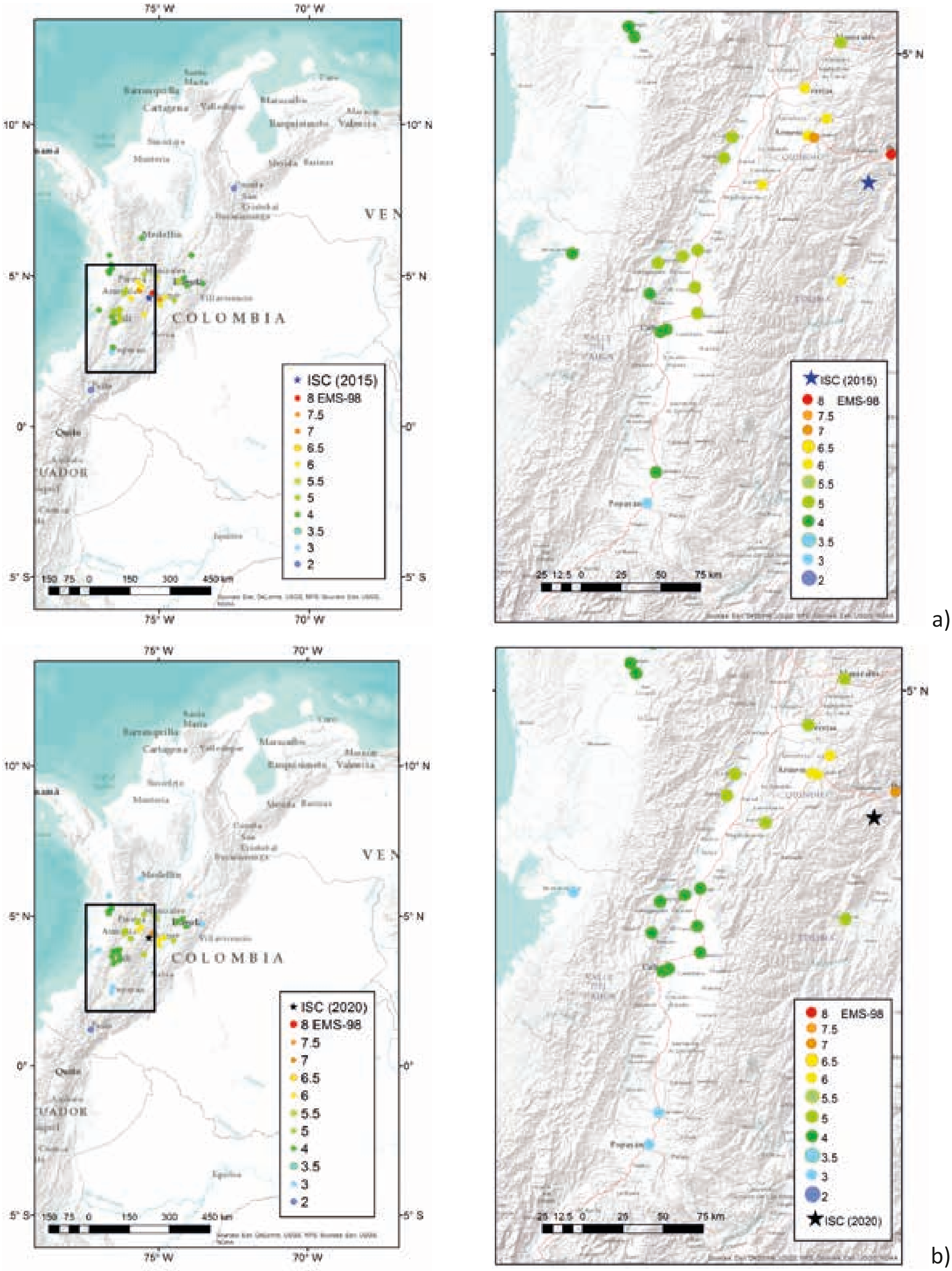


Fig. 5. IDPs calculated distribution caused by the 7 June 1925 event located at the ISC (2015, 2020) instrumental epicentres (Table 1) and using the macroseismic intensity attenuation model (Gomez-Capera *et al.*, 2020) and the localities given by Salcedo-Hurtado *et al*. (2021a) (Table A1): a) M_w = 6.29 (ISC, 2015); b) M_w = 6.08 (ISC, 2020) right, A zoom for the Cali area is reported in the right panels.

4. Methodology

Bakun and Wentworth (1997) proposed a method (BW97 from here on) to estimate the location and magnitude of historical earthquakes directly from IDPs. The BW97 method has been applied in several regions of the world, such as Japan (Bakun, 2005), California (Bakun, 2006), France (Bakun and Scotti, 2006), Europe (Gomez-Capera *et al*., 2009), Andean (Beauval *et al*., 2010; Choy *et al*., 2010), Switzerland (Alvarez-Rubio *et al*., 2011), Italy (Bakun *et al*., 2011), Caribbean (Bakun *et al*., 2012; Gomez-Capera *et al*., 2013), central Asia (Bindi *et al*., 2013), and intraplate earthquakes in Brazil (Quadros *et al*., 2019) among others.

In the central Colombia region, BW97 is applied to compute earthquake parameters of the 1743 and 1785 seismic events that caused damage in Bogotá (Salcedo-Hurtado and Gomez-Capera, 2013; Gomez-Capera *et al.*, 2014). In the framework of the SARA project, an earthquake catalogue has been compiled for South America in terms of M_W. Following this aim, a macroseismic intensity attenuation model for the Colombian territory was calibrated, and the BW97 method has been applied for computing earthquake parameters for a set of 29 Colombian historical earthquakes from 1644 to 1963 (Gomez-Capera *et al*., 2020). The earthquake of 7 June 1925 is not included in this set of 29 historical events. In this section, we introduce the basic principles of the BW97 method and in the next one its application to compute the earthquake parameters of the 1925 seismic event in Colombia.

The BW97 method needs a macroseismic intensity attenuation relation as a function of the distance and earthquake magnitude, and it assumes a source depth h = 10 km:

$$I_i = a + bM_i - cR_i - dLogR_i \tag{1}$$

where M is magnitude, R is the hypocentral distance [$(x^2 + h^2)^{1/2}$, x is the epicentral distance, h is the depth], and a, b, c, and d are constants that are calibrated according to the region studied. The constant c represents the inelastic attenuation and d is a constant representing the geometric spreading (Howell and Schultz, 1975).

Eq. 1 is, then, inverted to estimate the single-site magnitude M_i (with i = 1, …, P_j where P_j is the total number of IDPs available for the earthquake studied) from individual intensity values I_i observed at distances R_i:

$$MI_i = \frac{1}{b}(I_i - a + cR_i + dLogR_i). \tag{2}$$

We indicate with MI_i (intensity magnitude) the earthquake magnitude estimated from macroseismic intensity (I_i). The location and magnitude of a given earthquake are estimated by computing the magnitude MI^k_i over a grid of trial source locations x_k (i.e. grid nodes).

For the seismic event studied, the magnitude MI^k is defined as the average of the magnitudes MI^k_i estimated from individual intensity observations (IDPs) and assuming the epicentre located in the grid node x_k, that is:

$$MI^k = \frac{1}{P}\sum_{i=1}^{P} \quad MI_i^k. \tag{3}$$

Then, considering a grid of trial source locations x_k, the root mean square $rms[MI^k]$ is computed as:

$$rms[MI^k] = rms[MI^k - M_i] - rms_0[MI^k - M_i] \quad (4)$$

where:

$$rms[MI^k - M_i] = \left\{\frac{1}{\sum_i w_i^2} \sum_i [w_i \left(MI^k - MI_i^k\right)]^2\right\}^{1/2} \quad (5)$$

$rms_0[MI^k - M_i]$ is the minimum of all $rms[MI^k - M_i]$ over the grid of assumed trial source locations, and w_i the distance weighting function (Bakun and Wentworth, 1997):

$$w_i = \begin{cases} 0.1 + \cos\left[\left(\frac{\Delta_i}{150}\right) * \frac{\pi}{2}\right] & for\ \Delta_i < 150km \\ 0.1 & for\ \Delta_i \geq 150km \end{cases} \quad (6)$$

The minimum of all the *rms* over the grid of assumed trial source locations is subtracted from each of the *rms* of the grid node x_k. The grid node x_k corresponding to the minimum $rms[MI^k]$ is the intensity centre (IC):

$$rms[MI^k - M_i] - rms_0[MI^k - M_i] = 0 \quad (7)$$

where the intensity magnitude *MI* is given by MI^k evaluated at point IC. The IC corresponds to the location on the fault plane where the energy release is the highest [i.e. the location of the maximum fault displacement, or centroid moment (Beauval *et al.*, 2010)]; therefore the IC does not always match the epicentre (Bakun, 2006). Unlike the classic definition of epicentre as the point on the surface that is the vertical projection of the seismic focus where the rupture begins, in this work the IC is used as the location of the seismic event from the IDPs and is adopted as 'macroseismic epicentre'. The *rms* levels represent confidence intervals indicating that the IC is within the area delimited by them: usually the 95%, 90%, 80%, 67%, and 50% are represented and their shape is based on the number of IDPs (Bakun and Wentworth, 1999).

The magnitude *MI* of the IC is equivalent to the M_W of the earthquake if Eq. 1 is calibrated in M_W. According to Bakun and Wentworth (1999), the uncertainty for determining the calculated M_W is associated with the number of IDPs used.

5. Earthquake parameters from macroseismic data

The present study uses a macroseismic intensity attenuation model proposed for shallow earthquakes (i.e. crustal earthquakes) for the Andean region in the Colombian territory by Gomez-Capera *et al*. (2020), which is expressed as follows:

$$I = -1.92 + 2.33M_W - 0.0021R - 3.68\log R \quad (8)$$

where I is the macroseismic intensity, M_W is the moment magnitude, R is the hypocentral distance, which is defined with a fixed depth at 10 km. Eq. 8 and 41 IDPs (Salcedo-Hurtado *et al.*, 2021a) are used as input for BW97 to estimate location and earthquake magnitude.

The earthquake parameters computed are presented in the last line of Table 1. The IC location (black triangle in Fig. 6) is within a 50% to 67% range of confidence and approximately 50 km away from Cali, SW direction; it is very far from the solutions proposed by other sources (Gutenberg and Richter, 1949; Engdahl and Villaseñor, 2002; ISC, 2020).

The magnitude (M_w) obtained is 6.6, and the 67% probability range corresponds to M_w = 6.6 ± 0.2. The contours of M_wI (black lines) are the best estimates of M_w from the 41 IDPs over a grid of trial source locations (Fig. 6). Table 1 shows the solution obtained in this work compared with the 7 June 1925 earthquake parameters given by other sources.

The macroseismic distribution with the epicentral distance of the 41 IDPs follows the trend of the intensity attenuation model by Gomez-Capera *et al.* (2020) for M_w = 6.6 ± 0.2 and IC computed for the 1925 earthquake. Fig. 7 shows that 88% of the IDPs are within the uncertainty interval of σ = 0.52 given by such an attenuation model. The damage threshold (I > 5), by Gomez-Capera *et al.* (2020), is at the epicentral distance x = 98 km from I = 6 EMS-98.

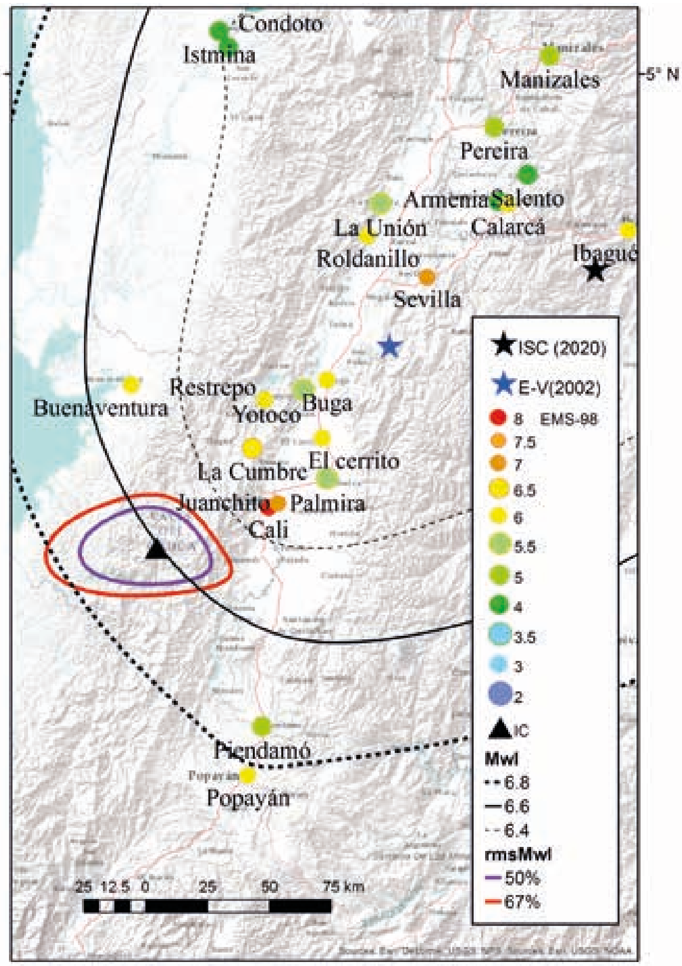


Fig. 6 - Results for the 7 June 1925 earthquake. Location of the IDPs (circles) taken from Salcedo-Hurtado *et al.* (2021a), colour coded according to their intensity value. The location of the IC is indicated by a black triangle. The black solid/dashed isolines correspond to the magnitude (M_wI) and uncertainties contours and the coloured ones are related to the IC location contours for the confidence intervals (50% and 67%).

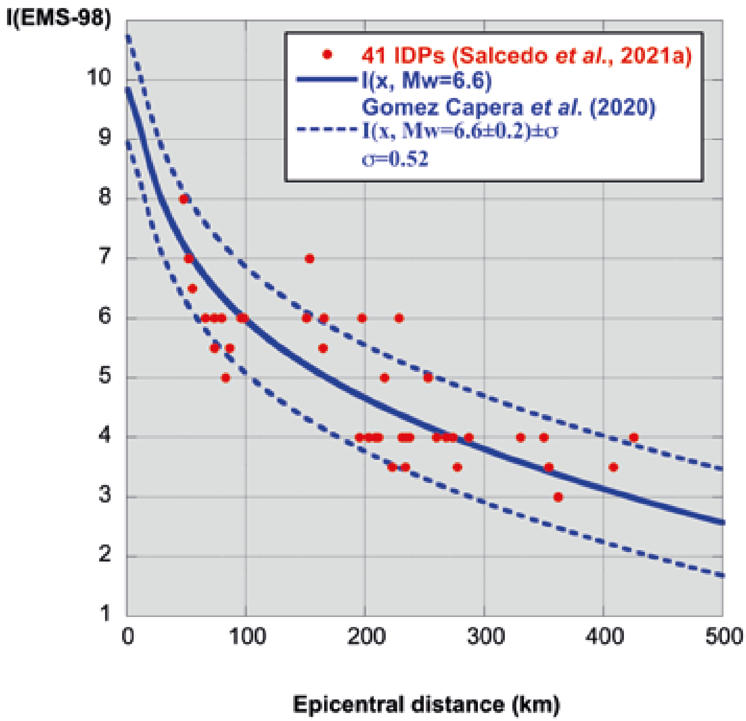


Fig. 7 - IDPs of the 7 June 1925 earthquake in Valle del Cauca department (Colombia) vs. macroseismic intensity attenuation model and its standard deviation (σ) (Gomez-Capera *et al.*, 2020) for M_w 6.6 ± 0.2.

According to the previous analysis, the IDPs with I = 6 EMS-98 (Buenaventura, Buga, El Cerrito, Popayán, Restrepo) are in good correlation with the intensity attenuation model used ($59 < x$(km) < 160). The three points observed at distances greater than 159 km, out of the range of the uncertainty of the curve (Fig. 7), correspond to the towns of Calarcá, Ibagué, and Sevilla. Despite the epicentral distance being greater than 160 km, according to the sources cited by Salcedo-Hurtado *et al.* (2007, 2021a) and Sarabia and Cifuentes (2010), buildings were damaged in these cities. It should be noted that these cities are located in the Central Cordillera and their urban areas are located on unstable slopes (Lizcano *et al*., 2006). Fig. 7 shows that the macroseismic intensity I = 8 EMS-98 is in the uncertainty range, at a distance of 47 km from the position of the IC calculated from the macroseismic data in this study (Fig. 6).

From the attenuation model (Gomez-Capera *et al*., 2020), the macroseismic field is calculated for two scenarios caused by the earthquake located at the instrumental epicentre and M_w defined by ISC (2015, 2020) (Table 1). The maximum intensity calculated, observed in Ibague, which is located in the Central Cordillera, is: i) I = 8 EMS-98 for the scenario related to the earthquake parameters by ISC (2015); ii) I = 7 EMS-98 with the earthquake parameters by ISC (2020). In both scenarios, the calculated macroseismic intensity for the city of Cali is I = 4 EMS-98. The two macroseismic field scenarios calculated diverge from the one observed by Salcedo-Hurtado *et al*. (2021a) (Fig. 4) and are presented in Fig. 5 and in the Appendix (Table A1).

6. Discussion

In Colombia, macroseismic databases and the earthquake catalogue are constantly updated and homogenised on a national scale. Seismic studies are underway both on a national scale by the Colombian Geological Survey (SGC) and on a regional scale by other local institutions. The IDPs of the 1925 earthquake are an example of the results of a historical-macroseismic study conducted on a regional scale (Salcedo-Hurtado *et al.*, 2021a), funded by the University of Valle del Cauca, in Cali. In the present work, we continued the analysis of the location and magnitude, starting from the macroseismic data obtained by Salcedo-Hurtado *et al*. (2021a). This analysis was conducted following homogeneous methodologies to those proposed in the initiatives of the GEM Foundation and in particular by the SARA project earthquake catalogue (Gomez-Capera *et al*. 2020).

Cali was a small village founded in 1536, whose lands were occupied for agricultural purposes until the 18th century. However, Cali has been the most important city in the Valle del Cauca since the days of Spanish colonisation. This meant that this city and the region had historical sources of pre-1900 seismic events, albeit few and scattered, due to the low population density of the region. In the years following 1900, the city of Cali saw the birth of local and regional newspapers, contemporary sources to the events of the 20th century. The instrumental location of seismic sources in Colombia improved after the 1940s (Ramirez, 1975; Espinosa Baquero, 2003; Salcedo-Hurtado *et al*., 2005; SGC, 2020; ISC, 2021).

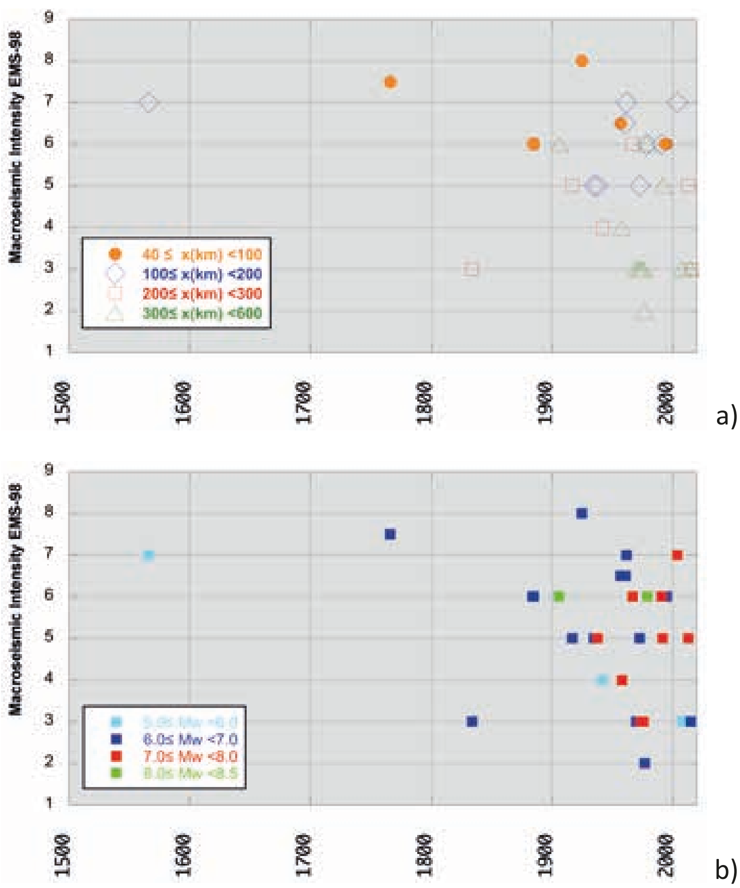


Fig. 8 - Seismic history of Cali: a) as a function of epicentral distance *x*(km); b) as a function of M_w. The earthquake parameters are given in Table 3.

The seismic history of Cali is visible in Fig. 8 (Gomez-Capera *et al*., 2020; SGC, 2020; ISC, 2021), which highlights the sequence of seismic effects reported for this city in terms of macroseismic intensity, obtained from the relative macroseismic database (Stucchi *et al*., 2004). The events that caused damage to Cali, with macroseismic intensity of site I_{site} ≥ 6 EMS-98 at Cali, are available in Fig. 9 and Table 3. Those earthquakes had their origin in diverse sources: the Pacific Subduction Zone, the intermediate-depth Benioff zone and near and far continental crustal faults. The first known historical earthquake in Colombia is the 1566 event, causing damage in Popayán (*I* = 7 MM) and Cali (*I* = 7 MM) (CERESIS, 1985). The historical data are scarce, which makes the seismological information very uncertain (Espinosa Baquero, 2003).

Table 3 - Events that have caused damage in Cali with I_{site} ≥ 6.
Legend: Source Epi = source of epicentre; *h* = focal depth; Unc = uncertainty; q = quality [A(highest)/B/C]; I_{Max} = maximum intensity; I_{site} (Cali) = site intensity in Cali; *I* = intensity; R (km) = epicentral distance from Cali; ISC021 = International Seismological Centre (2021); SALAL021 = Salcedo-Hurtado *et al.* (2021a); SGC020 = SGC (2020); CERES985 = CERESIS (1985); CERES995 = CERESIS (1995); SARA016 = Catalogue before 1964 of the SARA project (Gomez-Capera *et al.*, 2016).

Year	Mo	Da	Lat. N	Long. W	Source Epi.	M_w	Unc M_w	q M_w	Source M_w	*h* (km)	Unc *h*	*h* q	Source *H*	Imax	I_{site} (Cali)	*I* Scale	Source *I*	*R* (km)
1566			2,500	-76,599	CERES995	5,89	0,17		SARA016					7	7	MM	CERES985	103
1766	7	9	3,880	-76,671	SARA016	6,83	0,26		SARA016					8	7-8	EMS-98	SGC020	53
1884	11	5	5,000	-76,000	CERES995	6,52	0,20		SARA016					8	6	EMS-98	SGC020	218
1885	5	25	2,880	-76,540	SGC020	6,40	0,20		SGC020					8	6	EMS-98	SGC020	61
1906	1	31	0,988	-79,347	ISC021	8,45	0,30	B	ISC021	20	20,5	C	ISC021	10	6	EMS-98	SGC020	414
1925	6	7	3,290	-76,910	Present study	6,64	0,16		Present study					8	8	EMS-98	SALAL021	46
1957	5	24	3,700	-76,752	ISC021	6,12	0,26	B	ISC021	52,3	5,2	A	ISC021	7	6-7	EMS-98	SGC020	40
1961	12	20	4,493	-75,508	ISC021	6,81	0,20	-	SARA016	162,9	5,3	A	ISC021	8	6-7	EMS-98	SGC020	163
1962	7	30	5,173	-76,352	ISC021	6,51	0,20	B	ISC021	64	4,7	A	ISC021	8	7	EMS-98	SGC020	195
1967	2	9	2,849	-74,980	ISC021	7,00	0,30	B	ISC021	55	5	A	ISC021	10	6	EMS-98	SGC020	201
1979	11	23	4,731	-76,160	ISC021	7,20	0,10	A	ISC021	110	4,5	A	ISC021	8	6	EMS-98	SGC020	151
1979	12	12	1,555	-79,276	ISC021	8,09	0,10	A	ISC021	23,6	4	A	ISC021	10	6	EMS-98	SGC020	369
1991	11	19	4,526	-77,337	ISC021	7,18	0,10	A	ISC021	20	4,9	A	ISC021	8	6	EMS-98	SGC020	150
1994	6	6	2,889	-75,949	ISC021	6,78	0,10	A	ISC021	10	3,8	A	ISC021	8	6	EMS-98	SGC020	86
1995	2	8	4,058	-76,557	ISC021	6,35	0,10	A	ISC021	70,6	4,9	A	ISC021	8	6	EMS-98	SGC020	71
2004	11	15	4,686	-77,471	ISC021	7,19	0,10	A	ISC021	15	13,9	C	ISC021	8	7	EMS-98	SGC020	176

Cali has suffered a site macroseismic intensity *I* = 8 EMS-98 at least once, corresponding to the heavily damaging event of 1925. The earthquakes of 1766 and 1925 are the only events currently known with an epicentre in the Valle del Cauca department (Table 3 and Fig. 9) with macroseismic intensity at site *I* > 7 EMS-98.

The seismic history of Cali (Fig. 8a) shows that with the location obtained in the present work, the 1925 event is the epicentral zone of a heavily damaging earthquake closest to the Cali city (46 km). The 1766 event is located 53 km from Cali. The epicentres of both events are located in the Western Cordillera (Cordillera Occidental; Fig. 9).

Referring to the near field, in the Western Cordillera (epicentral distance *x* < 100 km), in the Valle del Cauca department, for events that caused damage to the city, the macroseismic

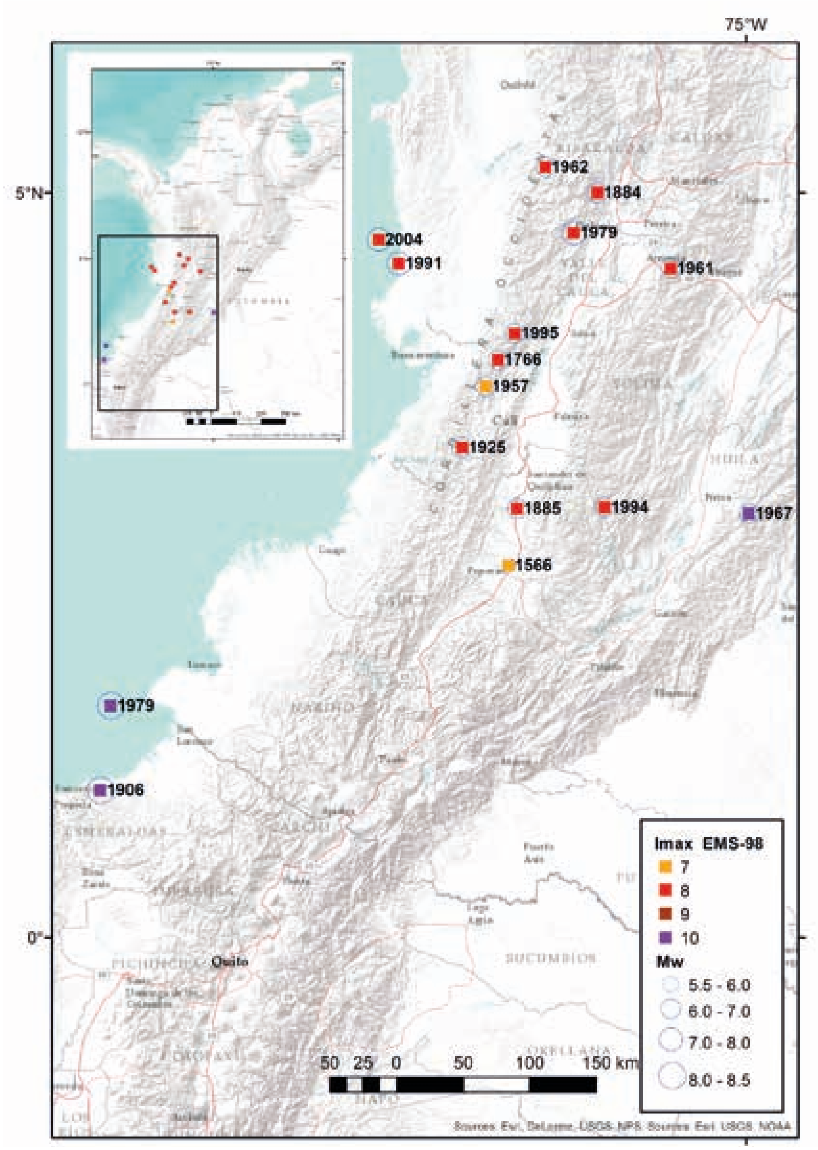


Fig. 9 - Events that have caused damage in Cali with I_{site} ≥ 6 EMS-98.

intensities I = 6-7 EMS-98 and 6 EMS-98 in Cali are linked to the earthquakes of 1957 (M_w = 6.1) and 1995 (M_w = 6.4) respectively, located 40 and 71 km from Cali (ISC, 2021; Fig. 9 and Table 3).

The magnitude obtained in the present work for the 1925 earthquake (M_w = 6.6) is in agreement with that of the 1766 event (M_w = 6.8) in the SARA project earthquake catalogue and 1957 and 1995 events in the ISC (2021).

Earthquakes from distant sources (100 < x(km) < 600) of the instrumental period have been observed in the seismic history of Cali (I ≤ 7 EMS-98) with M_w > 6 (Fig. 8), in the Colombian Andes (WC, CC, RFS, EC; Fig. 1) and in the Pacific Ocean (Fig. 9).

The seismic parameters obtained in the present work for the 1925 event are compatible with other sources in the near field that caused damage both in the pre-900 and in the instrumental period, in the seismic history of Cali.

The aim of this study was to improve the knowledge on the earthquake parameters of the 1925 Colombian event, drawing on macroseismic data proposed in literature (Salcedo-Hurtado *et al.*, 2021a), using the Bakun and Wentworth (1997) method and applying the last intensity attenuation model for the Andean Territory in Colombia (Gomez-Capera *et al.*, 2020). This attenuation model is calibrated on M_w and shows good performance in computing earthquake parameters, for historical seismic events in Colombia, starting from macroseismic data. Likewise, the Salcedo-Hurtado *et al*. (2021a) study improves understanding of the macroseismic field for the 1925 event, compared to previous studies. Its 41 IDPs are distributed in a SW-NE direction, following the Cauca valley, which coincides with the strike of the main geological faults in south-western Colombia (Paris *et al*., 2000). The damage threshold macroseismic intensities are mainly located in Valle del Cauca department. The maximum macroseismic intensity (*I* = 8 EMS-98) is at Cali. These results, however, are very different from the most recent epicentre solution given by ISC catalogue and located 165 km north of Cali. As the La Paz (Bolivia) seismic station is critical in the instrumental location of the 1925 earthquake, these parameters therefore show great uncertainty in comparison with the maximum damage occurring along the Cauca valley. We have summarised the complex regional tectonics in Colombia in order to be able to correlate the sources of earthquakes with the damage of events such as that of 1925 and to understand how sensitive this correlation can be if the instrumental earthquake parameters (Fig. 1) change drastically in the state of the earthquake of such an event.

The present work, applying an objective and reproducible method, provides a methodological alternative to improve the solution of the location, magnitude and uncertainties of the 1925 earthquake, starting from the IDPs proposed by Salcedo-Hurtado *et al*. (2021a) and using the macroseismic intensity attenuation model proposed by Gomez-Capera *et al.* (2020). The IC location (3.29° N, 76.91° W), thus obtained, is computed 47 km SW of Cali and is adopted as the 'macroseismic epicentre' for the 1925 event; it is 208 km away from the ISC (2020) instrumental epicentre. The uncertainties about the position of the IC fall within a range of 50% to 67% of the confidence boundaries, which correspond to an average error in the distance up to 30 km. The equivalent M_w is 6.6 ± 0.2, half a degree of magnitude higher than the instrumental one (ISC, 2020). The magnitude uncertainty is related to the number of intensity data points (41 IDPs). The Cauca River valley runs between the Western and Central Cordilleras of the Colombian Andes, which in turn delimit the region's major fault systems. Historically, the Cauca River valley was the area where most of the populations of the homonymous department settled. Therefore, due to this geographical situation and the vulnerable conditions of the population at the advent of the earthquake of 7 June 1925, it is evident that the IDPs assessed for this earthquake are mainly distributed along the line of regional faults. There is a good agreement between the distribution of the IDPs with the epicentral distance and the macroseismic intensity attenuation model used, within the uncertainties associated (σ = 0.52), for the M_w = 6.6 ± 0.2.

Regarding the focal depth of this earthquake, there are still many uncertainties, as initially Gutenberg and Richter (1949) placed it offshore at 170 km depth, Engdahl and Villaseñor (2002) and ISC (2015, 2020) located it onshore and superficial (35 and 15 km), while, more recently, Di Giacomo and Sarabia (2021) assigned it a depth of 120 km. Although the functional form of the attenuation model (Eq. 8) has a depth defined at 10 km, the earthquakes used in the calibration process of such a model (Gomez-Capera *et al*., 2020) have depths between 5 and 55 km: the crustal event in the Eastern Cordillera (Dimaté *et al*., 2005) of 9 February 1967 [M_w = 7, h = 55 km (ISC, 2021)], Table 3) was used in this calibration process. To check the influence of assumptions dealing with depth values, Bindi *et al*. (2013) also compute the magnitudes considering models calibrated for a fixed depth equal to 20 km, as well as considering the depths listed in the ISC catalogue (h < 50 km) for each earthquake. The differences among the obtained magnitudes were negligible, confirming the assumption that the depth values are not critical for the BW97 method applied in this study.

7. Conclusions

The south-western Colombia 7 June 1925 earthquake is one of the most important intraplate seismic events to have occurred and should be taken as a reference for the seismic history of the region. This seismic event caused damage at several localities along Cauca valley. However, despite its importance and the studies that have been carried out on it, there was still considerable uncertainty about its location and magnitude. The early instrumental coverage was limited and poor in South America: the 1925 seismic event presents instrumental parameters recorded mainly by a station located in La Paz (Bolivia). For these reasons, starting from the most recent macroseismic data and the macroseismic intensity attenuation model for the Andean territory in Colombia, applying an objective and reproducible method, earthquake parameters have been recomputed in this work. The distribution of the macroseismic intensity reveals a trend line in the SW-NE direction, located on the Andean mountain range, which coincides with the strike of the main geological faults existing in the SW of the country. The M_w obtained is 6.6 ± 0.2. The location of the epicentre is located at a distance of approximately 50 km SW of Cali. The earthquake parameters, thus obtained, are in accordance with the maximum intensities observed in such an event, with the macroseismic attenuation trend observed for the Colombian territory and with the seismic history of Cali. There is still uncertainty in the location of the focal depth. However, the presence of various fault systems close to the epicentral zone could suggest a shallow depth. For this reason, we consider this topic as a future research.

Finally, this study aims to contribute to the compilation of a homogeneous historical seismic catalogue, in moment magnitude, essential for assessing probabilistic seismic hazard in Colombia.

Acknowledgments. Support for this research was provided through the project 'Analysis of the seismic risk scenario in Cali in the event of an earthquake similar to that of June 1925', funded and registered by the Vice-Rectory of Investigations of the Universidad del Valle (Cali) with the code CI 4354 and is sincerely appreciated. The authors thank the Istituto Nazionale di Geofisica e Vulcanologia, sezione di Milano and the Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (Trieste) for supporting the development of this work. The authors extend sincere thanks to editor Dario Slejko and two reviewers for suggesting improvements to the article.

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Appendix: Tables with macroseismic data

Table A1 - List of the IDPs: i) used in the present study (gray header; Salcedo Hurtado *et al.*, 2021a). Q is the quality (q: A(highest)/B/C), A: enough information to classify the macroseismic intensity given by the historical sources; B: information is less sufficient to classify the macroseismic intensity given by the historical sources; C: information is insufficient and doubtful to classify the macroseismic intensity given by the historical sources. List of IDPs: ii) observed by ESP2003 = Espinosa Baquero (2003); observed by SAR2010 = Sarabia and Cifuentes (2010) (green header) iii) List of intensities calculated (yellow header) using the macroseismic attenuation model (Gomez Capera *et al.*, 2020) and the instrumental earthquake parameters (epicentre and Mw) given by ISC (2015, 2020; Table 1).

No	Locality	Lat. N	Lon. W	SAL2021 EMS-98	Q	ESP2003 MM	SAR2010 EMS-98	I calculated (M_w = 6.29; ISC, 2015) (EMS-98)	I calculated (M_w = 6.08; ISC, 2020) (EMS-98)
1	Armenia	4.54	-75.67	4	B	5	5	6	6
2	Barranquilla	11.00	-74.82	3	B	4	-	1	-
3	Bogotá	4.67	-74.07	4	B	4	4	4	4
4	Briceño	5.69	-73.92	4	B	5	-	4	3
5	Buenaventura	3.88	-77.01	6	B	6	5	4	3
6	Buga	3.90	-76.30	6	B	7	6	5	4
7	Calarcá	4.53	-75.64	6	A	6	5	7	6
8	Cali	3.43	-76.51	8	A	8	7.5	4	4
9	Cértegui	5.37	-76.61	3	B	-	-	4	4
10	Chaparral	3.72	-75.48	6	B	5	-	6	5
11	Chicoral	4.21	-74.98	4	B	5	-	7	6
12	Condoto	5.10	-76.65	3	B	-	-	4	4
13	Cucuta	7.90	-72.51	2	B	-	-	2	1
14	El Cerrito	3.69	-76.31	6	B	-	7	5	4
15	Facatativá	4.81	-74.35	4	B	4	-	5	4
16	Girardot	4.30	-74.80	4	B	5	5	6	6
17	Guamo	4.03	-74.97	4	B	4	-	6	6
18	Ibagué	4.44	-75.20	6	B	6	5	8	7
19	Istmina	5.16	-76.69	4	B	-	-	4	4
20	Juanchito	3.45	-76.47	7	B	-	5	4	4
21	La Cumbre	3.65	-76.57	6.5	B	8	7	4	4
22	La Unión	4.53	-76.10	5.5	B	7	6	5	5

Table A1 - continued.

23	Líbano	4.92	-75.07	4	B	4	-	6	5
24	Manizales	5.07	-75.49	5	B	5	5	5	5
25	Medellín	6.26	-75.57	3	B	4	4	4	3
26	Palmira	3.54	-76.30	5.5	B	5	5	5	4
27	Pandi	4.19	-74.49	4	B	4	5	5	5
28	Pasto	1.21	-77.27	4	B	3	-	2	2
29	Pereira	4.81	-75.69	5	B	6	5	6	5
30	Piendamó	2.64	-76.53	5	B	7	-	4	3
31	Popayán	2.47	-76.58	6	B	6	6	3	3
32	Quibdó	5.69	-76.65	4	B	4	4	4	3
33	Restrepo	3.82	-76.52	6	B	8	-	5	4
34	Roldanillo	4.41	-76.15	6	B	7	7	5	5
35	Salento	4.64	-75.57	4	B	4	5	6	6
36	Sevilla	4.27	-75.93	7	B	-	6	6	5
37	Subachoque	4.93	-74.17	3.5	B	4	-	4	4
38	Tadó	5.26	-76.56	3	B	-	-	4	4
39	Ubalá	4.75	-73.53	3.5	B	4	-	4	3
40	Villahermosa	5.03	-75.12	3.5	B	4	-	5	5
41	Yotoco	3.86	-76.38	5.5	B	8	6	5	4

Table A2 - Primary Sources that were used (after Salcedo Hurtado *et al.*, 2007, 2021a; Blandon and Rios, 2017).

N	Source	Source Type	pages	Archive
1	Mundo al dia (1925)	Daily newspaper	1, 11	Hemeroteca Biblioteca Nacional de Colombia, Bogotá
2	Delgado (1925)	Daily newspaper	2	Hemeroteca Biblioteca Nacional de Colombia, Bogotá
3	El Gráfico (1925)	Journal	1	Biblioteca departamental de la ciudad de Cali
4	El Espectador (1925)	Daily newspaper	1	Hemeroteca Biblioteca Nacional de Colombia, Bogotá
5	El Tiempo (1925)	Daily newspaper	1	Hemeroteca Biblioteca Nacional de Colombia, Bogotá
6	ABC (1925)	Daily newspaper	1	Hemeroteca Biblioteca Nacional de Colombia, Bogotá
7	Correo del Cauca (1925)	Daily newspaper	7	Biblioteca departamental de la ciudad de Cali
8	El Relator (1925)	Daily newspaper	1, 2	Biblioteca departamental de la ciudad de Cali
9	Aragón (1930)	Book	406	Archivo Central del Cauca, Popayán
10	Castrillón Arboleda (1986)	Book	23-35	Archivo Histórico de Popayán

Table A3 - Secondary Sources that were used (after Salcedo Hurtado *et al.*, 2021a).

N	Source	Source Type	Archive
1	Espinosa Baquero (2003)	Book-CD	Academia Colombiana de Ciencias Exactas, Físicas y Naturales, Bogotá
2	Martinez (2014)	Monograph Study	Universidad del Valle, Cali
3	Salcedo Hurtado *et al.* (2007)	Paper	Academia Colombiana de Ciencias Exactas, Físicas y Naturales, Bogotá
4	INGEOMINAS (2005)	Report	Servicio Geologico Colombiano
5	Sarabia and Cifuentes (2010)	Report	Servicio Geologico Colombiano

Table A4 - Summary of the earthquake effects descriptions, examples for the city of Cali, La Cumbre and Calarcá from several sources given by Tab. A1 and Tab. A2 (after Salcedo Hurtado *et al.*, 2021a).

Effect Type	**Cali**
Effects on humans	The earthquake was fatal for Cali, the shaking was extremely strong. One person died and many injured due to the collapse of roofs in several buildings. All the people ran into the streets and many people found it difficult to stand. Many families have left the city, and others are hastily preparing to travel. The people in their rooms have been seriously injured. Panic spread extraordinarily in the city, they spent the night outside their houses, in makeshift tents, fearing new landslides. The horror was unspeakable.
Effects on objects	The clock in the church of San Pedro stopped at the precise time of the earthquake. The pharmacy was totally lost, as the bottles were broken. Considerable damage is recorded in almost all the canteens and bars, as almost all the bottles were broken. The Cali telegraph office was completely isolated, because the batteries broke. Problems in the telephone network and many cords snapped.
Damage to buildings	**Churches** The earthquake caused considerable damage to valued buildings. The church of the *Hermita de Nuestra Señora de la Soledad del Rio* collapsed entirely. The domes of the churches of San Francisco and Santa Librada collapsed. Very severe damage to the church of San Pedro, where all the arches were broken, the roof suffered structural failures. Serious damage and collapse of walls and towers in the churches of San Nicolas, La Merced, Santa Rosa. Several private buildings suffered serious damage. **Houses and public buildings** All houses and buildings in the city were damaged, some were totally destroyed, others were seriously damaged. Several private buildings suffered serious damage. The whole ground floor collapsed in the *Hotel Francia*. The building of *La Clinica* partially collapsed. *Las Casas del Sindacato Popular*, which were adobe buildings, were completely destroyed. A collapsed Barracks tower. Heavy damage, large cracks in most walls in the house of Mr. Miguel Calero, the Velez family, the *Edificio Lora*, the *Edificio Emilio Otero*, the slaughterhouse, the municipal administration buildings and *Ferrocarril del Pacifico*. Heavy non-structural damage to the building of the daily newspaper El Relator. Some houses in the Cañaveralejo neighbourhood collapsed.
	La Cumbre
Effects on humans	Most people are frightened. The tranquillity of the inhabitants turned into madness. In desperation, some were screaming, others were crying inconsolably. One woman died and a few were injured. A few people lost their balance.
Effects on objects	The event caused serious losses in that population. Considerable losses in pharmacies, warehouses and tobacconist. The telegraphic office battery was destroyed.
Damage to buildings	Partial collapse of the Railway Warehouse
	Calarcá
Effects on humans	The earthquake was of extremely violent intensity. Two dead people. The people are in the greatest panic, all the houses were abandoned by their occupants. The terror is unstoppable.
Effects on objects	The poles that hold the strings of the light fell down.
Damage to buildings	Two people were killed by a wall collapse. The church towers collapsed, causing some damage and misfortune. Cracked houses.