Monthly report on the volcanic activity of *La Soufrière de Guadeloupe* and on the regional seismicity

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**A - Volcanic activity of La Soufrière de Guadeloupe**

**Synopsis** - La Soufrière de Guadeloupe is an explosive-type active volcano that has experienced many magmatic and phreatic eruptions in the past. Since 1992, its seismic, fumarolic and thermal activity shows a fluctuating but generally increasing regime, which results in a strong activity of the hydrothermal system (circulation and interaction of gas, steam and water under pressure within the porous and fractured rock).

Since the beginning of 2018, we have remarked a cyclic process of deep magmatic gas injection at the base of the hydrothermal system, at a depth between 2 and 3 km below the summit. This generates a recurring process of heating and pressurisation of the hydrothermal system that results in: 1) disturbances in hydrothermal fluid circulation; 2) evolution in the activity of the summit fumaroles, one of which shows evidence of projections of hot and acid mud over a range of several metres; 3) an increase of seismic swarms of volcanic origins; 4) some volcanic earthquakes being felt by the surrounding population (four between February and April 2018 including the M4.1 on 27 April 2018, the strongest since 1976; 5) low-amplitude ground deformation limited to the La Soufrière dome, on the order of 3-7 mm/year, as well as the continued opening of summit fractures; 6) fluctuations in fumarolic gas flow rates emitted from an overpressured hydrothermal reservoir; 7) propagation of the ground thermal anomalies on the summit and dome of La Soufrière.

Though these phenomena incite the observatory to exert extra vigilance, they are currently not clearly accompanied by anomalies in other monitoring parameters related to a possible rise of magma. These could include, though not in every case the occurrence of increased deep and/or felt seismicity, large scale deformations, and sulphuric gas emissions at high temperature (> 150 °C).

On the basis of the observations recorded by the OVSG-IPGP during the month of August 2020 and summarised in this bulletin, and in accordance with the provisions laid down by the authorities, the current level of volcanic activity (see table in annex) remains:

**VIGILANCE (= YELLOW)**

The short-term probability of eruptive activity remains low. However, given the increase in seismic and fumarolic activity recorded since February 2018, a change of the volcano regime has been observed such that we can not exclude an intensification of phenomena in the future. As a result, the OVSG-IPGP is in a state of increased vigilance.

The gaseous emissions in the vicinity and leeward of the main summit fumaroles (in particular Cratère Sud, Cratère Tarissan and Gouffre 1956) have, since 1998, proven risks of irritation and burns (eyes, skin, respiratory tract).

Given the evolution described above and the other observations on the activity the OVSG-IPGP considers important to keep a distance of at least 50 m radius from the main centers of fumarolic gas emissions (Cratère Sud Sud, Cratère Sud central, Cratère Sud Nord, Napoleon Nord, Napoleon Est, Gouffre 1956, Gouffre Tarissan) as a precautionary measure.

Considering the evolution of the anomaly zone at the summit (with the ground heat propagation, the recrudescence of fumarolic activity, accompanied by the appearance in time of new centers of emission and projection of mud and fragments, the signs of the impact of sulfur and acid gases on the ground and on the vegetation) and therefore of a general increase in areas of instability, the Préfecture de Guadeloupe with the decree n°2019/001 CAB SIDPC of 14 January 2019 instituted regulated access to the top of the Soufrière volcano, based on the identification of a security perimeter and the prohibition of any unauthorized person crossing it.

**Volcano seismicity**

During the month of August the observatory recorded 840 earthquakes of volcanic origin, located mainly under and around the dome of Soufrière (Figure 1), between ~0.1 and 2.4 km deep under the summit. A large part of the activity is grouped around one swarm, recorded from 15 August 2020 to 19 August 2020 (560 earthquakes).

838 events are of the volcano-tectonic type (so-called VT); 2 are of the long-period type (so-called LP) or low-frequency. A large proportion of these VT earthquakes have a low frequency (or long-period, LP) component in the coda of the signals which is diagnostic of their "hybrid" type behaviour.

This behaviour is characteristic of hydrofracturing processes generated by the migration of fluids into the volcano.

The aforementioned activity is typified by micro-earthquakes of weak magnitude (M < 1).

VT earthquakes correspond to small-size rupturing of the volcano fractures. LP earthquakes are associated with pressurised fluid resonance phenomena (water, gas) in the fractures of the volcanic building.
The entire seismic activity released a total energy of the order of 2 MJ (1). The energy released by the seismic activity of this past month represents about 16% of the seismic energy released during the last 12 months (Figure 2).

The recorded and very localised earthquakes testify to: 1) the typical dynamics of a highly-developed hydrothermal system, whose activity is marked by the interaction between the gases that rise from the depth and the water circulating in the shallow fractures; 2) releasing of tensional stresses that affect the deeper roots of the La Soufrière hydrothermal and magmatic system, which are related to the complexity of the numerous faults of tectonic origin that intersect the dome and the volcanic complex of Soufrière-Grande Découverte.

Since early 2017 the OVSG-IPGP has improved its networks, which now acquire seismic data at unprecedented instrumental sensitivities. In conjunction with an improved data treatment, these changes allow for the detection of a greater number of earthquakes, especially those of very small magnitude. Nevertheless, since the beginning of 2018, the OVSG-IPGP has also recorded an increase in seismic activity. During the first half of the year 2018, such an increase culminated in the highly-energetic crisis recorded at the end of April 2018 (Figure 3). In addition, since 4th August 2018, OVSG-IPGP has recorded an increase in the number of very low energy seismic swarms (many earthquake events closely spaced in time). This past month, we detected one swarm related to this low-energy seismic activity. As of 31 August 2020, the OVSG-IPGP has detected 33 swarms (Figure 3). This increase recorded since August can not be solely attributed to the aforesaid improvements to the seismic network.

The OVSG-IPGP has therefore established a new communication protocol for these low-energy phenomena related to La Soufrière's activity. Since 12th November 2018, we report daily regarding scientific observations when we detect a seismic swarm, during, and at its end.

We consider that it is important to communicate on this increased seismic activity that is associated with the rock fracturing in the hydrothermal reservoir. Although the events remain of very low energy, this increased seismicity nevertheless marks a change in the behaviour of La Soufrière over the past few months as it implies the involvement of other processes related to hydrothermal fluid circulation. If this trend intensifies, this could have implications for the evolution of the activity at the summit, including sudden and highly localized phenomena such as: geysering with emission of hot and acidic sludge, projection of ash and fragments over few meters, rapid "steam flashing", and the opening of new fumaroles.

Since September 2019. Nevertheless, this does not imply a decrease of the average seismic energy released since August 2018.

Deformations

Ground deformations are measured by GNSS (1) and extensometry. The GNSS network extends over the entire south Basse-Terre and highlights movements at different scales: a) in southern Basse-Terre, far from the La Soufrière dome, to detect possible mass migrations from deeper roots of the magmatic system; b) around the dome, at the level of the hydrothermal system; c) at the level of the dome, in addition to the extensometry on the fractures.

In the south of Basse-Terre, we do not observe movements that show any significant contribution of mass arrival at depth. At
the dome scale, the movements are globally more important at the top of the volcanic edifice, where we measure among the strongest horizontal and vertical deformations since the onset of the network in 1995. On the dome, the deformation signal is globally radial (3 to 7 mm/year).

The fracture extensometry measurements, since the onset of the network in 1995, show a general tendency of opening of the faults and fractures in the active fumarolic zones as well as along the “Falaise de 30 August”. This signal is observable mainly at the top of the dome, in the active zone and particularly at the Napoleon crater where the deformations have always been more marked. These opening movements can be partially compensated locally by closing of other fractures.

The last measurements carried out this past month are in line with the opening trend that has characterized active fumarolic zones during the last two years (Figure 4).

**Figure 4**: Radial spacing in millimeters measured at Crater Napoleon during the last 10 years. Located at the top of the dome, the Crater Napoléon is the site where we generally record the largest deformations as well as the appearance of new fumaroles very active and the progression of a thermal anomaly in the soil with temperatures that oscillate between 50 and 92 °C.

### Fluid Geochemistry

#### Fumarolic activity

Just prior the 27-28 April 2018 seismic swarm and the magnitude M 4.1 volcanic earthquake, we observed a significant decrease of gas emission velocities and therefore of gas flow rates. Since September 2018 gas flow rates have shown a continuous increase reaching very high rates in February 2019 and which peaked the last month of December 2019 from Cratère Sud fumaroles (Cratère Sud Sud, CSS; Cratère Sud Central, CSC; Cratère Sud Nord, CSN). After the decrease of the flux observed in January 2020, this past month too we observed that fluxes from these vents were comparable to those observed during September-December 2019 and since February 2020. Fumarolic activity at Cratère Sud is still characterized by extensive deposits of crystalline yellow sulphur.

This past month, during gas sampling, we measured a temperature of 101.8°C at CSC, which is higher than the liquid-vapour equilibrium temperature for the water at the local atmospheric pressure.

The volume concentrations (average of two measurements) of the main gases of the fumarole CSC are: H₂O=97.03 %, CO₂=2.47 %, S₀₂=0.48 % (1 < H₂/SO₂ < 10). The pH of 2.12 (average of two measurements) and the persistence of hydrochloric acid droplets mixed with volcanic gases testifies to the acidity of the fumarolic plume.

The fumarole temperature of the Crater Napoleon Nord is stable (95°C), at the liquid-vapour equilibrium temperature for water at the local atmospheric pressure.

The other active zones, indicated on the map of Annex C (Gouffre Tarissan, Cratère Napoleon, Gouffre 1956, Lacroix fractures, Cratère Breislack, Route de la Citerne, Ravine Matylis, denoted by yellow stars on the map) show a marked tendency to flow rates increasing, locally accompanied by the degradation of the nearby vegetation. The observation of the terrain around the fumarole known as Napoleon East shows signs of mud splashing over a few meters, which explains the enlargement of the fumarole vent, formed between 8-10 February 2016. This month, we sampled the acid lake at the bottom of the Tarissan crater, showing a pH of 0.71. The lake water table is at 103.94 m below the rim.

Figure 5 shows the temporal evolution of the chemical composition of the fumarole CSC. For this fumarole, the most representative for the monitoring and study of the hydrothermal system, the molar ratios gas/steam, C/S, CO₂/CH₄ and CO₂/CO₂ (°) are shown.

It should be noted that the ratio gas/steam, stable since 11/2017, rose considerably on 2nd June (up to 0.1), before falling on 21st June 2018, and then varies between 0.03 (the value of this past month) and 0.06.

The C/S ratio shows a fluctuating behaviour between values of 3 and 6, being around 5 this past month. The CO₂/CH₄ ratio shows a general upward trend, with values rising sharply at the end of April and beginning of May (200 000 to 250 000). This ratio reaches a peak of the same value as late April at the beginning of June and in September. Same as in early June 2018, this ratio has an average value of around 150,000 since October 2018, ranging between 120,000 (February and April 2019) and 170,000 (November 2018 and January 2019). In June the ratio had values around 100,000, in line with those of November 2017, then it decreased to around 50,000 in December 2019 and raised to around 100,000 this past month.

Overall, the behaviour of these indicators is related to the increase of the deep magmatic gas component in the hydrothermal system.

The progressive infiltration of magmatic deep gas was responsible for the rise in the CO₂/CO₂ ratio, which peaked to 0.000015 at the end of April - beginning of May 2018, typically in response to a process of deep heating of the hydrothermal system. As of June 2018, this indicator has returned to a baseline value that has been identified since November 2017, fluctuating between 0.000005 and 0.00001 with a minimum (0.000003) in September 2018. Since then, the CO₂/CO₂ ratio has fluctuated around a value of 0.0000050 (around 0.0000065 this past month), with a rise to 0.00001 observed in April 2020.

The infiltration of deep magmatic gases caused an increase in temperature and pressure inside the hydrothermal system, at depths of 2-3 km, compatible with the hypocentres of the seismic swarms recorded between February and April 2018. The latest data show that the Soufrière volcanic system is governed by the cyclically dynamics of energy recharge and discharge due to the infiltration of deep magmatic gases into the hydrothermal system. This generates a recurring process of overheating and overpressurising of the boiling hydrothermal fluids whose pressure and temperature conditions approach those of the critical point of water. Also the accumulation and energy release has for the moment reached its peak with the strong seismic and fumarolic activity of March-April 2018. Given the clear
infiltration of magmatic gases into the hydrothermal system, as well as the high temperatures and pressures inside the hydrothermal system, we estimate that the volcanic system is currently recharging energy.

**Figure 5.** Molar ratios of gases from the CSC fumarole since November 2017.

In particular, the recent evolution of the CO/CO$_2$ ratio, in conjunction with the low values of CO$_2$/CH$_4$, lead us to propose that the pressure and temperature inside the hydrothermal system have increased but likely in absence of a new anomalous input of deep magmatic gas. If this were present, it is not yet obvious from chemical information.

We also remark that the CO/CO$_2$ increasing trend measured during the last months and particularly in April 2020 seems to accompany the decrease of the frequency of seismic swarm occurrence that is observed since September 2019. Several hypotheses may explain these observations, such as an increase of the deep heat flux or the sealing of fractures and cracks that were opened after the episode of accelerated unrest that peaked in the M4.1 27 April 2018 earthquake.

**Thermal springs**

We did not take spring water samples this month. Previous measurements show that physico-chemical features of spring waters (pH, conductivity, cations and anions) are for the most stable.
Phenomenology

Acidic emissions carried by the wind continue the destruction of vegetation on the southern part of the summit and on the south-western and western flanks of the volcano. Depending on the hydrothermal activity and the wind regime, different areas can be impacted throughout the volcano summit and flanks. In particular, the weakening of the wind can promote a minor dispersion and therefore the accumulation of gases coming from the networks of fractures at the bottom of pits, gullies and other areas affected by diffuse degassing and relatively depressed compared to the local topography.

At the end of November 2019, the OVSG carried out an overflight of la Soufrière using the SIDPC's helicopter, during which thermal images of the summit were taken. Images such as that shown in figure 6 indicate the propagation of a summittal ground thermal anomaly (>50°C) that now extends from Gouffre Tarissan to Gouffre 1956. This fumarolic zone has continued to evolve in recent years with the appearance in July 2014 of a new diffuse active zone (with a low flow rate) north of the crater Napoleon associated with the thermal anomaly. A new fumarole was identified in early February 2016, east of Crater Napoléon (in the no-go zone). Its temperature is about 95 °C. Around the fumarole, which has grown since March 2018, there have been signs of past mud ejection and splashes a few meters away. The flow rate of the 1956 Gouffre has increased sharply since September 2015. These evolutions confirm that the increase in the activity of the hydrothermal system, observed since 1992, has become more important in the last period.

We recall here that in December 2018 we observed the decline of vegetation in two areas of the upper Ravine Matylis, as well as the presence of white sublimes in different points in the soil. In addition, we have identified a thermal flux released from the fracture located at the bottom of the Gouffre Breislack. This low flux was associated with the presence of white sublimes on the wall in the fracture, the emission of CO₂ and H₂S and an area without vegetation, or with declining vegetation in the immediate proximity of the wall below the chasm.

Other information

Weather conditions at the volcano summit

During the month, winds had an average speed of 39.9 km/h (maximum 69.7 km/h) and average direction East-North-East. Cumulative monthly rainfall was 108.2 mm. Average temperature was 18.1°C.

Figure 6. Thermal image of la Soufrière summit showing several key features. «Hot » colours indicate higher temperatures: red ~50°C, yellow ~65°C and white 80°C. Note that the summit path traverses this zone of elevated temperatures (the thermal anomaly)
**B – Regional Telluric Activity**

**Synopsis** - The insular arc of the Lesser Antilles results from the subduction of the America plate under the Caribbean plate. This active subduction has a convergence speed of 2 cm/year. It causes deformation in the contact zone of these plates, making our archipelago a region characterised by strong volcanic and seismic hazards. Some earthquakes are directly related to sliding processes between the two plates. Others, more superficial, result from the deformation of the Caribbean plate. Still others result from the breaking of the oceanic plate as it is subducted under the Caribbean plate. During the historical period, several earthquakes caused damage/victims in Guadeloupe (intensities greater than or equal to VII): 1735, 1810, 1843, 1851, 1897, 2004 and 2007.

During the month of August 2020, the regional telluric activity is characterized by a number of earthquakes comparable to the number recorded in the last months.

Earthquakes are not predictable and can occur at any time in the Guadeloupe archipelago. Risk prevention actions are still required: compliance with the seismic regulations in force, correct layout of the interiors of living and working space, training on the safe conduct to follow before, during, and after an earthquake.

**Regional Seismicity**

The Observatory recorded during the month a total of 71 earthquakes of tectonic origin, of maximum magnitude 4.1. Figure 7 shows the map of epicentres in an area of about 550 km around Guadeloupe.

With regard to the Guadeloupe archipelago, the geographical distribution of the seismic activity is comparable to that of the previous months, with a shallow seismicity located mainly along the large fault systems distributed between Martinique and Barbuda.

On 6 August February, a slight earthquake (M = 3.9) of tectonic origin was recorded at 17h39m UT (13h39m local time) and located 2 km north of Goyave, at a depth of 12 km. This earthquake was felt in Guadeloupe (macroseismic intensity II).

On 24 August, a minor earthquake (M = 3.5) of tectonic origin was recorded at 7h31m UT (3h31m local time) and located 53 km north of La Désirade, at a depth of 14 km. This earthquake was felt in Guadeloupe (macroseismic intensity II).

18 earthquakes were recorded between Les Saintes and Dominica (see Figure 7). The majority of these earthquakes could not be located (because of the too small magnitude) and no earthquake was reported felt.

**Kick’em Jenny**

The Kick’em Jenny is a submarine volcano that is located 9 km north of Granada. The summit is about 180 m below sea level.

It is currently the most active volcano in the Lesser Antilles. Since its discovery in 1939 by the Seismic Research Centre (SRC) of Trinidad, at least 13 underwater eruptions have been identified. The SRC records the evolution of the activity of the volcano via its seismic monitoring networks.

The level of alert reported in August by the National Disaster Management Agency (NaDMA) in Grenada is YELLOW. A 1.5 km exclusion zone is currently maintained around the summit of the volcano.

For more information, visit the websites of the Seismic Research Centre (http://www.uwiseismic.com) and of the National Disaster Management Agency (www.nadma.gd).

**Volcanic activity on Montserrat**

The activity of the Soufrière Hills volcano was low during the month of August. From 31 July to 28 August 2020, the seismic network of the Montserrat Volcano Observatory (MVO) recorded 31 VT-type earthquakes; sept of them grouped in a brief swam occurred on 17 August. In the same period, the alert level was 1. This level of alert provides for the prohibition of access to Zone V, which includes the city of Plymouth. The Eastern and Western Maritime Zones can be crossed, but without stopping and only during the day, between dawn and sunset.

All information can be found on the MVO website (www.mvo.ms).

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The Director of OVSG-IPGP, 20 October 2020
C – Annexes

(1): 1 megajoule = 1 MJ = 10⁶ Joules ; 1 gigajoule = 1 GJ = 10⁹ Joules ; 1 terajoule = 1 TJ = 10¹² Joules. For example, an earthquake of magnitude 6 releases as much elastic energy as the energy released by the Hiroshima atomic bomb (63 TJ). An increase of 1 point on the scale of magnitudes equates to about 32 times more energy; for example, an earthquake of magnitude M = 4 releases about 900 times more energy than an earthquake of magnitude M = 2.

(2): GNSS (Global Navigation Satellite System) includes GPS (USA), Galileo (EU), GLONASS (Russia) and Compass (China).

(3): Here we summarise the most accepted interpretations of the indicators shown in Figure 5. The variation in the gas / water vapour ratio essentially measures the variation of the relative proportion of magmatic gas to the meteoric component (rainwater) in the hydrothermal system; this ratio may increase due to the arrival of magmatic gases and / or the condensation of steam. The C/S ratio can increase during the rise of deep magmatic gases or by loss of sulphur, especially H₂S (“gas scrubbing”) in the hydrothermal system, often associated with a decrease in temperature. An increase in the CO₂/CH₄ ratio is considered as a clear signal of the arrival of oxidized magmatic gases and of high temperature, thus enriched in CO₂ and whose arrival oxidises and potentially warms the base of the hydrothermal system, limiting the conversion of CO₂ in CH₄. Finally, the CO₂/CO ratio, for an oxidation state within the system, is normally associated with the heating of the hydrothermal system. It is also recalled that in hydrothermal systems characterised by the coexistence of water vapour and the liquid (pure water or brines), the heating and overpressure phenomena are associated, so that temperature and pressure increase together.

Definition of volcanic activity levels for La Soufrière de Guadeloupe

<table>
<thead>
<tr>
<th>Overall observed activity</th>
<th>Low Base level</th>
<th>Increasing Variations of some parameters</th>
<th>Strongly increased Variations of many parameters, seismicity frequently felt</th>
<th>Maximum Intense volcanic seismicity, major deformations, explosions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Possible timescale</td>
<td>Century (s) / Years</td>
<td>Year (s) / Months</td>
<td>Months / Weeks</td>
<td>Imminent / In progress</td>
</tr>
<tr>
<td>Decision</td>
<td>Century (s) / Years</td>
<td>Year (s) / Months</td>
<td>Months / Weeks</td>
<td>Imminent / In progress</td>
</tr>
<tr>
<td>Alert level</td>
<td>GREEN= No alert</td>
<td>YELLOW = Vigilance</td>
<td>ORANGE = Pre-alert</td>
<td>RED = Alert</td>
</tr>
</tbody>
</table>

La Soufrière: further information

The Grande Découverte - Soufrière complex is made up of 3 stratovolcanoes, Grande Découverte, Carmichael and Soufrière which were built during the last 445 000 years. Soufrière is the most recent building and its eruptive history began about 9150 years ago. It is an active volcano, explosive type, that has experienced many magmatic and non-magmatic eruptions, the latter called “phreatic”, in the past. The most recent major magmatic eruption dates from 1530 AD. This complex eruption began with a collapse of the old building causing a landslide that reached the sea at Basse-Terre. The explosive eruption that followed resulted in ash and pumice fallout on southern Basse-Terre, the outpouring of pyroclastic flows (incandescent avalanches of gas, ashes and rock blocks) that reached 5-7 km away volcano, and mudslides. It ended with the formation of the Soufrière dome (about 50 million m³). The latest scientific data (i) suggest that a smaller magmatic eruption took place in 1657. Although the volcano of La Soufrière is the only volcano that has shown a historical activity in Guadeloupe (since 1635), the current knowledge shows that the volcanic complex of Madeleine Trois-Rivières has been active in the last 5000 years. Therefore, there are two active volcanic complexes in Guadeloupe. The magmatic eruption of 1530 is representative of the hazards caused by an explosive eruption of medium magnitude, although more intense explosive eruptions have been identified in the last 10 000 years.

The historical activity of La Soufrière since 1635 is characterized by non-magmatic eruptions, which were minor in 1690, 1812, and 1956, and major in 1797-1798, 1836-1837, and 1976-1977. The phreatic eruption of 1956 lasted ten days with two explosions. That of 1976-77 was particularly violent with 26 major explosions between July 1976 and March 1977. It produced acid gas emissions, vertical and laterally directed projections of blocks and ashes, small cold pyroclastic flows of low volume, mudslides and about 16 000 earthquakes of which 150 were felt, including the M4.2 earthquake on 16 August 1976. It was a phreatic or hydrothermal eruption. However, it can also be considered as a failed (aborted) magmatic eruption according to another hypothesis in which the magma did not rise to the surface. Although less intense than the magmatic eruptions, the more frequent non-magmatic eruptions of La Soufrière can generate very diverse hazards (rockfalls, ash fallout, explosions, pyroclastic flows, gas emissions, environmental contamination, mudflows, landslides, directed blasts / lateral explosions) that pose significant risks to people and infrastructure. The state-of-the-art knowledge on phreatic eruptions reveals that they are typically frequent and sudden, that there precursory signals are frequently absent or few and equivocal, that they are characterized by a variable duration and intensity, and the associated phenomena are varied and can be particularly dangerous up-close. The great majority of phreatic eruptions are not systematically followed by a magmatic eruption. However, any magmatic eruption, whose precursors are more numerous and marked, will be followed by a phreatic eruption.

(i): Feuillard et al., 1983; Boudon et al., 1988; Komorowski et al., 2005; Boudon et al., 2008; Komorowski, 2008; Komorowski et al., 2008; Feuillard, 2011; Legendre, 2012; Hincks et al., 2014; Rosas-Carabajal et al., 2016

The following map (Komorowski et al., 2013) represents the volcanic dome with the sites mentioned in this bulletin.
Clarifications on earthquake magnitude
The concept of Magnitude was introduced in 1935 by Charles F. Richter to express the "force" of an earthquake in a quantitative and non-subjective way. **Richter Magnitude**, a logarithmic scale also known as **Local Magnitude (M)_L**, is expressed in terms of the amplitude recorded by a particular instrument, the Wood-Anderson torsion pendulum. The Richter Magnitude has been calibrated only for earthquakes occurring in California within 600 km of the station having recorded the event.

To compensate for the distance limitation given by the expression of the Richter Magnitude, other logarithmic scales of Magnitude have been introduced to express the energy radiated by an earthquake. Most quantities are based on the maximum amplitude of the seismic signal on the seismogram or on the relationship between the amplitude and the period of recorded seismic waves.

In order to calculate the local magnitude of small or medium intensity earthquakes at local or regional distances, the **magnitude of duration (M)_d** was introduced. Its calculation is based on the measurement of the duration of the seismic signal on the seismogram, since the greater the magnitude of an event, the greater the duration of the recording.

**Moment magnitude (M)_w** measures the size of events in terms of the amount of seismic energy released. Specifically, moment magnitude refers to the displacement along a fault or fracture and to the surface of the fault or fracture. Since the moment magnitude can describe something physical about the event, the calculated values can easily be compared to amplitude values for other events. The moment magnitude is also a more accurate scale to describe the size of events.

From the relationships between magnitude and seismic energy, it is possible to deduce that a variation of 1 point of Magnitude is equivalent to an energy increase of about 30 times. In other words, the energy generated by an earthquake of magnitude 6 is about 30 times greater than that produced by a Magnitude 5 earthquake and about 1000 times greater than that produced by a magnitude 4 earthquake.

Finally, like any physical parameter, an estimate of magnitude is associated with **uncertainty**. On the local Magnitude, it is generally of the order of 0.2 to 0.3, rarely less. Magnitude values provided by other international agencies (USGS, SRC for the Caribbean) generally fall into this variability.

The data and parameters used to locate an earthquake may differ from one agency to another, and contribute to the uncertainty of the estimate. The OVSG-IPGP and the OVSM-IPGP use calibrated procedures for the West Indies and a higher density of seismic stations than other international agencies that use global parameters.

Therefore, the different magnitude estimation methods provide estimates of the same magnitude, but may actually be slightly different while remaining within the uncertainties of each estimate.

### Simplified definition of the European macroseismic scale (EMS98)

<table>
<thead>
<tr>
<th>Intensity</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
<th>IX</th>
<th>X-XI-XII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Perception</td>
<td>Not felt</td>
<td>Very weak</td>
<td>Weak</td>
<td>Light</td>
<td>Moderate</td>
<td>Strong</td>
<td>Very Strong</td>
<td>Severe</td>
<td>Violent</td>
<td>Extreme</td>
</tr>
<tr>
<td>Probable damage</td>
<td>No damage</td>
<td>Very slight</td>
<td>Slight</td>
<td>Moderate</td>
<td>Important</td>
<td>Destructions</td>
<td>Generalized</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Report a felt earthquake**

Actual intensities (the effects of an earthquake in a given place) can only be properly determined by collecting testimonies. If you have felt an earthquake, even weakly, you are invited to report it to the observatory and take a few minutes to complete the BCSF macroseismic survey form on the website [http://www.franceseisme.fr/](http://www.franceseisme.fr/).

**Centre de Données Sismologiques des Antilles (CDSA)**

The mission of the CDSA is to process and make available to the public technical and scientific information concerning the seismic activity in the Lesser Antilles archipelago ([www.seismes-antilles.fr](http://www.seismes-antilles.fr)). It is a collaboration between the Institute of Physics of the Globe of Paris (IPGP), the BRGM and the University of the Antilles. The CDSA was set up gradually between 2002 and 2007 as part of a CPER-SPD project “KASIS” and financed by the ERDF, the Ministry of the Environment, the Guadeloupe Region, the IPGP and the BRGM. The second phase of the project started in October 2013 (under the CPER-OP 2007-2013). Located on the Houëlmont and hosted by the Volcanological and Seismological Observatory of Guadeloupe (OVSG-IPGP), the CDSA benefits from the reliability of the infrastructures and the continuous operational support of the IPGP equipment deployed for surveillance.

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