Anticipating and following 2018 eruptive activity of Sierra Negra volcano

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Sierra Negra Caldera


Wolf: 1948, 1982

Darwin: 1813

Alcedo: 1953

Santiago: 1897, 1904
Sierra Negra’s main features

- Sierra Negra (1100 m high) is the largest volcano in Galápagos with the largest caldera 82 km².
- It is one of the most prolific volcanoes in the Galápagos islands.
- 90% of its surface is covered by young lavas (<4,500 yrs).
- Seven eruptions since 1948 with an interval average of 11.3 years, including 1979 (~1 km³ of lava) and in 2005 (0.15 km³ of lava).
- The rapid and high amplitude (~5 m) surface deformation detected by GPS and InSAR were related to shallow sources seen before 2005 and 2018 eruptions (see Amenlung talk in this session).
Sierra Negra 2005 eruption

Caldera interior before eruption

Volcan Chico 2005 lava fountain
2015-2018 SN seismicity
Unrest’s signals

- Steady increase of seismic activity at Sierra Negra from an average of 55 events/month in 2015 to an average of 1115 in January – May 2018.

- Energy release also showed an important increase since 15 events with magnitudes $\geq 4.0$ were detected in the period January - June 2018 before the eruption.
Spectral characteristics

• Most seismic events were classified as VT.
• Large events exhibit spectral peaks in the range of LP and VLP even at the closest station.
Evento 9 mayo 2018: 04h40 UT mag. 4,1

Galapagos network - 6 stations

VCH1 three component station and VLP
Spectral characteristics
2018 SN seismicity
Eruptive sequence

- On June 26, a ML 5.3 earthquake, registered 8 hours before the eruption onset.
- This event was followed about six hours later by a swarm with LP, VT and VLP events and two hours afterward by a low-frequency tremor that indicated the onset of eruptive activity.
26 June seismic sequence

5.3 Eq 03h15

Swarm 12h
Eruption 12h20

Tremor 14h00
Main seismic precursor

SEISMIC WAVEFORM

SPECTRA

2018 06 26 03:15 LT  Depth: 0.1 km. Mag. 5.3 Mlv
Main eruption pulses

Seismic and Infrasound records at 12h20 LT at VCH1 station
Mag. 4.5 Mlv, Depth: 1 km
Co-eruptive tremor

Tremor appears after eruption onset
Seen only at VCH1 station
Low frequency content 1-4 Hz
Seismic rate

![Graph showing seismic rate with labels for Seismic swarm, Eruptive pulse, and Volcanic Tremor.]
Hypocenter locations

• Epicenters are located at the borders of caldera. South epicentral branch matches with trap-door faults.

• Shallow foci presumably above either a horizontal magmatic reservoir or sill. Geodetic data show large, and differential vertical motions across the 10 km-wide caldera.
Epicentral locations & magnitudes
Epicentral locations and depths
Eruptive sources

Fissure 1: Upper N-NE caldera rim, 4 km long. 16 km². Max. length 7 km.
Fissure 2: Mid NW flank. 2 km². Max. length 3 km.
Fissure 3: Mid W flank. 0.3 km². Max. length 2 km.
Fissure 4: Low NW flank. 12 km².
CONCLUSIONS

• Sierra Negra 2018 eruption was preceded by continuous uplifts of caldera’s floor, overpassing critical uplift before 2005 eruption.

• Seismic evolution, first time in Sierra Negra, increased both in number of events as well as in magnitudes.

• Despite a majority of VT events, largest events have low frequency and very low frequencies and very short bandwidth. LP events have a fundamental frequency of 0.58 Hz and two overtones (f₂ and f₄).

• Hypocenters are located along caldera ring faults and at shallow depths.

• It is important to maintain a permanent multi-parametric monitoring of Galapagos volcanoes and densify seismic network with research purposes.

• Understanding internal phenomena could be a facilitates monitoring and correct decision of communities and authorities.
Gracias
IGUANA Temporary Seismic Network

16 BB stations from U. Edinburgh, DIAS Dublin, Tulane U. + IGEPN permanent stations
Sierra Negra’s previous seismic studies

- Short period network in Galápagos (1 station near SE park entrance)
- SIGNET Project
- Current Galapagos broad band network. Instituto Geofisico is monitoring this volcano with a permanent broad band seismic network since September 2013.
- IG-EPN promoted international collaboration to better understand SN unrest. IGUANA Project and NSF-Rapid Project joined efforts from Edinburgh U., Dublin, Tulane U., Miami, U. of Penn
Main stress changes at stations 10 and 12 due to an intrusion of a dike occurred between 4-10 June 2010. The arrow direction shows the change before and during intrusion (Anzieta, 2013)

SIGNET temporary network of 16 BB sensors registered an average of 3 earthquakes/day, with the majority of the activity coming in daily to weekly microseismic swarms.
Thermal anomalies (heat energy radiation) generated at Sierra Ñnegra since June to the end of July 2018 provided by MIROVA Project. Thermocouple temperatures reached 200 °C a week after main eruption pulse.
2017-2018: Families of seismic events

Computed by A. Bell
Spectral characteristics

![Graphs showing Sierra Negra seismicity and frequency distribution](image)
Focal mechanism
Eruptive sources

Lava from cráter rim, entering the ocean at the Nflank