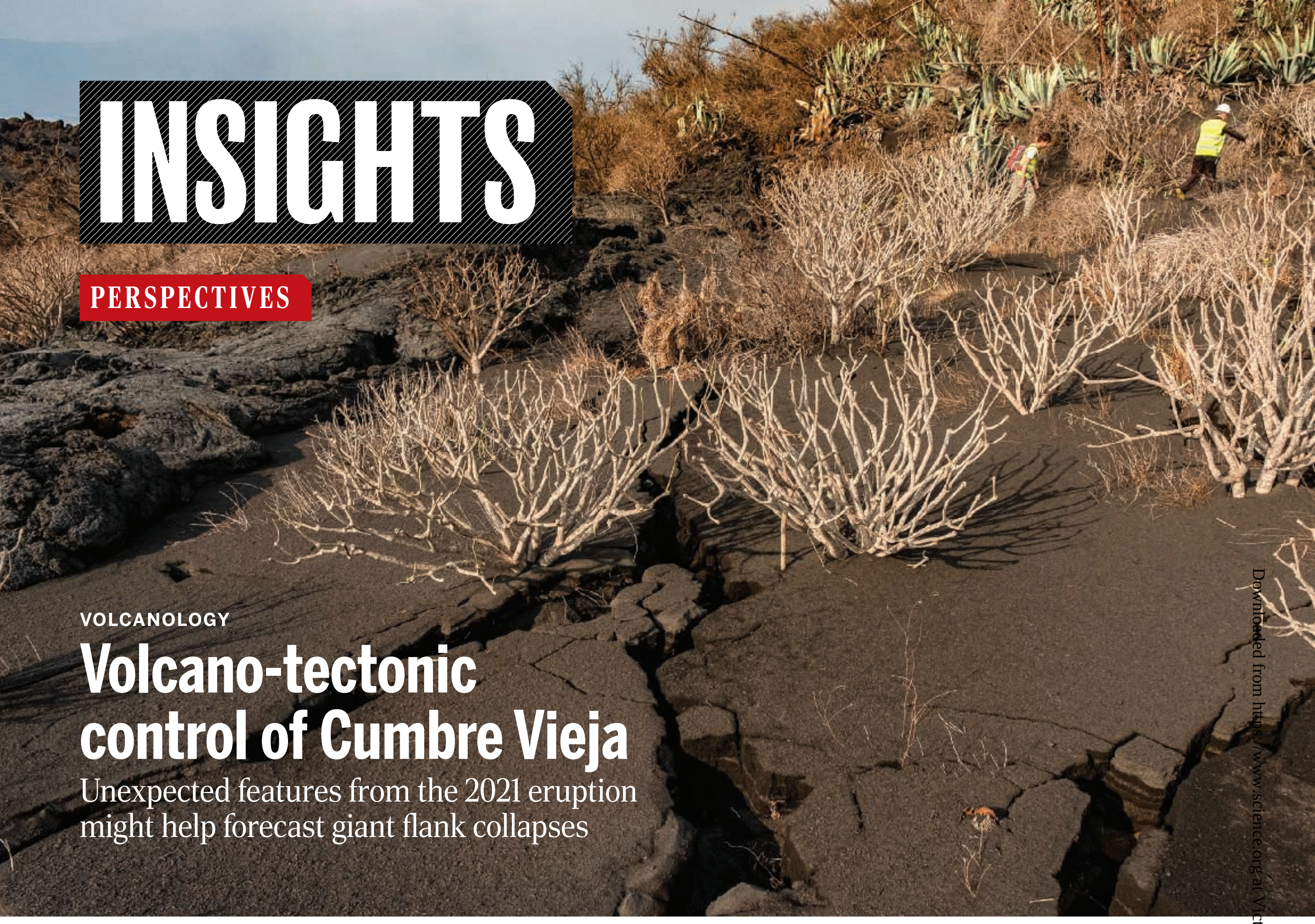


INSIGHTS

PERSPECTIVES

VOLCANOLOGY

Volcano-tectonic control of Cumbre Vieja

Unexpected features from the 2021 eruption might help forecast giant flank collapses

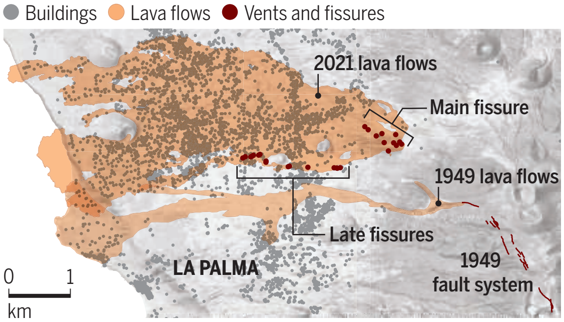
By **Pablo J. González**[1,2]

The 2021 Cumbre Vieja volcano eruption started on 19 September 2021 and ended after 85 days and 8 hours, becoming La Palma's longest and most voluminous (more than 200 million m³) eruption in historical times. Because of the good monitoring effort, this eruption will allow the testing of a wide range of scientific ideas, from the importance of a possible 436-year-long supercycle of duration-decreasing eruptions to using the geophysical observations to understand how magma is stored and migrates within a vertically extended upper mantle and crustal magmatic system (*1*). These types of magmatic and volcanological information will transform volcano eruption hazard assessment and long-term planning (*2*). Moreover, a key research question remains as to why this eruption did not create a catastrophic volcano flank collapse as perhaps expected (*3*). The answer may be tied to its distinct volcano-tectonic features and, in particular, an unexpected fissure system that opened during the eruption's last phase.

Many ocean island volcanoes grow at formidable rates over short geological periods, collapsing catastrophically to form many-kilometers-wide amphitheater-shaped valleys and causing tsunamis. The low recurrence rate of these events obscured the origin of the valleys until the identification of debris avalanche deposits around Hawai'i (*4*) and less–well-known studies of underground geology in the Canary Islands (*5*). Moreover, it was the catastrophic collapse accompanying the 1980 Mount St. Helens eruption (*6*) that revealed the sheer scale of this volcanic hazard. Among worldwide volcanoes, Cumbre Vieja has long been identified as a candidate tsunamigenic source, with models supporting variable transoceanic potential (*3*, *7*). Since the 1980s, progress has been made, but flank collapse–triggering mechanisms and feedbacks with active magmatic systems remain elusive.

Volcano-tectonic features of Cumbre Vieja

The main lava-erupting fissure is in a different direction than the later formation of fissures. These may be key to understanding flank collapse processes in this sort of volcanic system.



Cumbre Vieja is a volcano with a major 2000-m-above-sea-level-high topographic ridge elongated in a north-south direction—a pattern largely interpreted as the consequence of repeated intrusions and eruptions along the ridge. Over the past 150 to 125 thousand years (kyr), the volcano has rapidly grown, resulting in steep-sided volcano flanks. Two decades ago, Day *et al.* (*8*) presented a detailed volcano-structural map of the volcano. The picture was clear—during the past 7 kyr, its western flank has started to show signs of incipient volcano instability. The key elements were a well-developed pattern

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Unexpected effusive vents and fractures opened during the late phase of the 2021 Cumbre Vieja volcano eruption in La Palma, Canary Islands.

of recent northwest-southeast and east-west fractures and eruptive fissure systems and the reinterpretation of an unusual 3-km-long normal faulting system with a maximum 4-m throw movement that developed during the last summit eruption in 1949.

The 2021 eruption bursted along a northwest-southeast fissure because of the emplacement of a largely westerly dipping magmatic feeding dike, revealed by satellite radar interferometry and precise relocated seismicity (*9*). Notably, the 2021 eruptive fissure occurred along the northwestern continuation of the unusual 1949 normal faulting system and at the location of a previous eruptive site (Hoya de Tajogaite) with the same orientation (see the figure). Therefore, the 2021 magmatic pathways must be added to existing evidence for instability from geological structural studies (*8*); deformation during the intereruptive period (*10*); detailed gravity and electrical resistivity surveys (*11*, *12*); and the reappearance of erupted oceanic sediment xenoliths, which indicate the role of a rheologically layered crust (*13*). Moreover, the Cumbre Vieja western volcano flank, luckily, seems to have not yet reached runaway conditions.

But, like a blockbuster thriller movie, this Cumbre Vieja eruption left the biggest surprise for its last act. In mid- to late November, coinciding with an increase in the number of earthquakes, a complex set of fractures and slumps broke apart the northeastern flank of the 2-month-long active cone developed at the eruptive site. A north-northeast–south-southwest (NNE-SSW) fissure at the summit rapidly grew a large 100-m-high cone in less than 2 days. Almost simultaneously, short-lived vents opened along a roughly east-west trending direction downslope within 2 km of the summit active cone. Over the next week, multiple small vents and en-echelon fissures appeared at 1- to 3-km distance from the main fissure site and along that "late fissure" system. The spatial-temporal relationship will have to be carefully analyzed, but notably on 4 December, a well-developed graben opened near the summit of the active cone, and several more eruptive sites opened at the far west end of the late fissure system, feeding a more voluminous lava flow.

The puzzling aspect of this set of later events is twofold—that there is an apparent lack of large-magnitude and wide-area geodetic signals associated with such strong ground fracturing events and that this late fissure system has an unexpected orientation with respect to the focused NNW-SSE activity of the previous 2 months of eruptive activity. The late fissure system is roughly 100 m wide and hosts eruptive fissures with variable orientations. Those multiple fissures must have opened and erupted lava at low magmastatic pressures because some fissures developed extremely short—10- to 20-m-long—lava flows. Those volcano-tectonic structural changes should be critically assessed as to whether they released magmatic and/or gravitational volcano flank stresses.

Although it is still too early to provide a completed set of interpretations for all of the volcano-tectonic observations for the 2021 Cumbre Vieja eruption, exploring complex volcano-tectonic stress fields should be a possible venue for understanding the timing, occurrence, and character of this eruption. Taking it further, the volcano-tectonic control of this eruption will certainly help advance our knowledge of elusive magmatic and tectonic feedbacks that influence eruptive activity. Particularly revealing should be the sequence of events that resulted in there being no catastrophic collapse, as it should inform how to assess the likelihood of these for other systems. Finally, the detailed study of this eruption should contribute to answering the open question of what physical mechanism triggers giant catastrophic volcano flank collapses, such as those that are up to orders of magnitude larger than the recent and deadly 2018 Anak Krakatau volcano flank collapse (*14*). ■

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CORONAVIRUS

Effective surveillance of variants

Community testing studies can provide insights as SARS-CoV-2 evolves

By **Adam J. Kucharski**[1] *and* **Cheryl Cohen**[2]

As countries move into a third year of the COVID-19 pandemic, they continue to face the threat of novel variants and the challenge of monitoring them. In England, the Real-time Assessment of Community Transmission (REACT-1) study has been tracking community infection levels since May 2020, routinely collecting samples from hundreds of thousands of randomly selected individuals and testing for the presence of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). On page 1406 of this issue, Elliott *et al.* (*1*) show a rapid increase of the Omicron variant in REACT-1 data during December 2021, estimating that this variant grew from comprising 10% of all infections to 90% in just over a week. By contrast, it took around a month for Delta to reach such prevalence. The REACT-1 program demonstrates the value of community surveillance programs as immunity builds and new variants emerge.

Whereas the emergence of the Delta variant of SARS-CoV-2 was accompanied by scenes of overwhelmed hospitals in India, the initial identification of Omicron in South Africa was not followed by the same severe impact of earlier waves. Faced with a new variant, it is crucial to understand its ability to spread and cause disease. Early analysis of clinical data in South Africa suggested that Omicron was associated with a lower risk of hospitalization than other circulating SARS-CoV-2 variants, using a surveillance system that links case and hospital records with genome data (*2*). Even so, it is increasingly hard to extrapolate conclusions about emerging variants because of variations in population immunity through natural infection and vaccination across different countries.

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