Recent Unrest at Canary Islands' Teide Volcano?

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When a volcano that has been dormant for many centuries begins to show possible signs of reawakening, scientists and civil authorities rightly should be concerned about the possibility that the volcanic unrest might culminate in renewed eruptive activity. Such was the situation for Teide volcano, located on Tenerife in the Canary Islands, when a mild seismic swarm during April–July 2004 garnered much attention and caused public concern. However, that attention completely ignored the fact that the seismic recordings of the swarm were due to a much improved monitoring system rather than due to an actual event of alarming magnitude or extent.

It is important in any effective program of volcano-risk mitigation that the response to an apparent change in the status of a volcano should include the immediate implementation or augmentation of monitoring studies to better anticipate possible outcomes of the volcanic unrest. Equally important, emergency-management officials, using available scientific information and judgment, must take appropriate precautionary measures—including information of the populations at potential risk—while not creating unjust anxiety or alarm.

This article briefly reviews the circumstances and unfortunate societal consequences of the scientific, governmental, and media response to the seemingly heightened seismic activity on Tenerife in 2004. This article describes a series of misinterpretations of geophysical and geological data that led to raised levels of alarm on the island, although being of little actual volcanological significance.

Volcanological and Structural Evolution of Mount Teide

At 3718 meters, Mount Teide volcano is the third-highest volcanic structure on the planet and the highest peak in the Atlantic Ocean. Conversely to the intensely studied and geologically well-understood Hawaiian volcanoes, many crucial geological aspects of Teide volcano were insufficiently addressed until quite recently. As an example, until 2001, only a single radiometric age was available for the most recent activity of the Teide volcanic complex.

A joint Spanish-French project in 2001–2005 produced a detailed geological map of Teide and its northwest and northeast rifts, and provided 28 new radiocarbon ages and 26 K/Ar (potassium/argon) ages. This project completely changed the understanding of the geological and structural evolution of the Teide volcanic complex, allowing the majority of the eruptions to be separated into a stratigraphic sequence, particularly those eruptions that have occurred in the past 10,000 years (the Holocene).

The results of this study indicated that the central differentiated (phonolitic) Teide volcanic complex was the direct consequence of the activity of the rifts. The rifts developed a progressively steepening and unstable volcano at the center of Tenerife, and about 180,000–200,000 years ago rift activity triggered a massive landslide that generated an impressive horseshoe-shaped collapse embayment. The embayment's headwall is the 17 by 10 kilometer Las Cañadas caldera. Subsequent rift and central activity progressively filled the embayment, finally building up the 3718-meter-high Teide stratovolcano, which is nested in the collapse embayment. The main phase of construction of Teide concluded 30,000 years ago. Since then, the stratovolcano has erupted just once: the eighth-century summit eruption, during which the vent system and lavas increased the elevation of the volcano from about 3600 to 3718 meters.

This recent eruptive history is in stark contrast to the much higher explosivity, with frequent plinian eruptions, of the precollapse activity of the Cañadas volcano (>200,000 years ago). In the past 30,000 years, eruptions have occurred at a rate of only four to six per millennium, with a predominance (70%) of very low hazard, basaltic eruptions from fissures and cones on the rift zones, and the remaining eruptions from phonolitic lava domes with only localized explosive activity (e.g., Mña Blanca, ~2000 years ago) at the basal perimeter of the main stratovolcano.

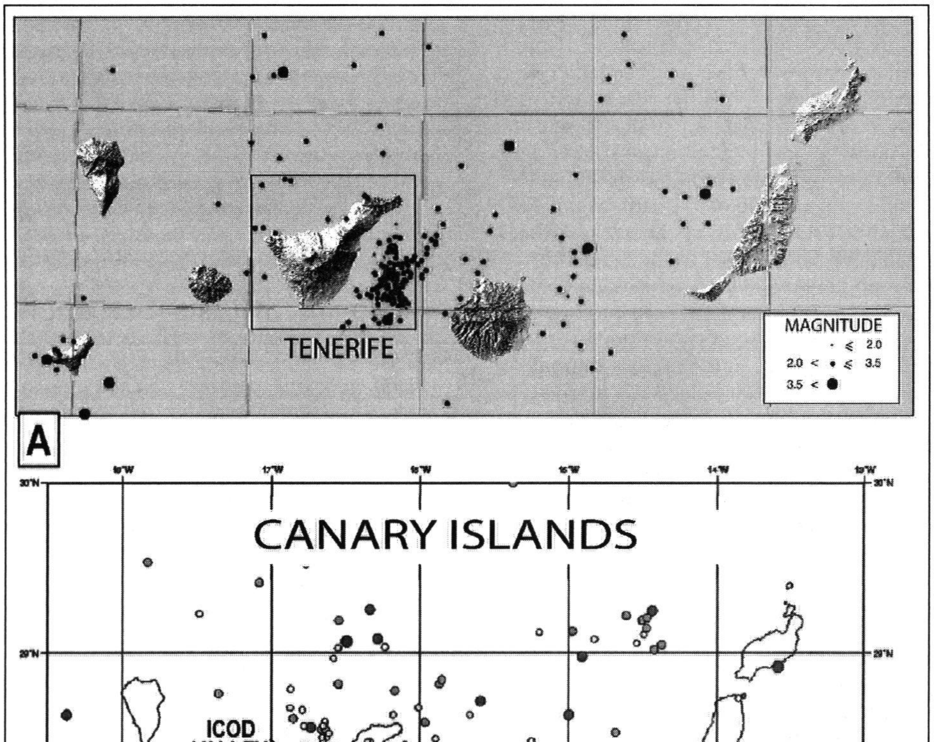

Fig. 1. Seismicity within the island of Tenerife: (a) From 1 January 1985 to 31 December 1999; values listed are the local 'Richter' magnitudes; (b) From 1 January 2000 to 1 April 2005 (modified from Instituto Geográfico Nacional, Spain); MbLg is the body wave magnitude using the Lg wave (a surface wave). Note that the MbLg values in (b) are essentially equivalent to the local magnitudes in (a), suggesting that seismic intensity between these two time periods has remained constant.

The recent eruptive record, combined with the available petrological and radiometric data, provides a rather optimistic outlook on major volcanic hazards related to Teide and its rift zones, posing only very localized threats to the one million inhabitants of Tenerife and the 4.5 million annual visitors to Teide National Park.

Unrest at Teide Volcano?

The prediction of an explosive eruption in 2004 was based on reports of significantly increased earthquake activity and volcanic gas emissions. However, no major eruption followed and questions remain whether the available evidence was used in a correct and sensible way.

From 22 April to 28 July 2004, about 50 low-magnitude (M = 1–3) earthquakes were recorded in Tenerife, with most of the epicenters localized at the northwest rift zone, in the area of the Icod Valley. Only three were felt by residents. Earthquakes of this type are normal in volcanic oceanic islands (e.g., Hawaiian Islands, Reunión). In addition, low-magnitude earthquakes (generally M < 3) have been reported in all of the Canary Islands (Figure 1). In May 1998, a bigger earthquake (M = 5.3) hit Tenerife, but television and newspaper sources notified the public that the seismic activity was not hazardous, and the event was promptly forgotten. Prior to 1998, smaller earthquakes were frequently recorded throughout the archipelago, but no volcanic activity took place since the 1971 Teneguía eruption on La Palma island.

In 2004, however, the local and international mass media were bombarded with persistent reports of unrest at Teide volcano with little to no mention of more conservative views, and predictions were made of an imminent, large-scale explosive eruption that was dubbed 'El Volcán de Octubre' (the 'October Volcano'). The tourist island of Tenerife was renamed 'Terrorife' in the international press [*Christie,* 2004], and residents along the northern coast towns began sleeping fully dressed and panic-buying food and other household supplies.

Instead of providing clarifying and reassuring press communiqués, the authorities decided to raise the level of alert on the basis of a reported increase in seismicity and the emission of volcanic gases. At no time was there universally accepted scientific evidence of volcanic activity on the island, but the 'volcanic crisis' alert was officially maintained until February 2005, with frequent reports in the media of enormous emissions of volcanic gases, boiling of the island aquifer, movements of magma underneath the volcano, and impending explosive eruptions of Teide forecast for October 2004.

Was there any convincing evidence for this at all? The official institution responsible for monitoring seismic and volcanic activity in Spain—the Instituto Geográfico Nacional (IGN)—improved the seismic network of Tenerife in 2000. According to the IGN, the addition of new seismic stations immediately led to low-magnitude events within the island being recorded for the first time since surveillance work began in 1985 (Figure 1).

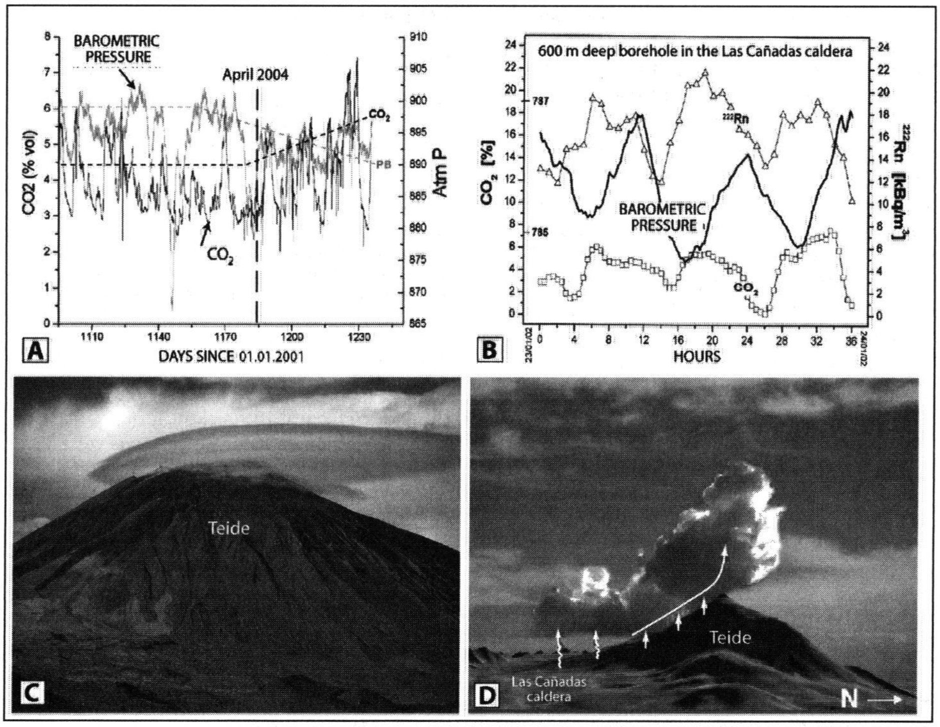

*Fig. 2. (a) Long-term variation in CO_2 emission in Tenerife [*Martín, *1999]. (b) Short-term variation of radon-222 (^{222}Rn) and carbon dioxide (CO_2) in a deep borehole in Las Cañadas caldera [from* Soler et al., *2004]. (c) Frequent spectacular 'plumes' in the summit area of Teide known locally as 'la Toca del Teide,' or 'Teide's headdress' (Photo by J. C. Carracedo). (d) Model of the formation of clouds at the summit of Teide volcano by local orographic convergence (see http://www.acanmet.org.es/menu_archivos/documentos/FTLCTeide.doc).*

The focal depths of the majority of these events were not determined as part of the routine seismic monitoring, and therefore one of the most powerful constraints in locating the source of the seismicity was lacking. An initial interpretation of the seismicity suggested dyke emplacement at a depth of three to four kilometers. However, the majority of the epicenters were located far from the rift zone, in an area in the Icod Valley that satellite interferometry has shown to have subsided by up to 10 centimeters [*Fernández et al.*, 2003]. Groundwater has been continuously and intensively extracted in this area since the 1960s, depleting the aquifer and causing the ground to sink. Microfaulting associated with the subsidence may well have caused seismicity. It is noteworthy that according to the interferometry study, this is the only area of recent ground deformation in Tenerife. The putative eruptive regions of Teide and Las Cañadas are completely stable.

But if the source of the seismicity is nonvolcanic, what about the reported enormous increase in gas emission? Continuous, real-time monitoring of gas emissions at Teide and the rifts [*Martín,* 1999] provided evidence of the nearly constant total gas emission of the volcanic system (Figure 2a). Significant diurnal and seasonal variations in gas emission rates are observed [*Soler et al.*, 2004] and linked to systematic changes in barometric pressure (Figure 2b). Therefore, if discrete measurements are taken and reported, apparent 'significant' increases in gas emissions can be obtained, which simply correspond to barometric pressure changes.

Nevertheless, a recent article [*García et al.*, 2006] insists on the reawakening of Teide based on the aforementioned seismicity and volcanic gas emissions. In support of the prediction of increasing volcanic activity, these authors have cited two apparently new features: fumaroles at the summit crater of Teide and a new fumarole inside the Orotava Valley. Spectacular 'plumes' in the summit area of Teide (known locally as 'la Toca del Teide,' or 'Teide's headdress') are caused by strong winds and other atmospheric conditions as well as by increased fumarolic activity related to barometric pressure changes, and have frequently been cited over the centuries in ships' logs (Figures 2c and 2d). The new 'fumarole' of the Orotava Valley, in turn, which gave a clear meteoric water isotopic signature, is located 50 meters from an unlined 40-meter-deep well used for the disposal of high-temperature wastes from a nearby cheese factory, suggesting a rather more simple explanation for the origin of this particular vapor exhalation site [*Carracedo et al.*, 2006].

It would thus seem that the prediction of an imminent volcanic eruption at Teide was and is lacking hard scientific evidence, and its dramatic presentation by the media was not only unnecessarily damaging to the tourism-based economy of the island industry, but also caused undue anxiety and hardships for citizens coping with the alarmist forecasts (Note, none of the authors is in any form associated with the tourism industry anywhere).

Effective and reliable communications must be established among scientists, government officials, the news media, and the populace affected, and must be tried and tested before an actual crisis. This is an essential step in restoring the credibility of the scientists and civil authorities, so that they, working together, will be much better positioned to respond adequately to a potential genuine volcanic crisis at Teide.

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NEWS

Refocusing NASA Planetary Science Funding

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NASA should invest more money in data analysis for its planetary science missions, even if it means delaying or canceling a future mission, members of the science committee of the NASA Advisory Council (NAC) suggested at a 12 October meeting.

Science committee member Mark Robinson, director of the Center for Planetary Sciences at Northwestern University in Chicago, Ill., said that large amounts of data from NASA planetary science missions are accumulating, and the funds for data analysis often are inadequate to properly analyze all of it. For example, there is a large amount of currently unanalyzed Mars data that could be used in planning for the Mars Science Laboratory (expected to launch in 2009), and particularly for site selection. This includes data from the recently arrived Mars Reconnaissance Orbiter, which is likely to send more data to Earth in its first year than has been collected by all previous Mars missions combined.

Science committee member Alan Stern, executive director of the Space Science and Engineering Division of the Southwest Research Institute in San Antonio, Tex., explained that missions need to have more research and analysis (R&A) funds attached to them from the beginning. As a comparison, in the field of astrophysics, researchers who are awarded observing time with the Hubble Space Telescope also are provided funds for analyzing the data and publishing results. In planetary missions, the data usually are certified and archived, but very little of it is properly analyzed and transformed into scientific results, he said.

"This is really an issue of getting our value for the dollar. We spend hundreds of millions, sometimes billions, [of dollars] on these planetary missions, and very little of the data is ever looked at," Stern said. "I think that it is the sense of the planetary [science] community that skipping a future mission to solve this problem would be worth it," he said.

Mary Cleave, associate administrator for NASA's Science Mission Directorate, said that the agency has been trying to maintain an opportunity for launching a mission to Mars every 26 months. The agency could skip one of these launch opportunities and put more money into R&A, but it needs guidance from the NAC, she said.

NAC Chair Harrison Schmidtt asked Robinson to draw up a formal recommendation emphasizing the need for NASA to provide funds for data analysis for these missions. The council could consider the recommendation at its next meeting in February 2007.

Another issue that could be addressed by the NAC in February, following initial discussion at the October meeting, is the future availability of rockets for small- and medium-sized science missions.

Science committee member Neil DeGrasse Tyson, director of the Hayden Planetarium at the American Museum of Natural History in New York, N.Y., noted that the marketplace for these rockets has diminished, and that this could threaten the ability of NASA to obtain them on time and in needed quantities. He suggested that the NASA administrator should discuss with other federal agencies the potential for using other types of rockets as launch vehicles for NASA science missions.

Science Committee Chair Edward David, Jr., president of EED, Inc., and a former presidential science advisor, said that "it is important that the whole NAC continues to monitor the situation and make suggestions how to address the shortage of access." Schmidtt noted that there are many other potential launch systems available and in use by other federal agencies, particularly the U.S. Department of Defense.

David also told the NAC that the science committee needed a member with expertise in Earth science, citing the departure of former committee chair Charles Kennel. Schmidtt said that he hoped such an appointment would be made by the NASA administrator within the next few weeks. Kennel was one of three science committee members who resigned in August and were replaced the next month (see *Eos 87*(40), 2006).

—SARAH ZIELINSKI, Staff Writer