

# Volcanic hazards

## Hazard, vulnerability and risk assessment

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It is estimated that more than 500 million people, mostly within the developing world, live under the threat of hazards posed by volcanoes. The potential therefore exists for major loss of life and damage to property and infrastructure, especially where large urban areas occur in proximity to dangerous volcanoes. As population pressures intensify, hazardous areas are likely to become increasingly developed, so raising the level of risk.

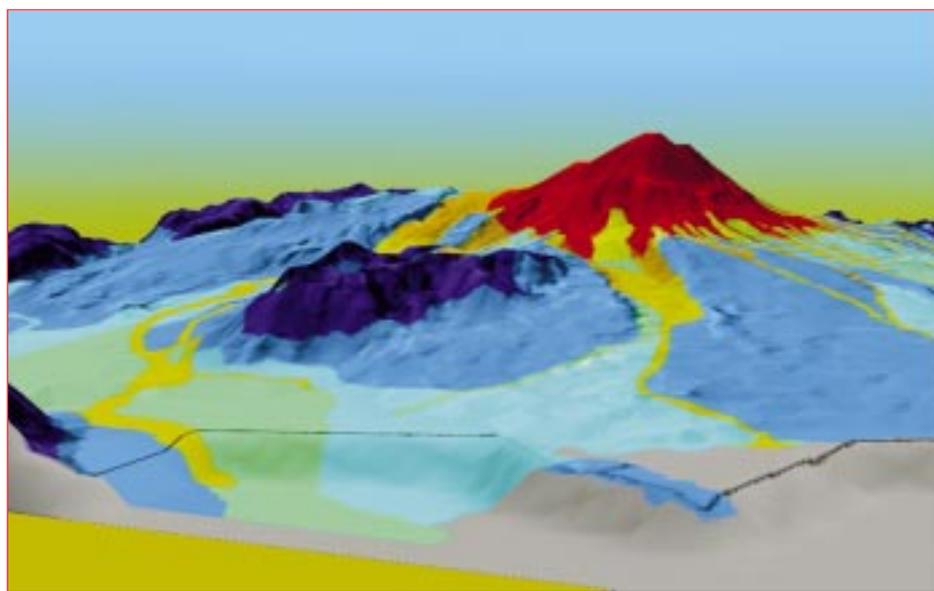
Volcanic eruptions produce a number of different hazards, including lavas, pyroclastic falls, pyroclastic flows, pyroclastic surges, lateral blasts, debris avalanches, volcanogenic tsunamis, mudflows and floods and gases. A basic premiss of volcanic hazard assessment is that hazard impact is generally related to the size of the eruption and proximity to the volcano. There are exceptions to this rule, as exemplified by a number of snow-capped Andean volcanoes that produce catastrophic floods and mudflows which have on several occasions devastated distant urban areas. Such a catastrophe befell the Colombian city of Amaro in 1985, where 24,000 people were killed by mudflows generated by a relatively small eruption which partly melted the summit ice cap of Nevado del Ruiz, some 50 km from the city. Whilst such dramatic volcanic disasters are well-publicised, even relatively benign activity such as prolonged periods of degassing and light ashing can have substantial adverse effects. Studies undertaken by the BGS of Volcán Irazú near the Costa Rican capital of San José indicate that a prolonged but relatively small eruption in 1963–65 caused health problems, and resulted in a marked reduction in GDP despite increased

prices for the country's principle export commodities.

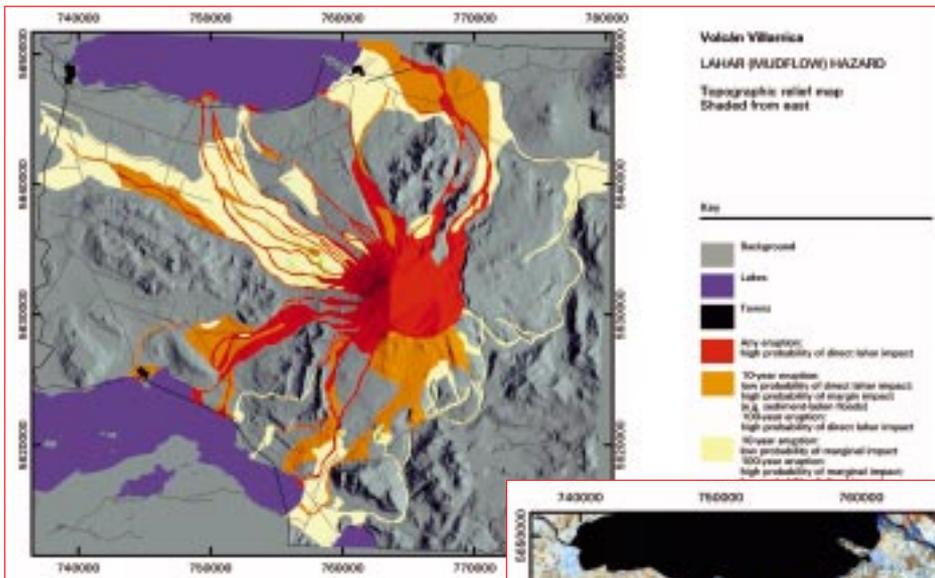
As with other natural hazards, the level of volcanic risk may be reduced by disaster prevention, preparedness and emergency response measures. Hazard assessment underpins all of these activities and is fundamental to sound land-use planning, which offers the most effective means of reducing volcanic risk in the longer term. As part of the United Kingdom's contribution to the United Nation's International Decade for Natural Disaster Reduction (IDNDR), the BGS was commissioned by the Department for International Development (DFID) to investigate the role of volcanic hazard maps in development planning and to develop a methodology for the rapid production of first-pass hazard maps.

Volcanic hazard assessments are generally based upon the assumption that the future activity of a volcano will be similar to past activity, in terms of style, size and frequency of eruption. Such information on past activity may be obtained from historical records, and from the examination, interpretation and dating of ancient deposits which permit the elucidation of a volcano's evolution. Reconnaissance survey methods, including photogeological interpretation and satellite image analysis have been applied by the BGS to a number of volcanoes in Chile and Costa Rica and have been shown to be effective for the rapid production of first-pass volcanic hazard maps. Combined with GIS-based digital techniques, such hazard maps may be presented in forms more easily visualised and understood by non-geoscientists involved in the downstream activities of volcanic risk reduction.

Experience from past volcanic crises and disasters has shown that problems exist in the uptake and utilisation of volcanic hazard information by civil authorities. To improve this interface non-geoscientists need to be involved in the process of hazard assessment and should be educated in the nature and effects of the hazards. As described above, better visual presentation methods for hazard maps are also advantageous, although probably the most effective means of communicating the potential impact of volcanic eruptions



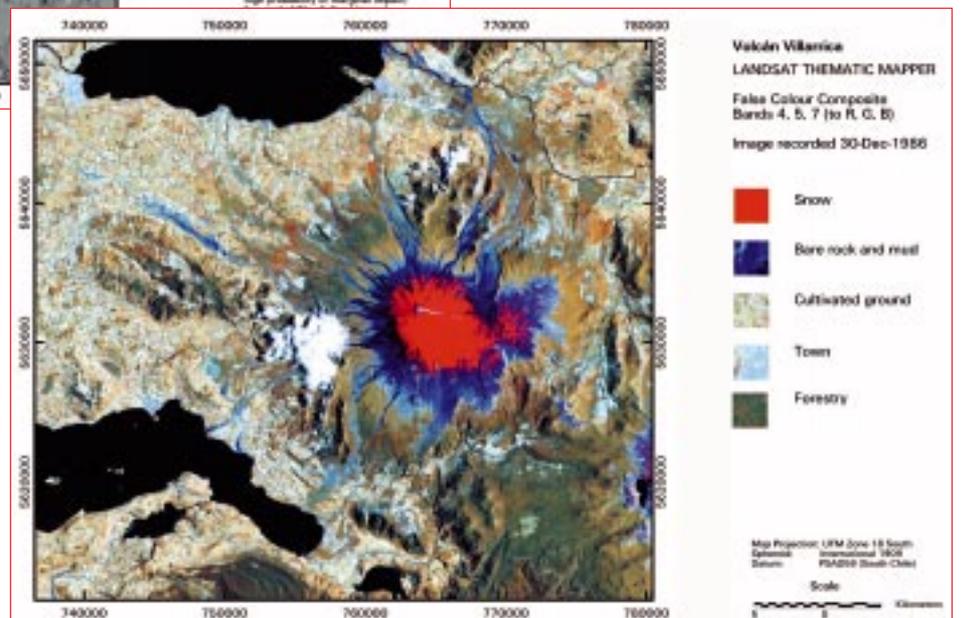
Example of a hazard map of Volcán Villarrica, Chile, draped over a perspective view of the volcano.



Left: Lahar hazard zones for Volcán Villarrica, presented on a shaded relief map to aid visual interpretation. The probability of impact varies from high (red) to low (yellow). Grey areas are not affected by the hazard.

Below: Landsat image of Volcán Villarrica and surrounding area. Lakes appear black and snow red. The white streak over the summit is due to sensor overload by heat from the lava-filled crater.

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is to incorporate information within risk maps. These offer distinct advantages over hazard maps, by providing more meaningful or tangible indications of the losses that may arise as a consequence of volcanic activity. Such losses may be expressed in economic terms or as human casualties, and are useful in demonstrating the need for, and the cost benefits of, hazard mitigation, including long-term planning, volcano monitoring, and civil defence measures.

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In order to quantify risk, it is necessary to undertake vulnerability assessments. Vulnerability may be defined as the degree of loss to a given element or group of elements, such as people, property or economic activity, resulting from the occurrence of a hazard of a given magnitude, and expressed on a scale from 0 (no damage) to 1 (total loss). Vulnerability may be assessed empirically or analytically. The empirical approach assesses vulnerability by examining the adverse impacts of hazardous volcanic phenomena during previous disasters. The analytical approach is particularly applicable to assessing the built environment, by

looking at the materials and designs used in construction and calculating the effects and failure rates of structures in response to physical conditions likely to be experienced during eruptions. Both of these approaches have been used to assess the vulnerability of buildings in the BGS study of Volcán Irazú and the methodologies were later applied to estimate the risk to buildings during the recent volcanic emergency on Montserrat.

Volcanic risk for a given hazard zone and specified period of time may be estimated as:

$$\text{vulnerability} \times \text{hazard probability} \times \text{value of the element at risk.}$$

Value may be expressed either as numbers of people or in monetary terms in the case of constructions or economic activity. In theory this is a relatively simple process, although in practice it

involves a great deal of laborious data gathering. As a result, very few volcanic risk assessments have been undertaken, and those that have been attempted have been restricted to the risks imposed by selected volcanic hazards on specific elements, such as estimates of human casualties or numbers of collapsed roofs due to ash-loading. Nevertheless, specific risk assessments of such key elements are sufficient to act as indices which demonstrate to planners and politicians in understandable terms the impacts that might be expected and how these may be mitigated within the framework of land-use planning. Whilst it has been demonstrated that the methods exist for producing effective and cost-beneficial hazard and risk assessments, the greatest challenge remains to convince politicians and administrators that such assessments are worth putting into action in the first place.