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Complex feedback between volcano-tectonics and cyclic eruptive activity: the case of Mount Etna, Italy

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Mount Etna is among the few volcanoes on Earth that erupt nearly continuously, but its activity (in terms of output rate and flank eruption frequency) undergoes significant fluctuations in time. Such fluctuations do not occur in a random manner but represent various stages of eruptive cycles on a scale of decades and centuries. Short-term cycles last 20-40 years and consist of three distinct phases: (I) a period of repose; (II) a period of summit activity; (III) a series of flank eruptions that occur at intervals of a few years, with frequent summit activity during the intervals between flank eruptions. Long-term cycles extend over many centuries and show a similar evolution from low to high level activity but are less completely documented due to an incomplete eruption record before 1600. The culminating phases of the two most recent long-term cycles probably occurred between ˜950 and ˜1050 A.D. and between 1600 and 1669. Here we present a model which explains the short-term cyclic behavior with the repetitive draining and recharging of a complex system of magma storage areas below the volcanic edifice. The output is low after draining of the system by one or more voluminous flank eruptions and during the initial period of recharging, but gradually increases as the system grows both laterally and vertically. For example, the system is presently expanding, as is evident from the clear increase in the output rate of Etna and more frequent and voluminous flank eruptions during the past 55 years. The 2001, 2002-2003 and 2004-2005 flank eruptions were probably only the first three in a new series of possibly up to 10 or more events that will occur at intervals of a few years. The timing and frequency of flank eruptions seems to be related to the instability of the eastern to southern sector of Etna, which is expressed in episodic slippage of portions of the unstable sector. During such events, displacement on a scale varying from centime-

ters to meters affects one or more distinct slide blocks, commonly accompanied by shallow seismicity along the faults confining the slide blocks (e.g., the Pernicana and Ragalna Fault Systems, the S. Venerina and Mascalucia-Trecastagni faults). Since the beginning of monitoring of the Pernicana Fault System in the early 1980s, flank slip episodes have commonly preceded flank eruptions by several hours to a few months. The most spectacular of these cases occurred in September-October 2002 when flank slip along the Pernicana started five weeks before a destructive eruption on both the northeast and south flanks of the volcano; multidisciplinary evidence shows that this eruption was directly triggered by a dramatic acceleration of flank slippage on 26-27 October 2002. Similarly, the 2004-2005 eruption was preceded by another, less dramatic yet important flank slip event. We thus envisage the following scenario for a feedback mechanism between magma accumulation, flank instability and slippage, and eruptions: (a) magma accumulation occurs about 5 km below the sea level, about the same depth as the presumed basal décollement plane of the unstable, slipping flank sector, causing inflation of the volcanic edifice; (b) the swelling of the volcanic edifice leads to the destabilization (at first slow spreading and fault creep, followed by instantaneous flank slip accompanied by shallow seismicity) of the un-buttressed eastern to southern sector of the volcano; (c) extension at the head of the active slide block(s) permits magma migration from the central conduit system and/or shallow eccentric reservoirs into radial flank fracture systems, leading to flank eruption. The observed patterns in the eruptive history of Etna seems therefore to be controlled by two main processes: the long and short-term cycles are probably influenced by regional variations in the deeper magmatic supply, whereas the shorter term cycles involve a much more effective interaction with the shallow structure of the volcano and its unstable portions.