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Effect of lateral spreading on magma depressurization and volcanic gas release at Mt. Etna after the 2001 eruption

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During the period 2001-2005, Etna produced numerous paroxysmal episodes from South-East Crater (first 6 months of 2001) and three flank eruptions (2001, 2002-03 and 2004-05). On occasion of the 2001 and 2002-03 eruptions, two different types of magma were erupted from two distinct magmatic feeder systems: one linked to the central conduit and the other from an eccentric conduit. Unusually strong explosive activity at the eccentric vents indicated exceptionally high volatile contents in the emitted magma. The peculiar eruptive style described above matches a period of increased structural instability of the volcanic body caused by the acceleration of spreading affecting the eastern to southern flanks. Slow (<1 cm/yr) aseismic spreading had occurred starting from 1994. Continued and ever increasing deformation is indicated by the moderate seismicity on the E and S flanks before September 2002. A major abrupt acceleration of instability-induced flank slip occurred in October 2002, probably playing an important role in triggering the 2002-2003 eruption, namely the passive uprise of magma in response to flank sliding. A similar mechanism could explain the 2004-2005 eruption. In fact, the dynamics of the 2004-2005 eruption, together with the structural, petrological and volcanological data, demonstrate that magmatic overpressure played a negligible role in its trigger. Near-daily data on crater SO_2 fluxes from Mt Etna, coupled with soil CO_2 fluxes from two high emission sites on the volcano flanks, were analyzed in the period 2001-2005. During the inter-eruptive periods between the 2001 and 2002-2003 eruptions, persistently low values of both crater SO_2 fluxes and soil CO_2 fluxes from the upper flanks of the volcano were recorded. This suggests that new gas-rich magma was not accumulating, at least in significant amounts, at shallow depth (< 5 km) within Etna's central conduit. In August 2003,

a higher rate of crater SO_2 fluxes was observed, and in November 2003 an evident change in the behavior of soil CO_2 fluxes suggests migration of gas-rich magma from deep ($>$ 10 km) to shallow ($<$ 5 km) portions of Etna's feeding conduits. A similar sequence of events was also observed after the onset of the 2004-2005 eruption and until a few months after the end of that eruption. This degassing style is apparently in contrast to what was observed before the 2001 lateral eruption of Mt. Etna (i.e., increases of soil CO_2 emissions preceded increases in crater SO_2 fluxes) and seems to indicate a correlation both with the change in eruptive style and, therefore, with the increased spreading of the volcanic edifice. A new model is therefore proposed: significant spreading would cause progressively deeper depressurization in the central conduit, because of the propagation of huge crustal fracturing at ever increasing depth underneath the volcano. Consequently, magma would be subject to passive migration into shallower portions of Etna's plumbing system. Depressurization from shallower to deeper portions of Etna's feeder system would also determine firstly the increase in the release of the volcanic gas species with shallower exsolution depth (SO_2), followed by that of the gas species with deeper exsolution depth (CO_2). During this phase, any magma previously stored in the uppermost portion of the main conduit would easily be passively erupted, as in the case of both the 2002-2003 and of the 2004-2005 eruptions. If depressurization propagates down to the magma storage level located at $>$ 10 km depth, it would cause its replenishment with new gas-rich magma coming from the magma source. If this model is correct, it could describe a significant change in the known dynamics of magma ascent and storage within the volcano. This implies a new element of complexity in the framework of Mount Etna activity that must be taken into account when drawing future scenarios for the assessment of volcanic hazard.