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# Shallow and deeper deformation on the eastern flank of Etna from 2001 to 2006

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Flank instability is a common feature at several volcanoes in the world, in most cases directly related to volcanic activity. A magmatic dike intrusion can initiate, amplify and sustain volcano flank failures and collapses. Mt. Etna was affected in the past by a giant lateral collapse and is currently characterized by continuous sliding of the eastern to southern flank that produces extension on the upper part of the volcano, facilitating shallow intrusions and which, in turn, is accelerated by magma intrusions. The eastern flank of the volcano shows a continuous and fairly constant seaward motion, detected by InSAR and GPS data and modelled as a large-scale sliding involving the volcanic pile together with the upper part of the sedimentary substratum. From July 12 2001, Mt. Etna experienced a pronounced increase in seismic activity heralding one of the most intense eruptions of the past 30 years, which started on July 17. The temporal and spatial distribution of seismicity clearly indicates a weakened volume of rock that was intercepted by the uprising magma and that significantly conditioned its upward path, driving it westwards. A GPS survey, carried out when eruptive fractures were opening on the southern flank of the volcano, revealed that a NNW-SSE structure decoupled a triangular “slice” on the southern flank, allowing it to slide southward. From July 25 to 27 2001, the deformation induced by the dyke intrusion propagated south-eastward and also the upper south-eastern sector of the volcano started to slide south-eastward; the NNW-SSE fault changed its kinematics to right-lateral, as revealed by semi-kinematic GPS measurements. On the lower eastern flank, the ground deformation continued to propagate downwards, causing the failure of the NNW-SSE Timpe fault system about three months after the dyke intrusion. The seismicity and ground deformation data suggest that the stress induced on the eastern flank by the intrusion was cumulated at lower altitude until the Timpe seismically released the energy

allowing the sliding motion to propagate further eastwards. From October 2001, a strong increase of seismic strain release is evident on eastern flank. The earthquakes located along the NW-SE trending system show right-lateral kinematics indicating that the deformation propagated northwards, marking an acceleration of the sliding of the northernmost sector. The strain release on the north-eastern flank culminated with a seismic swarm on the Pernicana fault, with a main shock of M=3.7 on September 22nd, 2002. Ground deformation was too big (either in intensity and extension) for an M=3.7 earthquake, which may be interpreted as an effect of a continuous motion of the north-eastern sector that cumulated the stress along a locked segment of the Pernicana fault. The 22 September earthquake practically marks the unlocking of this sector of the volcano that began to slide eastward more rapidly, later allowing the intrusion from the summit craters along the NE rift. This extension allowed a partly passive intrusion of magma at least on the upper half of the NE rift, while on the lower part the intrusion was forceful, pushing the north-eastern flank of the volcano further eastward. The 2002 eruption, even if in part favoured by the acceleration of the sliding motion induced by the 2001 peripheral intrusion, gave another input of stress to the north-eastern flank that started to move seaward along the Pernicana fault with an initial rate of about 6 - 9 cm/day, rapidly decreasing to reach 1 cm/day after 1 month as measured by GPS. During the first phase of the 2002 eruption, a seismic swarm affected the S. Venerina fault, testifying how the north-eastern sector of the volcano continued to slide at unusually high velocity. About one month later, a seismic swarm affected the Trecastagni fault, testifying how the deformation was moving back southwards as though it were “reflected” by the Pernicana fault. During 2003 and 2004 the sliding rate of the eastern flank decreased with respect to the eruptive periods but remained significantly high if compared to the values recorded before the 2001 eruption. This phenomenon caused an exceptionally high extension on the upper part of the volcano producing the “silent” opening of tensile fractures that favoured the passive intrusion of previously degassed magma, which fed the purely effusive lateral 2004-2005 eruption. Eruptive activity resumed in the second half of 2006, with effusive-Strombolian phenomena affecting the South-East Crater characterized by the opening of fractures partially linked to the same extension process affecting the summit of Etna.