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Post-diking deformation in Harrat Lunayyir (Saudi Arabia) from InSAR

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Magmatic intrusions often produce ground deformation that can be studied by geodetic techniques. In the past two decades, many volcanic dike and sill emplacements (sometimes associated to eruptions) in different tectonic settings have been analyzed through InSAR. However, in only a few cases, the post-intrusive behavior has been studied. Here we analyze the post-diking deformation in Harrat Lunayyir, which is a mononogenetic volcanic field located in western Saudi Arabia on the eastern margin of the Red Sea Rift.

Between April and July 2009, an intensive seismic swarm occurred in the area with many earthquakes above magnitude 4 and the largest earthquake of M_w 5.7. InSAR data showed that the earthquake swarm was triggered by the emplacement of a dike intrusion that stopped only ~1 km below the surface. Dike length was estimated to be ~7 km and with a maximum opening 4 m. Above the intrusion, a ~10 km long and ~5 km wide graben formed during the activity with up to 1 m of fault slip on the border faults. In the post diking phase up to present, micro-sesmicity (0<Ml<3.5) has been continuously registered in the graben region gradually fading out either in terms of earthquake rate and energy release.

In February 2017, a new seismic swarm occurred ~60 km north of Harrat Lunayyir and another swarm started in October 2018, about 30 km southwest of the volcanic field. Both swarms are still ongoing with a few events per week and M_l<3.5. By using Sentinel-1 images, acquired during the period 2015-2019, we derived deformation rate maps for the entire Harrat Lunayyir volcanic field. No ground deformation was detected at the locations of the recent seismic swarms, and a thorough analysis of seismic signals excludes the swarms were caused by new magmatic intrusions. However, within the Harrat Lunayyir graben region, we noticed a steady and long-lasting subsidence of ~1 mm/yr. During the 2015-2019 period, the total seismic moment release would only be able to accommodate less than 0.1 mm of the observed subsidence and thus the current post-diking deformation is mainly aseismic.

In order to reconstruct the entire post-diking deformation history in Harrat Lunayyir we also analyze older available SAR images (Envisat, ALOS, TerraSAR-X, TanDEM-X). Our preliminary results show that the subsidence rate in the graben area was faster just after the intrusion (few cm in two months) but then rapidly decayed as well as the seismicity. We are now investigating different

processes that can cause post-diking deformation, such as residual opening of the dike, post-diking settlement of faults and fractures, release of gases into fractures, cooling of the dike, and post-diking viscoelastic relaxation. Modelling of the deformation source will contribute to the understanding on which of these post-diking processes might be the dominant one in Harrat Lunayyir.