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Assessing Volcanic Hazard of a Quaternary Lava Field in the Kingdom of Saudi Arabia

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Al-Madinah Quaternary lava field (Harrat), a part of a vast Cenozoic monogenetic volcanic field in western Saudi Arabia, is immediately contiguous to the southern, eastern, and western boundaries of the major Saudi city of Al-Madinah. The Harrat comprises seven episodes of Quaternary volcanicity of basaltic flows and associated scoria cones, as well as minor salic volcanic activity. Two volcanic eruptions only ∼600 years apart occurred close to the City, and their flows reached the current city bounds. The youngest of these erupted only ∼750 years ago and was preceded by a swarm of felt seismicity, the strongest of which was estimated to be of magnitude ∼5. The City is currently expanding right into the Harrat, exposing it to a significant volcanic risk and warranting a comprehensive assessment of volcanic hazard. To this end, long-term volcanic hazard forecasting in Harrat Al-Madinah was carried based on vent count and structural alignment of scoria cones determined guided by aeromagnetic data. These were probabilistically treated based on a non-homogeneous Poisson process, and spatial recurrence was obtained using a Gaussian kernel. The results indicated an area of high volcanic potential only ∼12Km southeast of the City. The probability of lava invasion subsequently estimated using Monte Carlo simulation further emphasized the volcanic vulnerability of the southeastern parts of the City. The proposed extension of the City into the Harrat is thus expected to be even more volcanically vulnerable. Further, based on a vent count of ∼500 Quaternary vents, an average temporal recurrence rate of 3.4x10-6 event/year was deduced, falling within the range of average recurrence rates of monogenetic volcanic fields of the world. This recurrence, however, was deemed to only represent the lower bound of expected recurrence in the Harrat due to the presence of buried cones not included in the count process. This indication was supported by drilling and published interpretations of aeromagnetic data, as well as by the results of recent passive seismic investigations carried within the Harrat specifically for that purpose. A similar treatment was applied to Harrat Al-Shaqah, the scene of the 2009 volcanic unrest and seismicity, to the northeast of Harrat Al-Madinah to validate the forecasting approach. The results were in good agreement with the recorded seismicity, the observed seismically-induced ground rupture, and the InSAR-inferred ground deformation, indicating the robustness of the forecasting approach applied to Harrat Al-Madinah.