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Re-assessment of the geological evolution and associated hazards of Merapi Volcano

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Merapi, a persistently active basalt to basaltic andesite volcanic complex in Central Java (Indonesia), is often referred to as the type volcano for small-volume pyroclastic flows generated by gravitational lava dome failures (Merapi-type nuées ardentes). Stratigraphic field data, published radiocarbon ages in conjunction with a new set of 40K-40Ar and 40Ar-39Ar ages, and whole-rock geochemical data allow a re-assessment of the geological and geochemical evolution of the volcanic complex. An adapted version of the published geological map of Merapi is presented, in which eight main volcano-stratigraphic units are distinguished, linked to three main evolutionary stages of the volcanic complex – Primordial Merapi, Old Merapi and New Merapi. The radiocarbon record points towards an almost continuous activity of Merapi since this time, with periods of high eruption frequency interrupted by shorter intervals characterised by of lower eruption rates, which is reflected in variations in the geochemical composition of the eruptive products. The Holocene stratigraphic record reveals that fountain-collapse pyroclastic flows are a common phenomenon at Merapi. The distribution and runout distances of these flows have frequently exceeded those of the classic Merapi-type nuées ardentes of the recent activity. Widespread pumiceous fallout deposits testify the occurrence of moderate to large (subplinian) eruptions (VEI 3-4) during the mid to late Holocene. VEI 4 eruptions, as identified in the stratigraphic record, are an order of magnitude larger than any recorded historical eruption of Merapi, except for, possibly, the 1872 and 2010 events. Both types of eruptive and volcanic phenomena require careful consideration in long-term hazard assessment at Merapi. Recent advances have been made in creating computational models of pyroclastic density currents for the purpose of hazard mitigation but there is an urgent need to test these models against well constrained filed examples. The latest events at Merapi present a rare opportunity to examine the influence of various digital representations of natural terrain on the behavior of numerical models through a detailed collection of key data that characterize their input parameters. Sensitivity analyses and inundation maps based on the probability of impact were used to produce a suite of potentially inundated areas from future events affecting the southern flank of the volcano. Our results provide the basis for defining hazard zonations of key areas at risk from future eruptions at Merapi.