Abstract

Small-scale volcanoes represent diverse group of landforms which vary in morphology, morphometry, and mechanisms of their formation. They are the most common volcanic form on Earth, and their existence and basic characteristics were also predicted for Mars. Availability of high-resolution image data now allows to search, identify and interpret such small volcanic features on the martian surface. This thesis extends our knowledge about the small-scale volcanoes with the following objectives: (a) to document the existence of martian analogues to some of the terrestrial volcanoes, in particular scoria cones, tuff cones, tuff rings and lava domes; (b) to establish their morphological and morphometrical parameters; and (c) to examine the effect of environmental factors, which differ on Earth and Mars, on the mechanisms of formation of the scoria cones.

Interpretation of remote sensing images and digital elevation models reveals that scoria cones, tuff rings and cones, and lava domes exist on different parts of the martian surface and, in some cases, far away from previously well-known volcanic provinces. Scoria cones have been identified in the volcanic field Ulysses Colles situated within the Tharsis volcanic province; tuff cones and tuff rings have been found in the Nephenthes/Amenthes region at the southern margin of the ancient impact basin Utopia, north of Isidis Planitia in the Arena Colles region and within an impact crater Lederberg in Xanthe Terra, and lava domes were located within an unnamed depression in Terra Sirenum. These findings document volcanic processes responsible for such diversity: the scoria cones prove the presence of explosive basaltic volcanic activity on Mars and formed in response to variations in magma volatile content over the geological history; the tuff rings and tuff cones provide evidence for the presence of (sub)surface water and/or water ice in the martian history; the lava domes record much larger variations in magma viscosity than previously interpreted.

In addition, the shapes of small-scale explosive volcanoes (scoria cones, tuff cones and tuff rings) reveal the effect of environmental setting such as the gravity field and atmospheric pressure as a significant factor affecting the physics of volcanic eruptions and causing the differences from their terrestrial analogues. Most of the scoria cones show larger volumes of ejected material, larger heights, and lower average slopes (rarely exceeding 30°) than their terrestrial counterparts. This is due to the lower gravity and atmospheric pressure on Mars which allow the ejected particles to be spread over a larger area than on Earth. As the volumes of erupted material are typically low, flank slopes do not reach the angle of repose – a common situation on Earth. This suggests only a minor role of avalanche redistribution during growth of martian scoria cones and permits their growth to be numerically tracked by modelling the ballistic trajectories and recording the cumulative deposition of repeatedly ejected particles. The ejected particles are about twenty times finer (about 2 mm) and ejected by a factor of two faster (~92 m/s) than on Earth.

The results indicate that small-scale volcanoes on Mars have wide spatial extent and diverse shapes. This extends our knowledge on the volcanological diversity of Mars and underlines the differences driven by local physical and environmental factors.