DO ALL ROCKY PLANETS UNDERGO EARLY DEVELOPMENT OF LARGE VOLCANIC OUTFLOW CHANNELS?

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The vestiges of large volcanic outflow channels are preserved at the surfaces of several bodies of the inner solar system. The largest lunar outflow systems are characterized by channel widths of up to 10 km and lengths of up to hundreds of kilometers, with the largest systems including Vallis Schroteri, Rimae Aristarchus, Rimae Prinz, and Rima Brayley. Hadley Rille, a lunar channel with widths of up to ~3 km, was visited by the Apollo 15 astronauts and confirmed as a past conduit for the flow of low-viscosity lavas of mafic composition. On Venus, the largest outflow channels include the 1200-km-long Kallistos Vallis system, located east of Lavinia Planitia, and an especially complex system of anastamosing channels and streamlined erosional residuals located near Ozza Mons, in easternmost Aphrodite Terra. Large volcanic outflow systems have recently been discovered on Mercury (Head et al., 2011, Science, Vol.333), and include a 25-km-wide channel formed during emplacement of flood basalts across landscapes of that planet's high northern latitudes. Lunar, Venusian, and Mercurian outflow systems typically head at ridged plains or zones of disturbance that mark sites of voluminous effusion of lava, and many such systems are characterized by features such as channel terraces and complex anastamosing reaches. All systems terminate at basins mantled by extensive volcanic flows. The best preserved of these systems show evidence for having developed as a result of thermal or mechanical erosion by low-viscosity lava under dry conditions. Though the outflow channels of Mars are widely interpreted as the product of aqueous processes involving catastrophic flow from aquifers, the excellent correspondence between properties of these systems and those of volcanic outflow systems strongly suggests common volcanic origins (Leverington, 2011, Geomorphology, Vol.132). Ongoing photogeological work, partly involving analysis of HiRISE and CTX images of Mars and LROC images of the Moon, further supports the interpretation of Martian outflow channels as direct analogs to volcanic systems of the Moon, Venus, and Mercury. Consistent with the past results of several research groups, development of large outflow channels in the inner solar system is predicted to have required voluminous magma sources stranded at subcrustal depths, within the uppermost parts of planetary mantles. Though there are few constraints on the absolute ages of Venusian outflow systems, formation of lunar, Martian, and Mercurian systems appears to have peaked during the early histories of these bodies, between ~4.0 and 3.0 Ga. The basic nature of these systems has potential significance regarding our understanding of terrestrial geology, with a volcanic origin for the outflow channels of the Moon, Venus, Mercury, and Mars suggesting the possible development of similarly large volcanic outflow systems on the Earth in the Hadean or Archean. More generally, these considerations suggest a possible predisposition of all rocky planets for development of large volcanic channels in their early or middle histories, offering a potentially important mechanism for the dissipation of heat accumulated through processes of accretion, differentiation, and radioactive decay.