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Mantle plume volcanism on present-day Mars

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Geologically recent volcanism has occurred on Mars, as demonstrated both by low impact crater densities on some lava flows and by the radiometric ages of shergottites, which are igneous meteorites from Mars. Adiabatic decompression melting in hot, upwelling mantle plumes can explain the roughly point-source nature of individual large volcanos, such as Olympus Mons. We model these plumes using finite element methods in spherical axisymmetric geometry. The simulations include temperature-dependent rheology, partitioning of radioactivity between mantle and crust, and the effects of moderate amounts of water. We test our results using the recent volcanism rate from geologic mapping, the partial melt fraction from trace element studies of the shergottites, the near-surface heat flux obtained from gravity models and the upper bound on core-mantle heat flux derived from the absence of a magnetic dynamo. The plume model is consistent with these constraints. Because of the temperature-dependent rheology, the mantle convects in the stagnant lid regime. The thick lithosphere limits the amount of adiabatic decompression melting that is possible on Mars. However, the shergottites suggest that the mantle of Mars is richer in Na and Fe relative to Earth. This lowers the solidus temperature on Mars, which can increase the magma production rate by a factor of three or more relative to models that assume Earth and Mars have the same mantle composition. Small amounts of water, up to a few hundred ppm, may also be important in controlling the Mars mantle solidus. Models with a volume-averaged thermal Rayleigh number in the range 10ˆ6 to 10ˆ7 can successfully explain the volcanic resurfacing rate observed for the geologically recent past on Mars. The Rayleigh number is a measure of convective vigor, and these values imply that mantle convection remains moderately vigorous on present-day Mars. In the stagnant lid convection regime, there is only a small temperature difference between the mantle and core. This implies that the heat flux out of the core is sufficiently

low to avoid generation of a magnetic dynamo, in agreement with observations.