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Provision of noble gases to Venus atmosphere from comets and volcanoes: constraints from Venus Express data

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In light of new data from Venus Express providing more detailed profiles of the variation in concentration of major and minor constituents with depth in Venus' atmosphere, we readdress the issue of the source of noble gases and minor constituent volatiles in Venus' atmosphere. We re-examine two hypotheses that have already been proposed for the sources of the noble gases: cometary impact and volcanic activity. In order to test the plausibility of the first source, we collect from the literature and analyse data (of both comet and atmosphere composition) from many studies including those that utilise recent spacecraft missions that have sampled comets directly, such as Stardust and Deep Impact. Where data is unavailable for some noble gas concentrations of comets, we estimate the likely concentrations inferred from the noble gas data that is available. For the volcanic hypothesis, we model the delivery of noble gases through volcanism and estimate the required rate of volcanic activity to produce the near-surface abundances of noble gases and other constituents as observed by instruments on board Venus Express. For both sources, we find the upper limit on the required rate of source activity assuming that only one of the sources is active. We envisage that the most likely situation in reality is a combination of the two sources, with the proportion of delivery from each source being between the two calculated extremes. The results could have implications for comet formation because we test whether the noble gas abundances in Venus' atmosphere are consistent with the noble gases of comets condensing at very low temperatures, or else being trapped as clathrates, or else inconsistent with either hypothesis, in which case comets would probably not have been a major source of gases for Venus. The calculated upper limit on the rate of volcanic activity may have significant implications for the geological evolution of the planet.