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Contributions of Volatiles to the Venus Atmosphere from the Observed Extrusive Volcanic Record: Implications for the History of the Venus Atmosphere

James Head[1], Lionel Wilson[2], Mikhail Ivanov[3], and Robin Wordsworth[4]
[1]Dept. of Earth, Environmental and Planetary Sciences, Brown University, Providence,RI USA (james_head@brown.edu)
[2]Earth and Planetary Sciences, Lancaster University, Lancaster, UK (l.wilson@lancaster.ac.uk)
[3]Vernadsky Institute, Moscow, Russia (mikhail_ivanov@brown.edu)
[4]Dept. of Earth and Planetary Sciences, Harvard University, Cambridge, MA USA (rwordsworth@seas.harvard.edu)

One of the most important questions in planetary science is the origin of the current Venus atmosphere, its relationship and coupling to Venus' geologic and geodynamic evolution, andwhy it is so different from that of the Earth. We specifically address the following question:Does the eruption of the total volume of extrusive volcanic deposits observed in the exposed geologic record of Venus contribute significantly to the current atmosphere through volatile release during emplacement of the extruded lavas? To address this question, we used the observed geologic and stratigraphic record of volcanic units and features, and their volumes, as revealed by Magellan (1; their Fig. 26 and Table 5). We converted the volumes of the main volcanic units to lava/magma masses using a density of 3000 kg m^{-3}. Next, we chose the upperthickness values, and added the contributions from allof the units; summing the values of the "total eruptives" gives the absolute upper limit estimate of the mass of documented volcanics that could contribute to the atmosphere, 7.335 x 10^{20} kg. We then compare this with the current mass of the Venus atmosphere (4.8 x 10^{20} kg). We find that in order to make the current atmosphere from the above volcanics, the magma would have to consist of 65.4% by mass volatiles, which is, of course, impossible. We conclude that the grand totalof the currently documented volcanics can not have produced other than a very small fraction of the current atmosphere.

Exsolution of volatiles during volcanic eruptions is significantly dependent on surface atmospheric pressure (2-3). However, the total volumeof lava erupted in the period of global volcanic resurfacingis still insufficient to produce the CO_2atmosphere observed today, even if the ambient atmospheric pressure at that time was only 50% of what it is today. Therefore, a very significant part of the current CO_2atmosphere must have been inherited from a time prior to the observed geologic record, sometime in the first ~80% of Venus history. Furthermore, the total volumeof lava erupted in the stratigraphically youngest period of the observed record (1) is insufficient to account for the current abundance of SO_2 in the atmosphere; thus, it seems highly unlikely that current and recently ongoing volcanism could be maintaining the currently observed 'elevated' levels of SO_2 in the atmosphere (4). In addition, because of the fundamental effect of atmospheric pressure on the quantity of volatiles that will be degassed, varying the nature of the mantle melts over a wide range of magma compositions and mantle fO_2 appears to have minimal influence on the outcome. We conclude that the current Venus atmosphere must be a “fossil atmosphere”, largely inherited from a previous epoch in Venus history, and if so, may provide significant insight into the conditions during the first 80% of Venus history.

(1) Ivanov and Head (2013) Plan. Space Sci. 84, 66; (2) Gaillard & Scaillet, 2014, EPSL 403, 307; (3) Head & Wilson, 1986, JGR 91, 9407;(4)Esposito, 1984, Science 223, 1072.