CONTRIBUTIONS OF VOLATILES TO THE VENUS ATMOSPHERE FROM THE OBSERVED EXTRUSIVE VOLCANIC RECORD: IMPLICATIONS FOR THE HISTORY OF THE VENUS ATMOSPHERE. J. W. Head[1], L. Wilson[1,2], M. A. Ivanov[3] & R. Wordsworth[4]. [1]Brown Univ., Providence RI, USA, [2]Lancaster Univ., Lancaster, UK, [3]Vernadsky Institute, Moscow, Russia, [4]Harvard Univ., Cambridge MA, USA.

The nature of the geologically recent runaway greenhouse Venus atmosphere, its relation to Venus geologic and geodynamic history, and why it is so different from that of the Earth, are all questions that perplex planetary scientists [1]. Recent studies have focused on *forward-modeling* of the origin and evolution of Venus' atmosphere with the current atmosphere as the end-product, defining and assessing the nature and abundance of volatiles derived from the interior and from space, their influence on the atmosphere and interaction with the surface, and the rates of their loss to space [2-4]. Several *forward models* have found that more Earth-like clement conditions [2], with oceans and an N_2-dominant atmosphere [3-4], may have existed into the last ~20% of the history of Venus (Fig. 1), the age of the oldest observed geologic units [5], the tesserae [6], and the global volcanic plains that followed [7].

Critical to the assessment of these models is the role of volcanism, the primary process of transfer of volatiles from the Venus mantle to the surface and atmosphere. In this study, we use the current atmosphere as a baseline and work *backward* in time, assessing the nature and magnitude of the major phases of volcanism revealed in the geological record [5], their style and magnitude of volatile output [7], and the candidate effects of their volatile release on the observed atmosphere [8-9].

Magellan provided global image coverage enabling identification of geologic units and their stratigraphic relationships, the construction of a global geologic map [5], assessments of the nature and role of volcanism [7] and tectonism [10] with time, and estimates of the absolute timescale. This record provides an estimate of the nature of volcanic units, their areal coverage, stratigraphic relationships and thicknesses, and estimates of the time scale of their emplacement. A summary of these data for volcanism is presented in [7], Fig. 26 and Table 5.

We converted volumes of the main volcanic units [7] to lava/magma masses using a density of 3000 kg m^{-3}. Next, we chose the *upper* value where there is a choice of 2 possible thicknesses, and added the contributions from *all* of the units ("total eruptives" in Table 1); 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, 7.335×10^{20} kg. We then compare this with the current mass of the Venus atmosphere (4.8×10^{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 total* of the currently documented volcanics cannot have produced other than a very small fraction of the current atmosphere.

Discussion and Conclusions: On the basis of these data/calculations we find: 1. The current high atmospheric pressure severely inhibits the degassing of mantle-derived S, H_2O and CO_2 and its contribution to the atmosphere [8-9]. 2. The *total volume* of lava erupted in the stratigraphically youngest period of the observed record (pl, rift-related, volcanic edifices) 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 [11]. 3. The *total volume* of lava erupted in the period of *global volcanic resurfacing* (psh, rp_1, rp_2) is insufficient to produce the CO_2 atmosphere 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_2 atmosphere must have been inherited from a time prior to the observed geologic record, sometime in the first ~80% of Venus history. 4. The amount of water degassed to the atmosphere during the period of *global volcanic resurfacing* would have been minimal, even if the atmospheric pressure was only 10% of what it is today. Therefore, the current low atmospheric water content may be an inherent characteristic of the ambient atmosphere and not necessarily require enhanced loss rates to space in at least the last 20% of Venus history. 5. 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 has minimal influence on the outcome. 6. The current Venus atmosphere may 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. 7. A critical question is: What was the atmospheric pressure/water content/solar insolation 'tipping point' that led to the general stabilization of this "fossil atmosphere"?

References: 1. Taylor et al., 2018, SSR, 214, 34; 2. Bullock & Grinspoon, 1996, JGR, 101, 7521; 3. Way et al., 2016, GRL, 43, 8376; 4. Way & Del Genio, 2020, JGR, 125; 5. Ivanov & Head, 2011, PSS, 59, 1559; 6. Ivanov & Head, 1996, JGR, 101, 14861; 7. Ivanov & Head, 2013, PSS, 84, 66; 8. Gaillard & Scaillet, 2014, EPSL 403, 307; 9. Head & Wilson, 1986, JGR 91, 9407; 10. Ivanov & Head, 2015, PSS, 113, 10; 11. Esposito, 1984, Science 223, 1072.

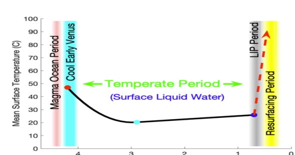

Fig. 1. Possible climate history (Way and Del Genio, 2020).