Evaluating methane clathrate destabilization by heat from lava flows as a mechanism for supplying Titan's atmospheric methane

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As previously noted [1-3], Titan may have an upper crust rich in methane clathrates which would have formed early in Titan's history [3]. Uncertainty prevails as to how methane, a major atmospheric component, and ^{40}Ar are replenished from Titan's interior. One possibility is that volcanic processes release these gases from Titan's interior. We have investigated the destabilisation of methane clathrates by the thermal interaction with cryolava flows and intrusions as a way of replenishing atmospheric methane and liberating trapped argon. We have adopted models of lava flow cooling and solidification [4] to chart the penetration of the thermal wave from such volcanic events and the evolving release of methane as clathrates are destabilised. For example, a 10-m-thick cryolava covering 100 km^2 of the surface would raise 3 x 10^8 m^3 of substrate methane clathrates to the destabilization temperature in $\sim$10^8 s, releasing 4 x 10^{10} kg of methane. This is an impressive amount, but it would take 5 million similar events to yield the current total mass of atmospheric methane, requiring the completely resurfacing of Titan with cryoflows six times just to produce the current methane inventory. If all the flows were, instead, $\sim$60 m thick, then Titan only needs to be completely resurfaced once. The idea of initially supplying all of Titan's atmospheric methane through the destabilization of clathrates by flow substrate heating seems to be unlikely. However, the potential reservoir of methane clathrates is sufficient to resupply present day losses of atmospheric methane, and requires only one such 10-m flow event about 40% of the time to do so. A somewhat lesser amount of intrusive activity would also release sufficient methane. In conclusion, we find that a near-global-scale resurfacing event some 0.5 BYa [5] involving cryolavas hundreds of meters thick, or perhaps widespread crustal foundering, would be required to yield sufficient methane from the thermal destabilisation of clathrates to explain current atmospheric abundances. However, meeting the current global methane replenishment rate is certainly feasible from thermal interaction between cryolavas and methane clathrate deposits on a relatively modest scale, one that might be hard to detect by remote sensing. References: [1] Choukroun, M. and Sotin C. (2012) GRL, 39, L04201. [2] Tobie, G. et al. (2006) Phil. Trans. R. Soc. A., 367, 617-631. [3] Lunine, J. I. et al. (2009) Origin and Evolution of Titan, in Titan From Cassini-Huygens, ed,. R. Brown et al., pp. 35-59, Springer. [4] Davies, A. G. et al. (2013) LPSC-44 abstract 1681, available online. [5] Sotin, C. et al. (2012) Icarus, 221, 768-786. Acknowledgements: This work was performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract to NASA. We thank NASA's OPR Program for support.