PREDICTION OF THE MAXIMUM TEMPERATURE FOR LIFE BASED ON THE STABILITY OF METABOLITES TO DECOMPOSITION IN WATER. W. Bains [1] , Y. Xiao [2], C. Yu [2] . [1] Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, 77 Mass. Avenue, Cambridge, MA 02139, USA; bains@mit.edu. [2] Department of Chemical Engineering and Biotechnology, University of Cambridge, Tennis Court Road, Cambridge CB2 1QT, UK

Background.

Identifying the maximum temperature at which life can complete its life cycle is of theoretical importance to the search for life on other worlds, and of practical importance to understanding our own planet's geochemistry. Archaeal life is know to be able to grow a ~120^{o}C, but no organism has been found that can grow at a higher temperature. Our study [1] seeks to identify a limiting maximum temperature for terrestrial life, based on the stability of its components.

Approach

The components of life must survive in a cell long enough to perform their function in that cell. Because the rate of attack by water increases with temperature, we can predict a maximum temperature above which a terrestrial metabolite cannot survive long enough to perform its function by analysis of the decomposition rates of the component at different temperatures, and comparison of those rates with the metabolite's minimum metabolic half-lives. A small number of metabolites can be 'swapped out' for other, more stable molecules, but there will be a limit to the adaptability of metabolism to loss of its components to thermal instability; that limit is one estimate of the maximum temperature for life.

We extracted decomposition rate data from published papers, and estimated the statistical reliability of interpolating or extrapolating across a range of temperatures. This approach includes the variation within and between experiments in our estimate of the stability of a metabolite. We then applied the rate equations to predict when the stability of a metabolite would drop below that required for life.

Results

The data set

To apply our method each study had to measure the rate of decomposition at three or more temperatures. For relevance to the interior of the cell, studies had to be carried out at roughly neutral pH. With these caveats, we identified literature sources for the decomposition rates of 63 metabolites.

Hydrolysis rates

Consistent rate equations could be found for most of the metabolites. For the rest, either the reported data had too much variability or there was too much inconsistency between studies to generate a high confidence prediction of hydrolysis rates. The required metabolic stability was approximated to be the metabolic half-life of classes of compounds in rapidly growing *E.coli* cells.

We found 14 compounds from the set of 63 for which we could not confidently predict that they would have a half-life to thermal degradation greater than their target metabolic half-life at 420K. These 'labile' compounds included metabolites known to be labile to hydrolysis such as carbamoyl phosphate, but also compound ssuch as xylose for which the data was inufficient to make a robust conclusion at any temperature.

Conclusion

Our study found that there is not enough data in the published literature to draw robust conclusions concerning the maximum temperature at which metabolism could function. The present study is a first step, providing an analytical framework and method. However our preliminary analysis suggests that terrestrial biochemistry is limited to environments below ~150^{o}C – 180^{o}C. Pressure is likely to have a small effect on this temperature threshold. As core biochemistry is believed to be common to the very earliest life, this places limits on the environment in which life originated as well as where life can currently survive.

References. [1] Bains, W. et al (2015) Life *in press*