# ASSESSING BIOMARKER SURVIVAL IN TERRESTRIAL MATERIAL IMPACTING THE LUNAR SURFACE

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## INTRODUCTION

The Moon's rich impact history is exemplified by an epoch circa 3.9 Gyr ago when the terrestrial planets are thought to have experienced frequent, large-scale impact bombardment. During this time, Earth would have experienced numerous, giant, hypervelocity impacts, potentially ejecting terrestrial material into Moon-crossing orbits. Terrestrial meteorites could provide a record of terrestrial biomarkers predating the earliest evidence of life on Earth. Here, we have used the iSALE-2D shock-physics code [1-3] to determine the pressure and temperature regimes of simulated terrestrial meteorites impacting the lunar surface (Fig. 1), in order to gauge the survivability of biomarkers in the projectiles.

## SIMULATION SET UP

Impact velocities:
2.5 km/s
5 km/s

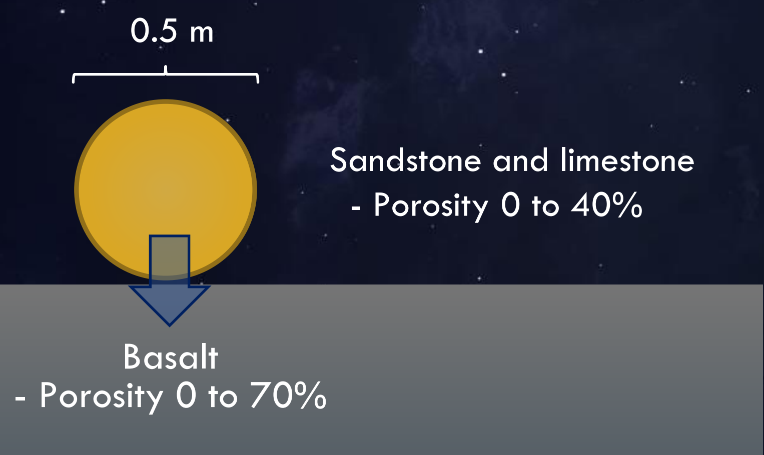
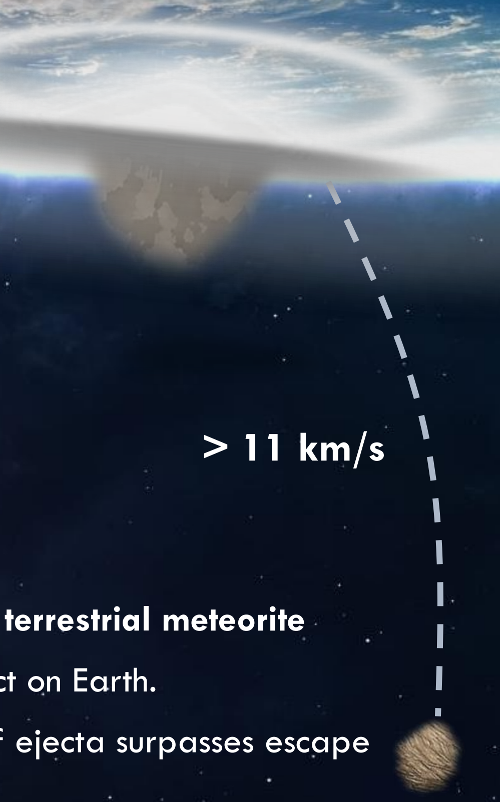



**Fig. 1:** Diagrammatic representation of the parameters used in the suite of simulations for terrestrial meteorites impacting the lunar surface.




**Formation of a terrestrial meteorite**

- Giant impact on Earth.
- Fragment of ejecta surpasses escape velocity.
- Ejecta reaches Moon crossing orbit.

# METHODS - MODELLING

Pressure and temperature regimes within projectiles were compared to known thermal degradation parameters for some example biomarkers (arginine, valine, glutamine, tryptophan [4], and lignin [5]), using a modified version of the Arrhenius equation and the method described by [6]. From this, we estimated a percentage of the original biomarker mass that survives after impact (Fig. 2).

Arrhenius equation[7]:

$$dM = -MAe^{-Ea/RT(t)}dt$$

Pressures and temperatures for a selection of microfossils which have survived in metamorphosed rocks were also used for comparison, including lycophyte megaspores [7] (results shown in Fig. 3).

# PRELIMINARY RESULTS

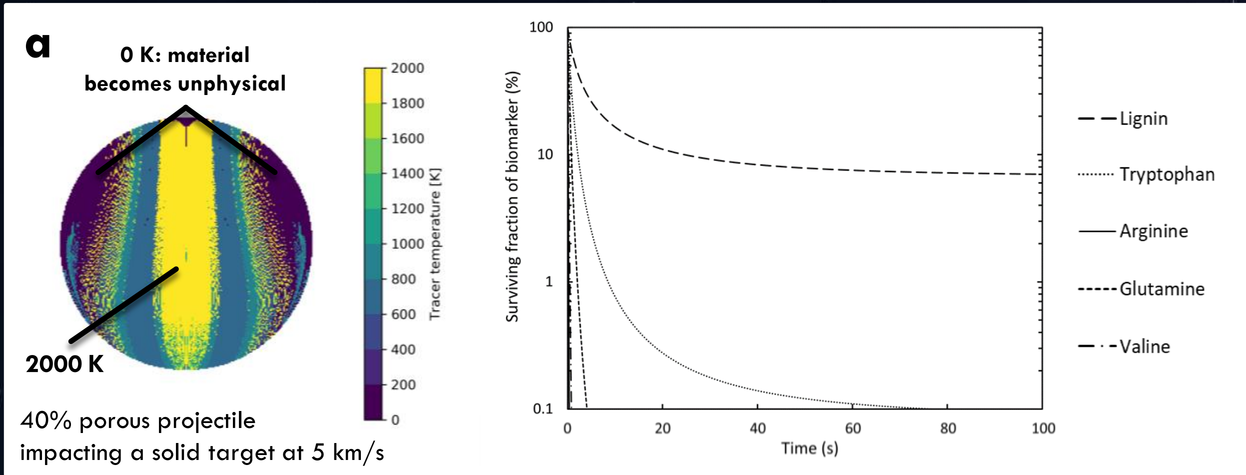
We know that increasing pressure and temperature in the projectile will lead to less favourable conditions for biomarker survival. Therefore, we can make some broad conclusions from the suite of simulations produced.

**Biomarker survival potential decreases with:**

- **Increasing projectile porosity**
- **Increasing projectile velocity**
- **Decreasing target porosity**
- **Sandstone experiences slightly higher pressures and temperatures vs. limestone**

# RESULTS – BIOMARKER SURVIVAL

## LEAST FAVOURABLE CONDITIONS




## MOST FAVOURABLE CONDITIONS

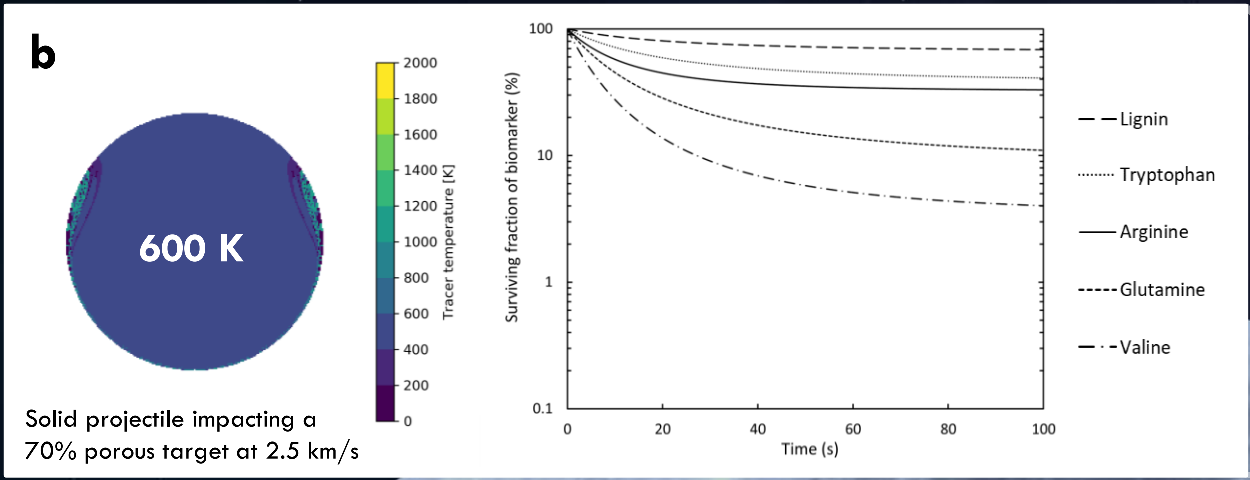



**Fig. 2:** Post-shock temperature maps (left) and survival of selected biomarkers (right) in the worst- and best-case impact scenarios. Survival is extrapolated over 100 seconds, based on starting temperatures of 2000 K (a) and 600 K (b) for a 1 cm diameter fragment whilst radiatively cooling into space [8].

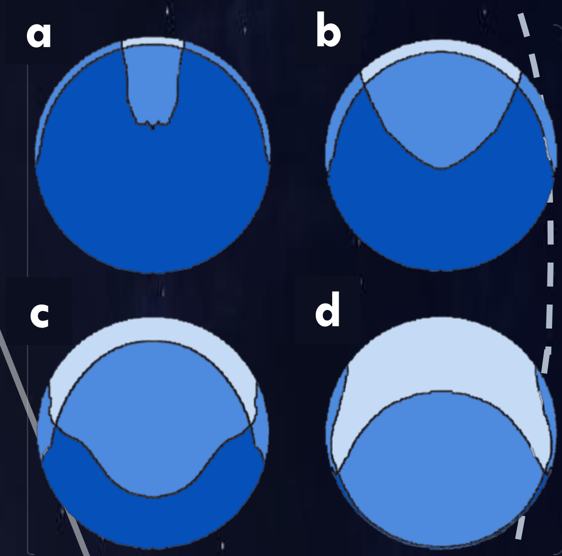



**Fig. 3: Survival maps for lycophyte megaspores in solid projectiles impacting increasingly porous targets (a = 10%, b = 20%, c = 30% d = 40%) at 2.5 km/s. Areas shaded with the lightest colour show highly likely survival.**

Maximum vertical impact velocity assumed as ~5 km/s [9].

# CONCLUSIONS

- Temperatures higher than expected in all simulations. Lowest post-shock temperatures recorded ~600 K.
- However, significant proportions of some biomarkers are still shown to survive post-impact, especially at lower impact velocities.
- Lignin and tryptophan survive well in a range of impact scenarios. Lycophyte megaspores survive in part of the impactor during only the most-favourable impact conditions.
- Long-term biomarker survival is highly dependent on the resulting location and size of ejected projectile fragments.

**For further explanation of the modelling process and an expanded set of results, please see our recently published paper at https://doi.org/10.1016/j.icarus.2020.114026.**

**References**

[1] Amsden A. et al. (1980) LANL Report, LA-8095. [2] Collins G. S. et al. (2004) MAPS, 38, 217-231. [3] Wünnemann K. et al. (2006) Icarus, 180, 514-527 [4] Rodante F. (1992) Thermochimica Acta, 200, 47-61. [5] Brebu, M., Vasile C. (2010) Cellulose Chemistry and Technology. 44. 353-363. [6] Pierazzo E., Chyba C. (1999) MAPS, 34, 909-918. [7] Bernard S. et al. (2007) EPSL, 262, 257-272. [8] Nave, R. (2017) Hyperphysics, Georgia State. [9] Armstrong, J. (2010) Earth, Moon, and Planets, 107(1), 43-54.