The impact of coupled aeolian abrasion – UV irradiation on the transformation of organic matter and detectability by the ExoMars 2020 MOMA instrument (ABRADE)

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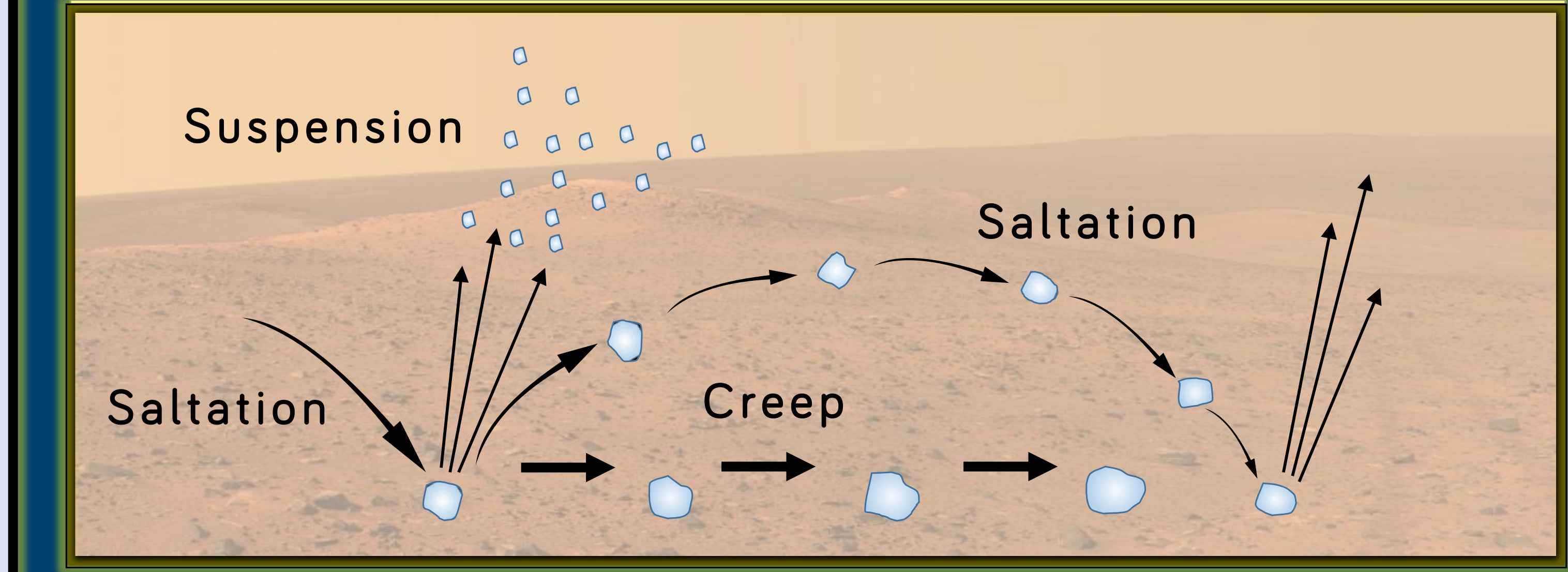
Summary

ABRADE will conduct experiments quantifying the effects of coupled aeolian abrasion - UV irradiation on the abundance and distribution of a wide range of organic molecules targeted by the ExoMars 2020 Mars Organic Molecule Analyser (MOMA). Data will a) constrain the potential survivability/detectability of organic molecules in Martian sediment, b) aid interpretation of MOMA data, and c) potentially improve methods to remediate some persistent terrestrial organic pollutants. It targets the high-level ExoMars science aim 'Search for signs of past and present life on Mars'.



Saltation

Sand transport by wind is evidenced on Mars by a plethora of modern aeolian bedforms, varying in scale from centimetres to tens of metres (Balme *et al.*, 2018). Sand particles greater than ~ 10 μm are too large to be suspended as aerosols and are transported by saltation. Saltating grains are lifted from the surface before crashing back down triggering a collision. This collision can result in the fracturing of the granular material leaving reactive mineral surfaces (Merrison, 2012).

Mineral Surfaces

The fracturing of silicate minerals leads to the mechanical cleaving of covalent bonds and the generation of reactive mineral surfaces. Certain modern industrial processes utilise mechanical 'activation' to increase production rates and lower the temperature of solid-state reactions (Berbenni *et al.*, 2003). Reactive oxygen species (ROS) can form at these activated surfaces. Mineral surface – water reactions have been suggested as a source of hydrogen in fault zones (Kita *et al.*, 1982) and in sub-glacial environments; potentially supporting life and biodiversity during extended global glaciations (Telling *et al.*, 2015). Hydrogen peroxide (H_2O_2) is generated in appreciable quantities from the reaction of crushed basalts with liquid Water (Hurowitz *et al.*, 2007). Further to this, hydroxyl radicals (•OH) can be generated upon contact of abraded silicates with water which has likely contributed to the high reactivity of the Martian regolith. (Bak *et al.*, 2017). The abiotic emission of nitrous oxide from hypersaline Antarctic ponds indicate unexpected and extensive links between the geosphere and atmosphere.

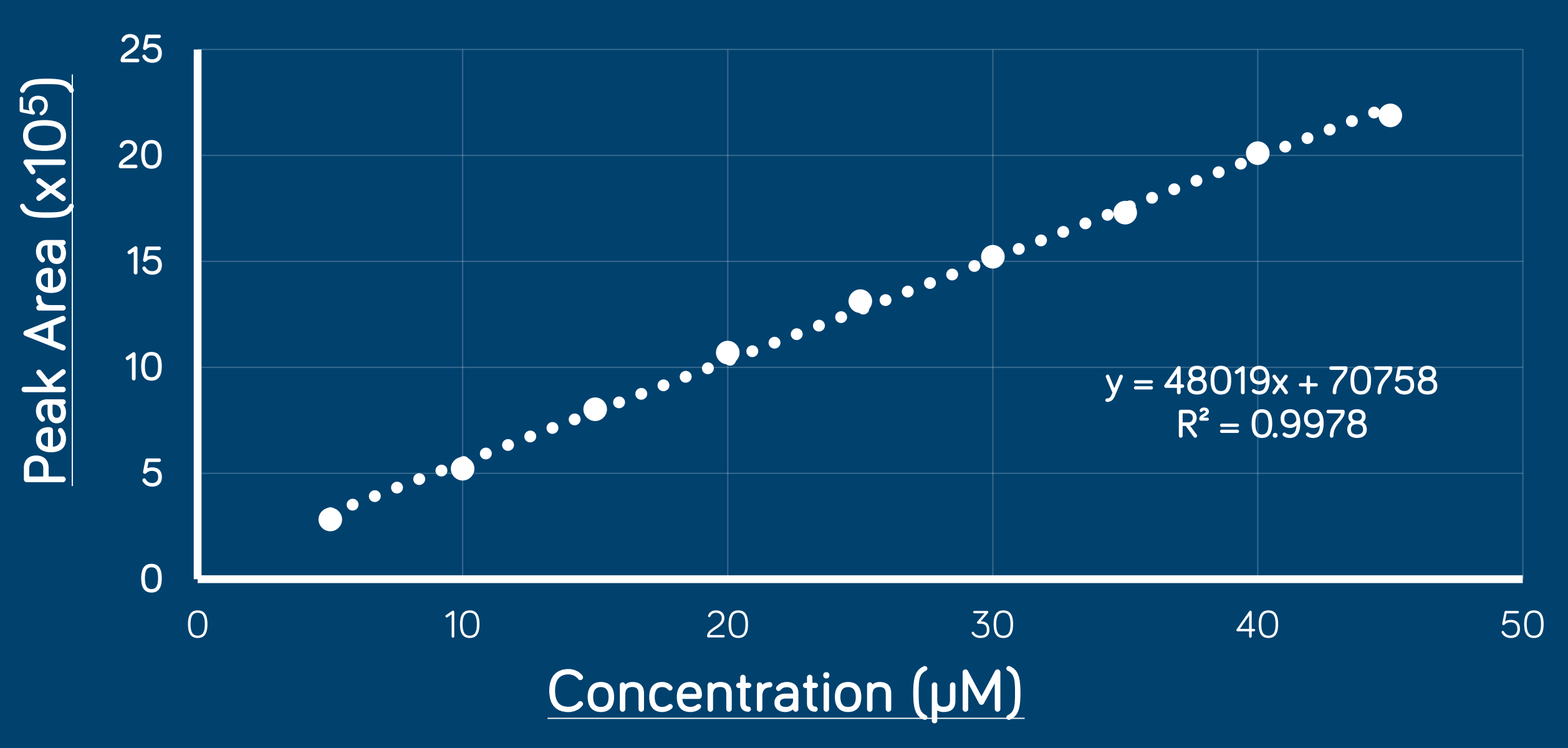
ExoMars 2020

ExoMars 2020 will deliver a European rover to the surface of Mars equipped to search directly for signs of life. The Mars Organic Molecule Analyser (MOMA) is the largest instrument on board the rover and is specifically designed to Target chemical biosignatures (Vago *et al.*, 2017). ABRADE has been designed to aid interpretation of data returned from MOMA by complementing ExoMars' analytical objectives: analysing patterns and relationships between a wide variety of organic species, measuring changes in the left to right balance (ee) of chiral molecules and investigating the inorganic reactions that could take place In the Martian regolith (Goesmann *et al.*, 2017).

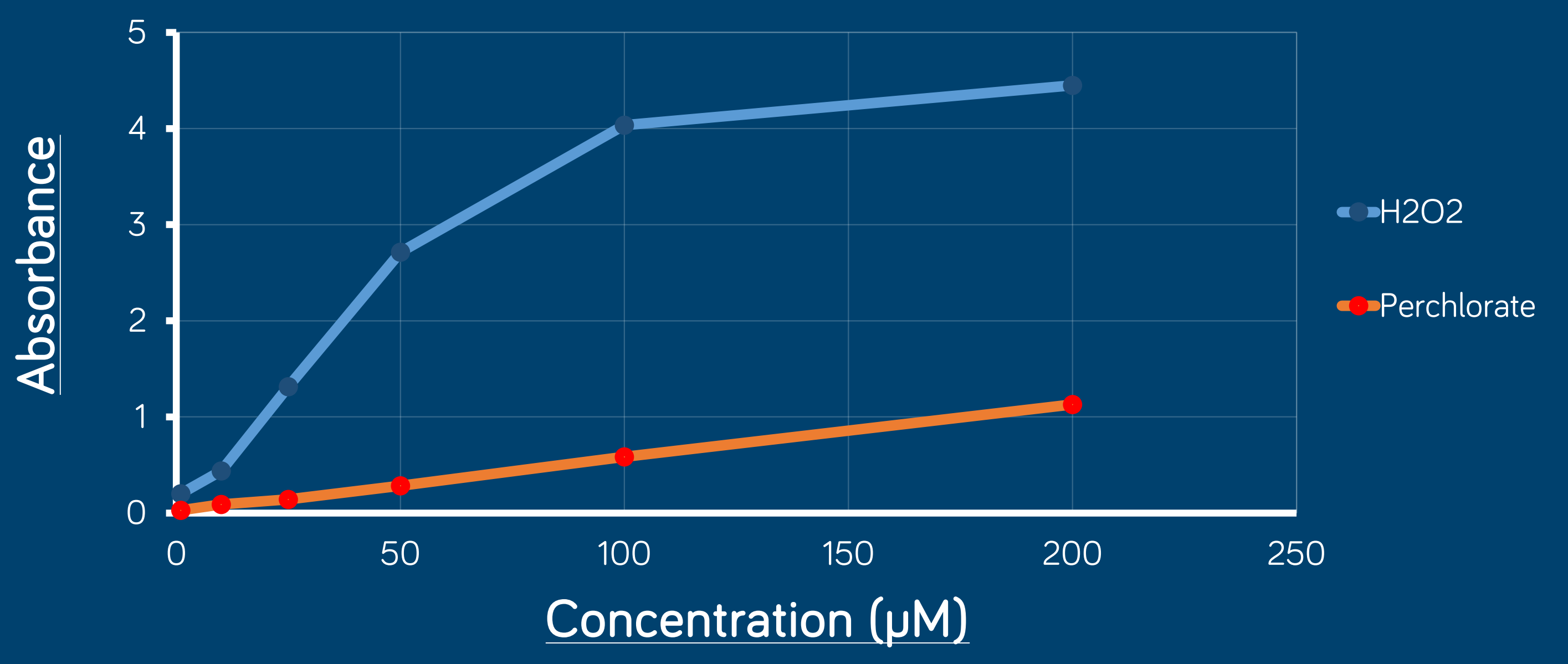
Method Development

To determine the concentration of H_2O_2 a simple spectrophotometric method based on the reduction of copper (II) ions in the presence of 2,9-dimethyl-1,10-phenanthroline (DMP) has been developed following Baga *et al.* (1988). A method to indirectly measure •OH by the breakdown of para-chlorobenzoic acid has also been developed utilising high performance liquid chromatography (HPLC) following Bak *et al.* (2017). Calibration curves for the H_2O_2 and •OH assays are shown below.

Calibration Curve for • OH assay

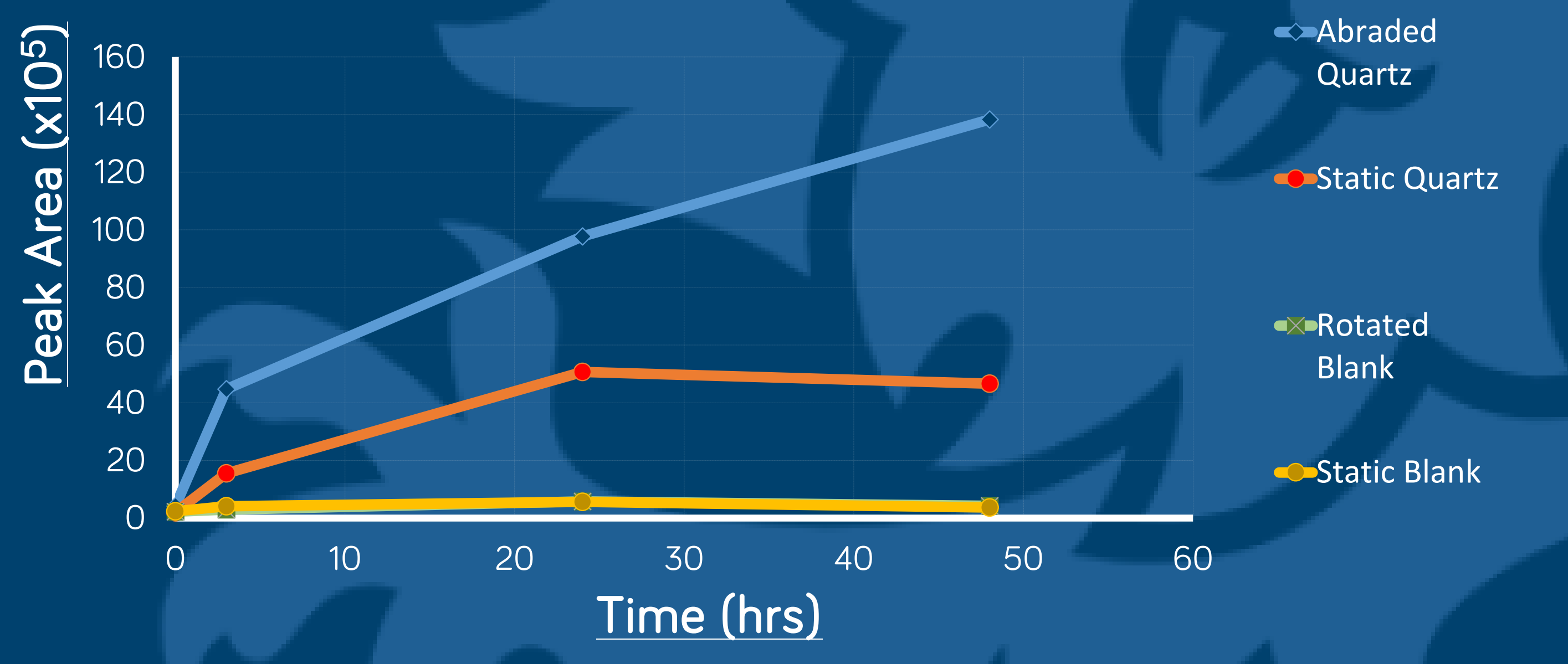


Calibration curve for H_2O_2 assay



A method for the detection of H_2 has been specifically developed for a pulse discharge detector gas chromatography mass spectrometer (PDD-GC-MS). Whilst H_2 is the primary target, other gas species of interest to current ESA/NASA missions (particularly N_2O and CH_4) can be evaluated with this method. Below are some preliminary results showing the production of H2 from abraded quartz.

Time response of H2 production after submersion of abraded quartz in water



Future Experiments

1) H2 generation through abrasion of silicates at low temperatures.

H_2 has been shown to occur as a product of crushed rock-water interactions in the range of temperatures 0 ˚C to 270 ˚C (Kita *et al.*, 1982; Telling *et al.*, 2015). This series of experiments will investigate the production of H_2 from abraded mineral-water interactions at –80 ˚C to 0 ˚C.

2) Mechano-chemical kinetic fractionation of organics.

Organic molecules can exist as a vast number of isotopologues. Kinetic fractionation of substances occurs to a greater extent at lower temperatures such as those found on Mars. A series of experiments will investigate if kinetic fractionation is observable in mechano-chemical reactions. Tumbling experiments with a suite of minerals and different isotopically labelled organic molecules will be conducted. The existence of and subsequent temperature dependence of any fractionation is the primary target of the experiment, however, a wealth of data on the transformation of organic molecules will be generated.

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