Laboratory studies of organic material under simulated martian conditions

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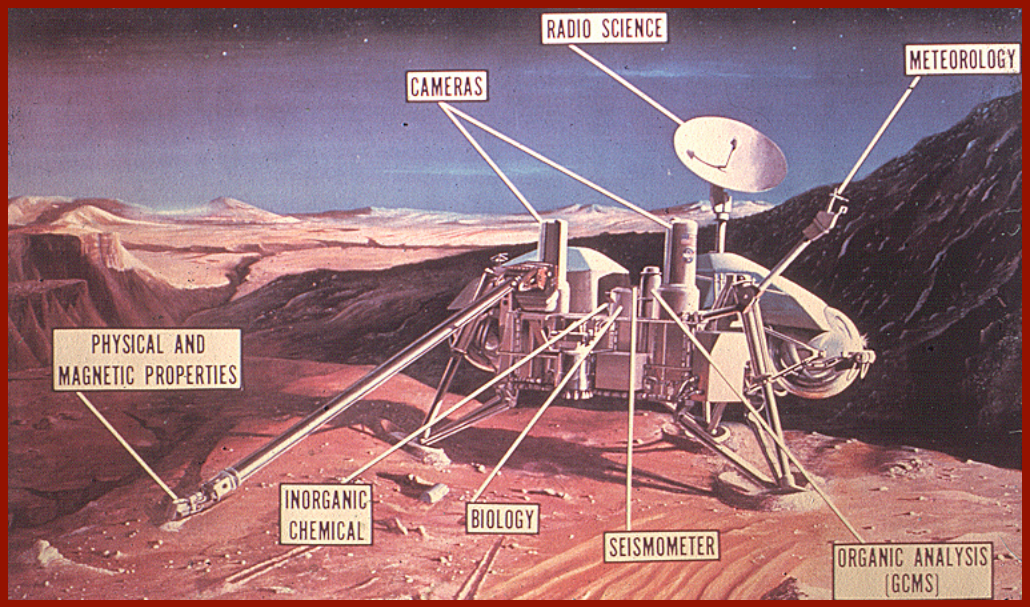
Viking – search for life

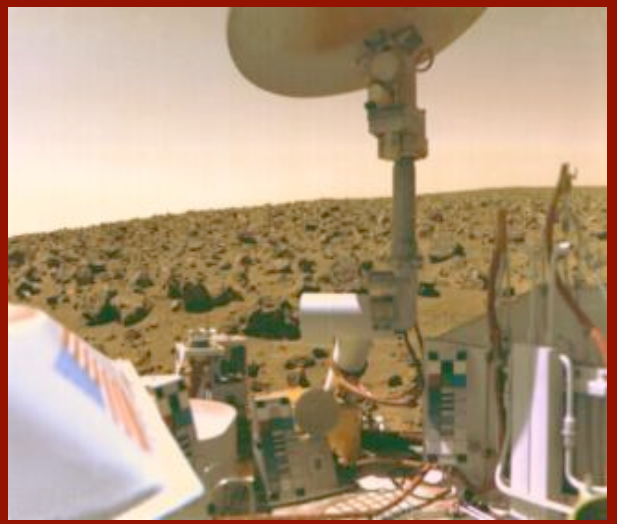


experiments

biology

molecular analysis

NO organic material detected



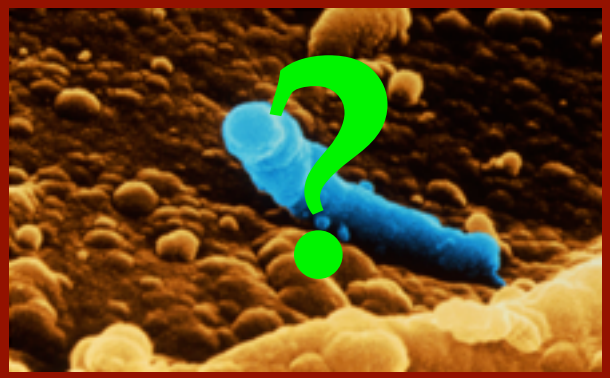
Potential sources of organics on Mars

Extramartian delivery

delivery rate:
2.4×10^6 kg yr^{-1}
Flynn (1996)

Abiotic synthesis

(Remnants of) life



Explanation for the absence of organics on Mars

Yen *et al.* (2000), Quinn (2005): destruction of organic compounds by oxidation processes occurring in the soil

Benner *et al.* (2000): complex organic acids can be present, Viking GCMS was not suited to detect these compounds

Glavin *et al.* (2002): detection limit of the Viking GCMS was too high to detect pyrolysis products of bacteria

Mars simulations

Research Goal

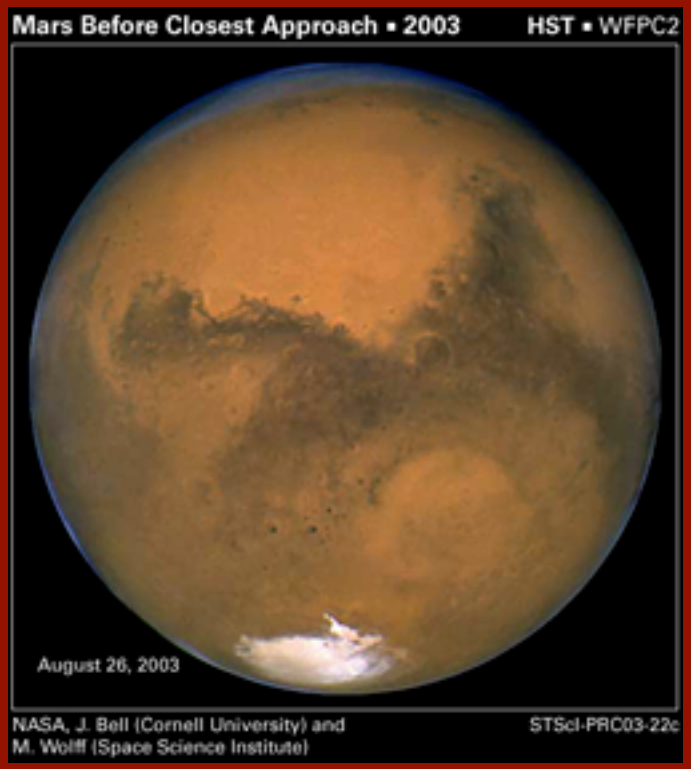
to characterise the response of biomolecules to simulated Mars' surface conditions

amino acids

pure

embedded in soil analogues

Parameters of interest



UV flux (190-325 nm) (Patel *et al.* 2002)	*Flux:* ~1.4×10^{15} photons s^{-1} cm^{-2} *Intensity:* ~37 W m^{-2}
Atmospheric composition	95.3% CO_2 & 2.7% N_2; 1.6% Ar; 0.13% O_2; 0.03% H_2O
Surface temperature	140 to 300 K *average*: 210 K

different conditions investigated separately and combined

Used amino acids

Glycine H_2NCH_2COOH Alanine $H_2NCH(CH_3)COOH$

well characterised
detected in meteorites
present in all organisms

Stability of amino acids on the martian surface

irradiation of thin layers of glycine and alanine, with Mars-like UV flux levels

focus on **pure** amino acids

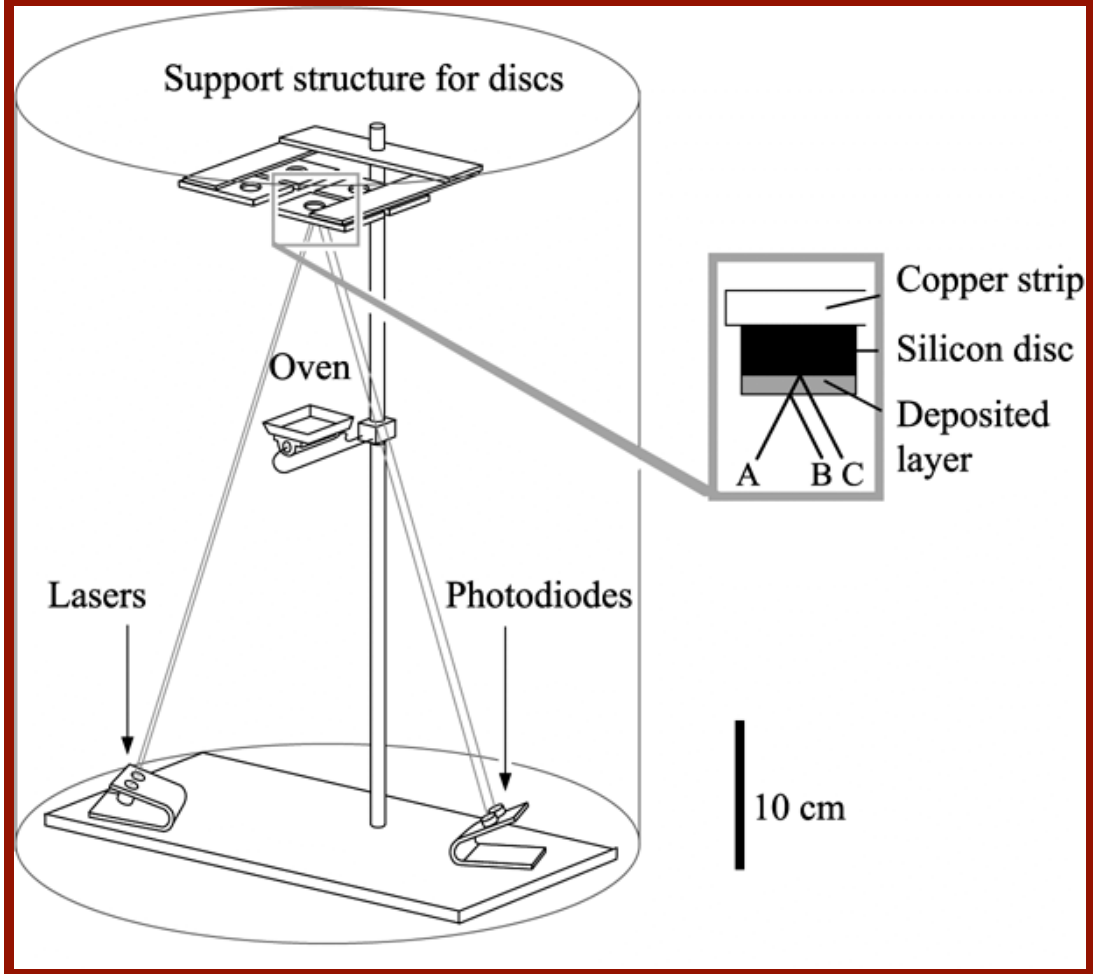
a) In vacuum (~10^{-6} mbar) at 294 K

b) In CO_2 (~7 mbar) at 294 K

c) In vacuum (~10^{-7} mbar) at 210 K

d) In CO_2 (~7 mbar) at 210 K

Amino acid thin layers



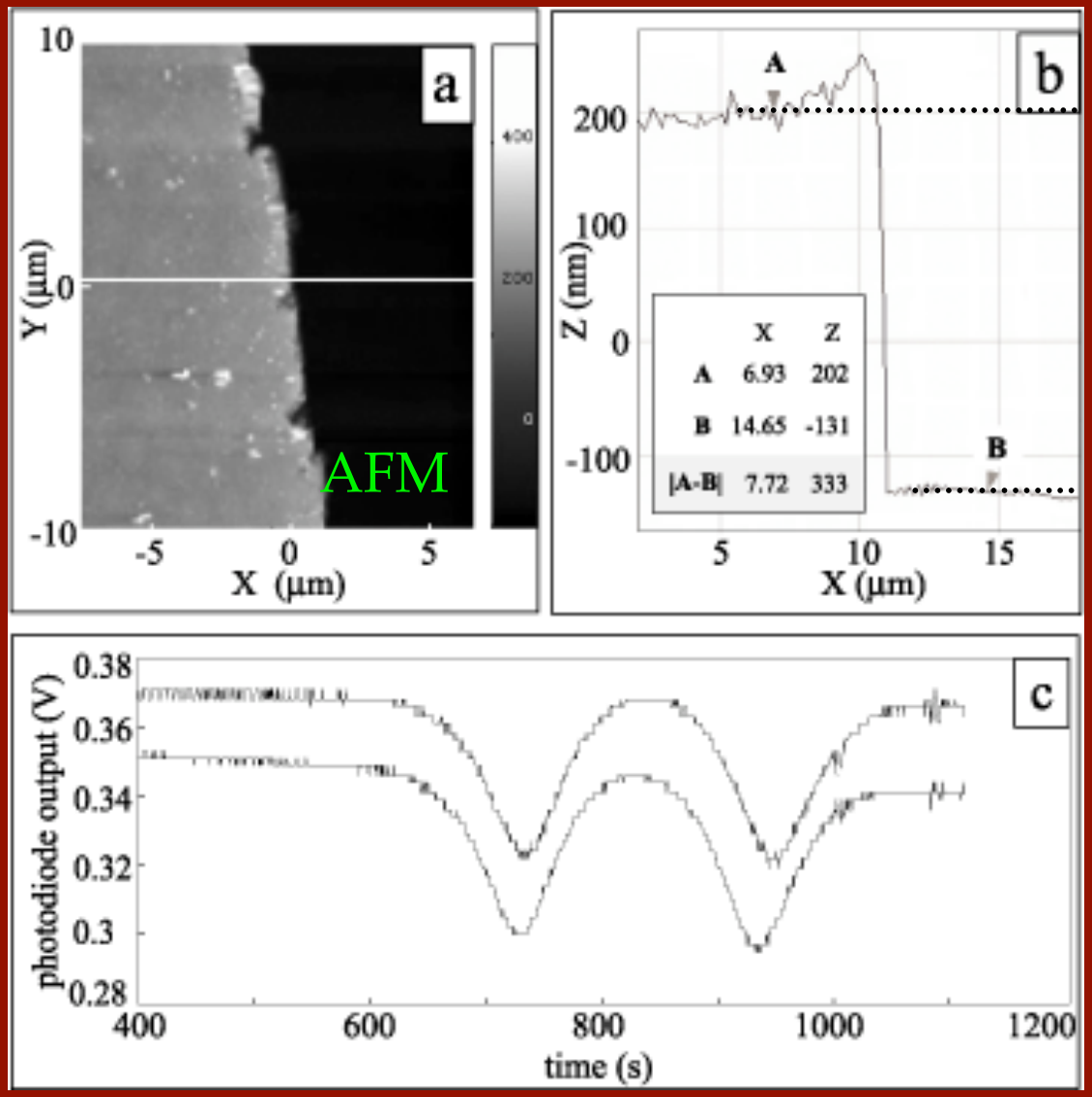
sublimation at
~10^{-5} mbar
~ 400 K

silicon substrate
→ IR transparent

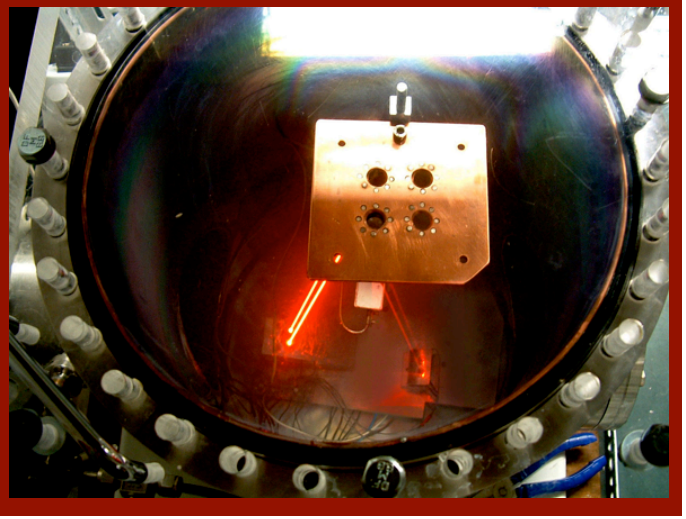
layer thickness:
in situ laser interferometry

ten Kate *et al.* 2005

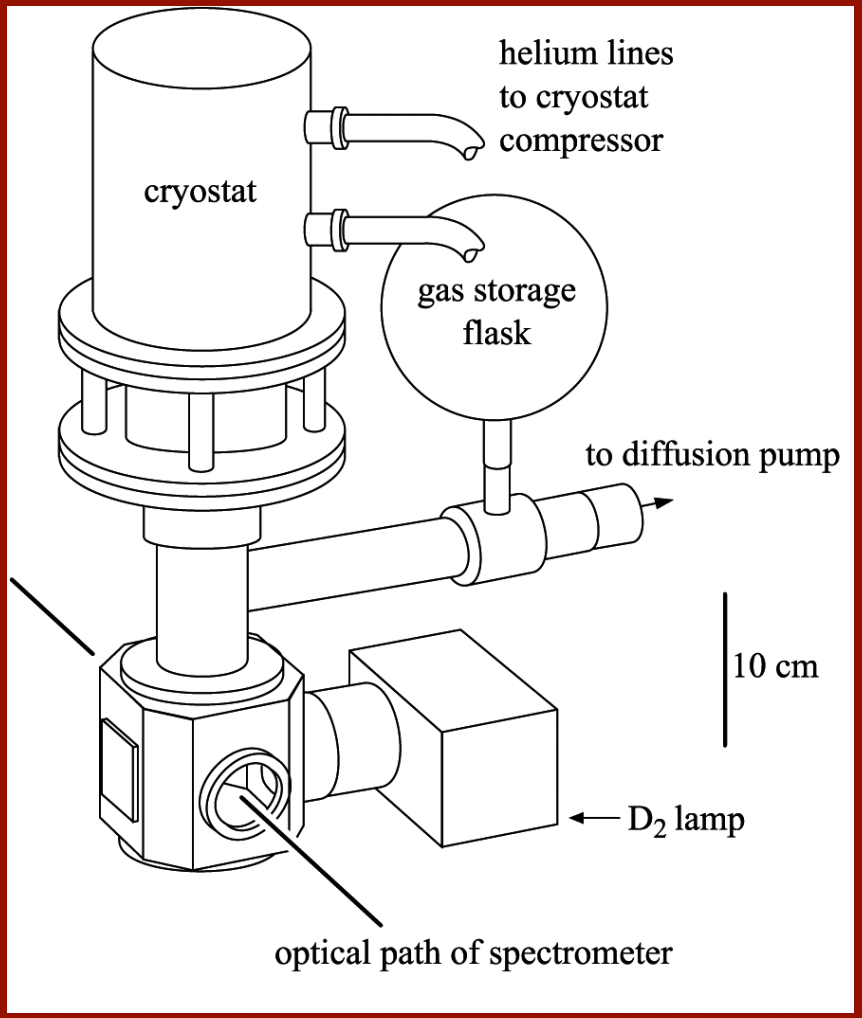
Amino acid thin layers



layer thickness
~300 nm

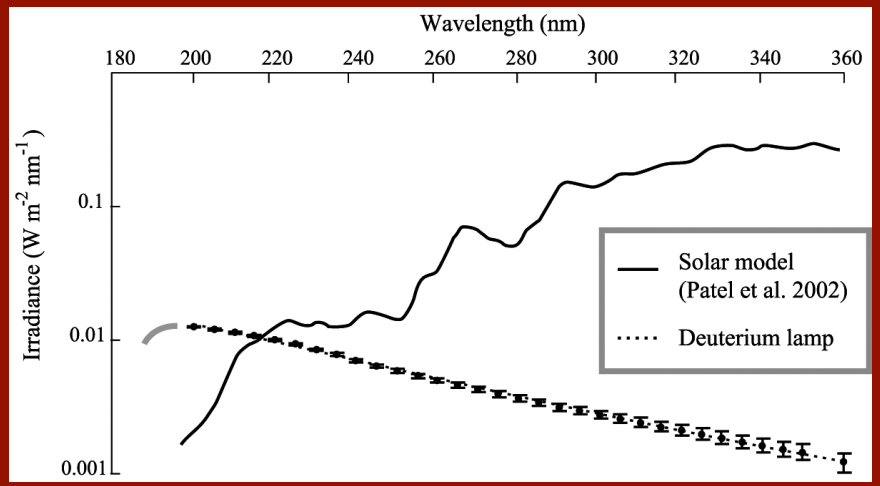


Experimental setup



IR spectroscopy

light source: deuterium discharge lamp



190-325 nm

Lamp: ~ 1.2×10^{14} photons cm^{-2} s^{-1}
Mars: ~ 1.4×10^{15} photons cm^{-2} s^{-1}

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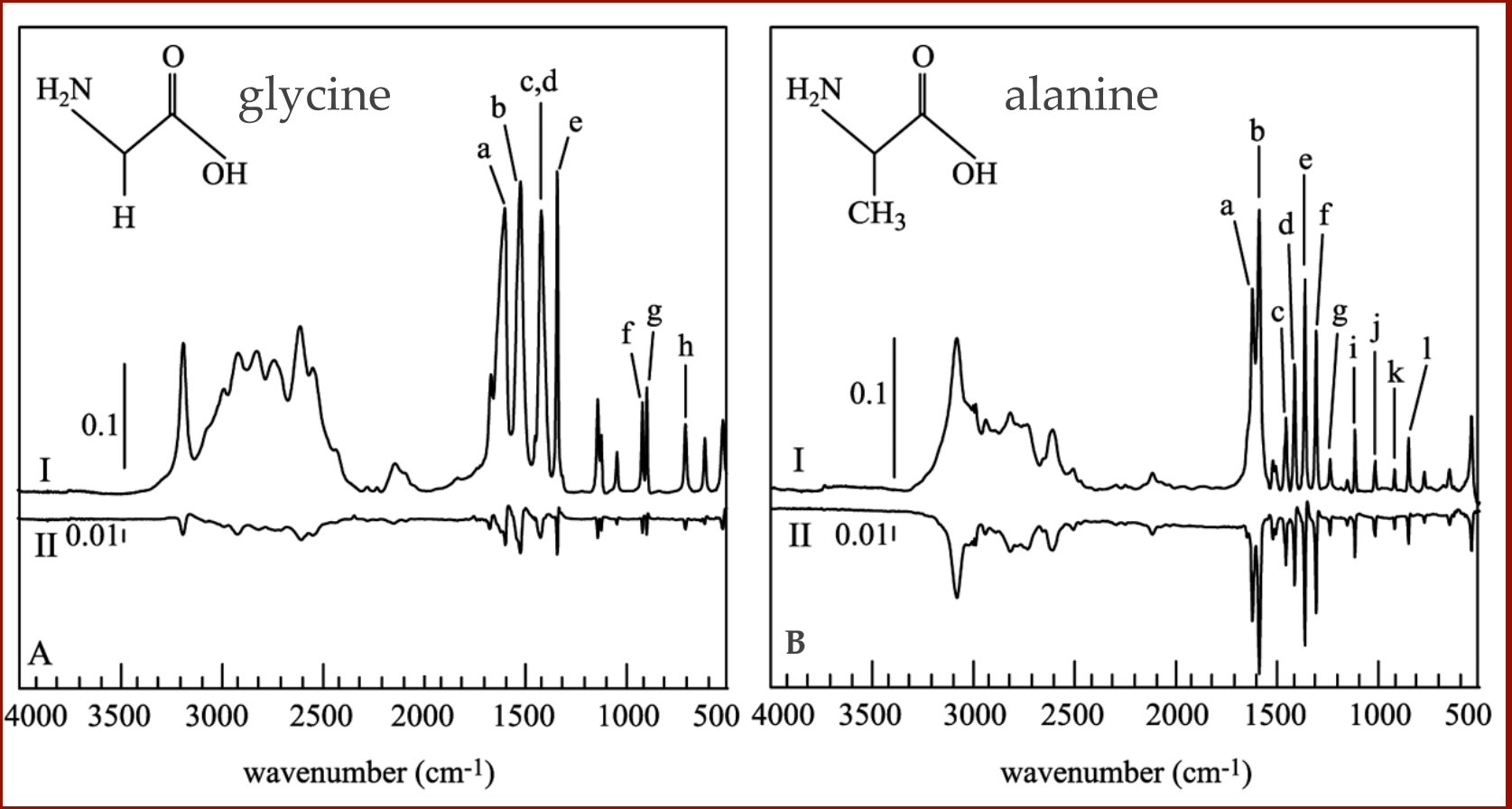
Results I - IR spectra



I – infrared absorption spectrum

II – amount of material lost after 50 hrs of UV irradiation

→ **uniform degradation**

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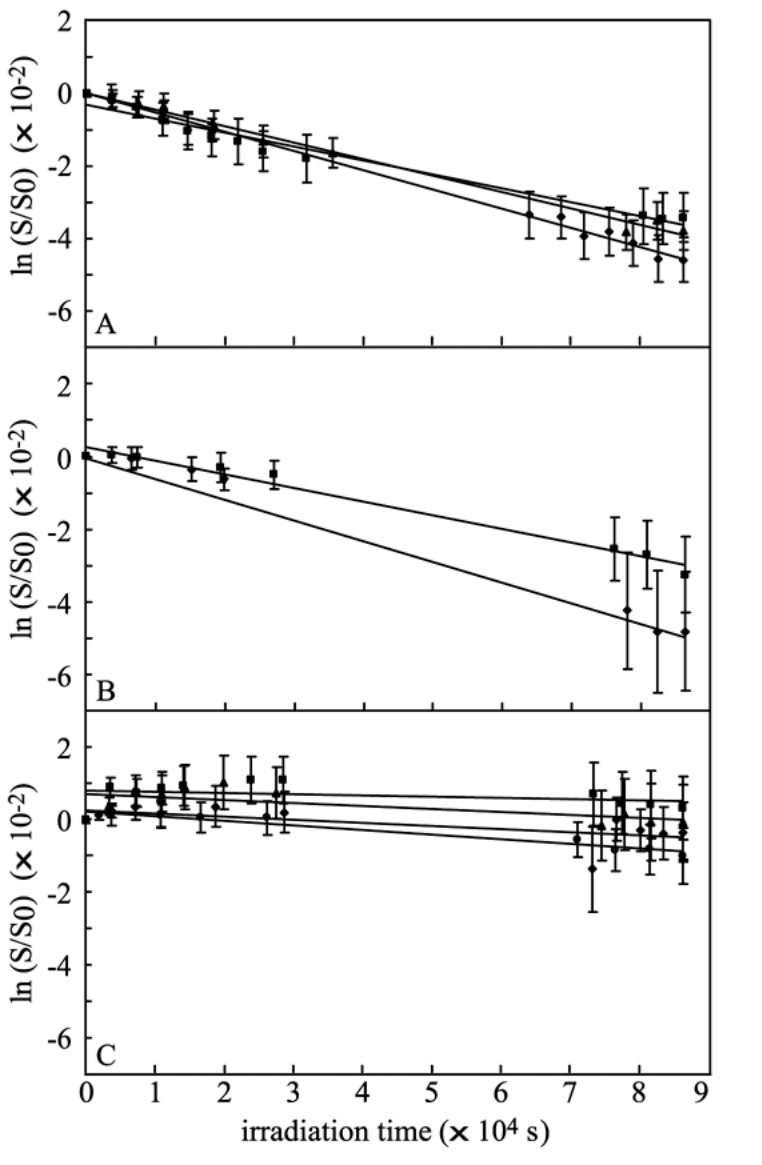
Results II – glycine destruction rates



A) in vacuum
B) in a 7 mbar CO_2 atmosphere at 294 K
C) in vacuum when cooled to 210 K

	destruction rate (s^{-1})	Mars half-life (s)
A	$4.5 \pm 2.3 \times 10^{-7}$	$1.3 \pm 0.8 \times 10^{5}$
B	$4.9 \pm 2.3 \times 10^{-7}$	$1.3 \pm 0.6 \times 10^{5}$
C	$0.8 \pm 2.9 \times 10^{-7}$	$0.9 \pm 7.5 \times 10^{6}$

D) 7 mbar CO_2 atmosphere at 210 K (not shown)

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Results III – cold vs warm

at room temperature (RT)

- reaction products in gas phase
- reaction products diffuse out of glycine bulk
- no means to measure reaction products

at 210 K

- destruction at same rate as at RT
- slower kinetics → less diffusion → recombination ?
- no reaction products measured

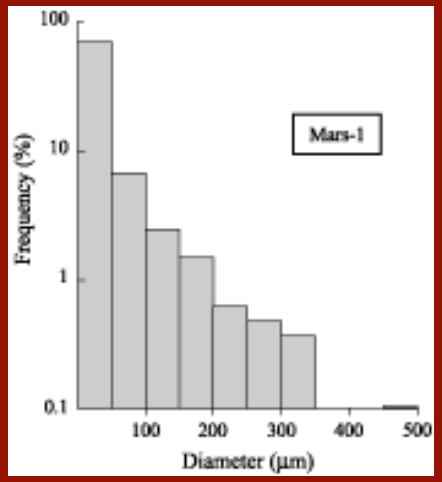
Stability of amino acids within the martian soil

UV irradiation of amino acids embedded in martian soil analogues, under simulated martian conditions

Analogues:

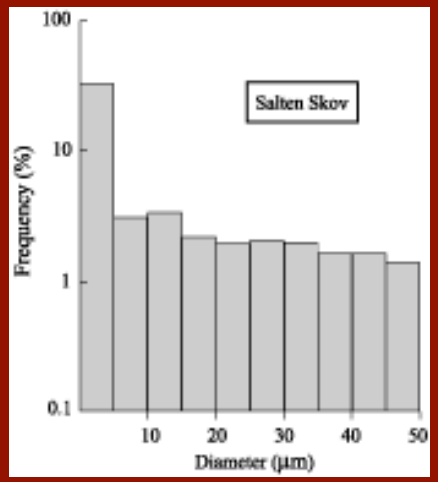
1) JSC / Mars-1, sample from Hawaiian volcano (Mauna Kea)
2) Salten Skov, sample from Jutland, Denmark

Soil analogues



1) JSC / Mars-1

coarse grains, crushed
elemental composition broadly similar to martian soil

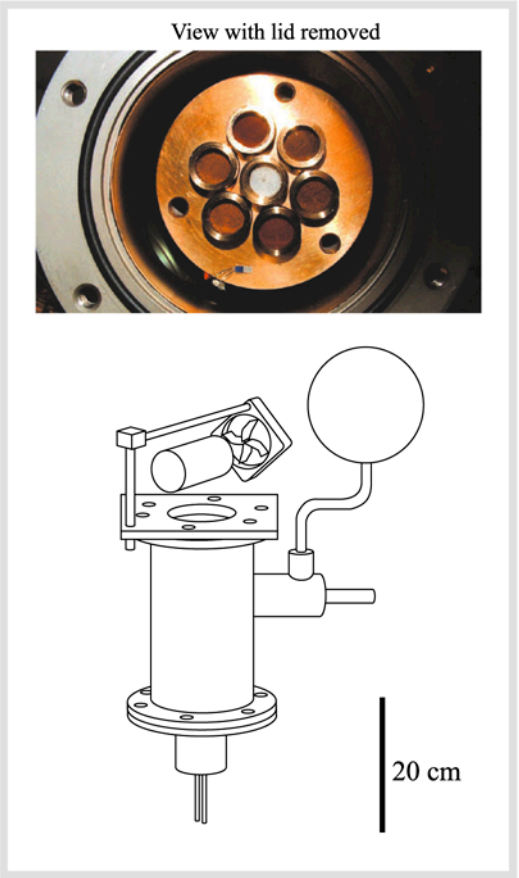


2) Salten Skov

fine grains, homogeneous size distribution
rich in iron precipitates

no cleaning or sterilisation

Experimental setup



irradiation source

deuterium discharge

190 - 325 nm

Conditions:

a) 24 hr UV irradiation at 294 K and ~1 × 10^{-5} mbar

b) 7 days UV irradiation at 294 K and ~1 × 10^{-5} mbar

c) 7 days UV irradiation at 210 K and 7 mbar CO_2 atmosphere

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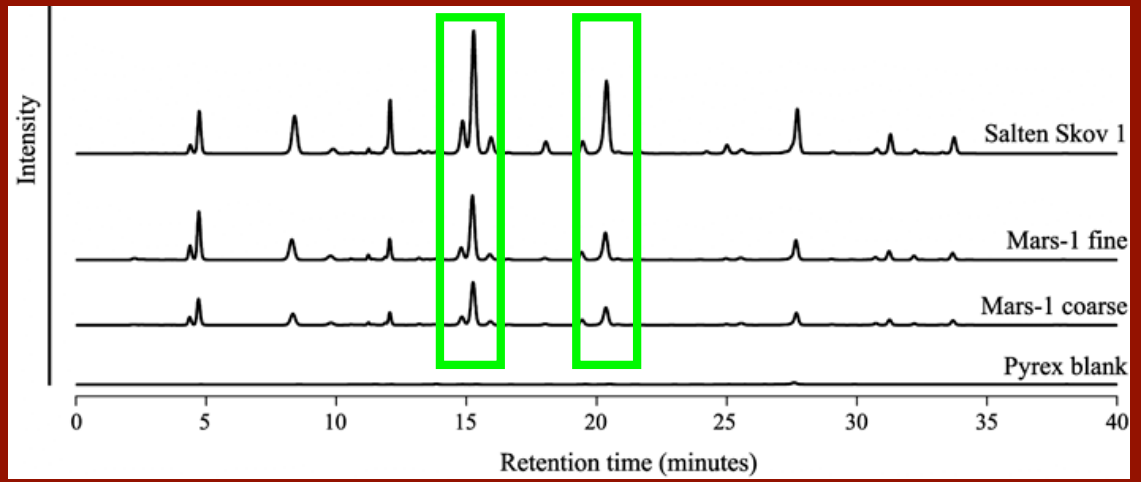
Results I - amino acid content

Intrinsic amino acid content of the soil analogues

HPLC



aspartic acid; glutamic acid; glycine; alanine; valine, leucine

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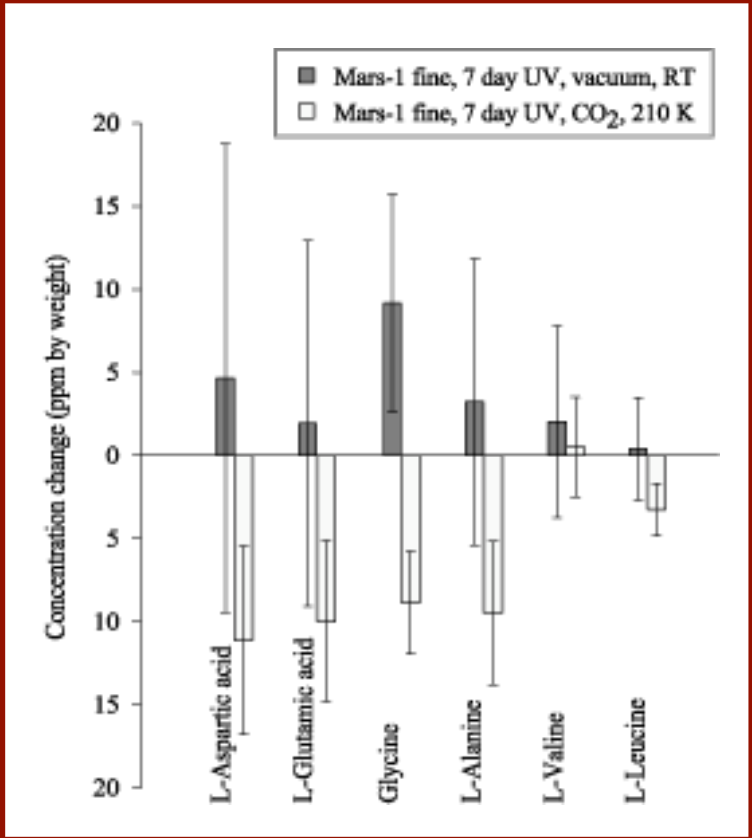
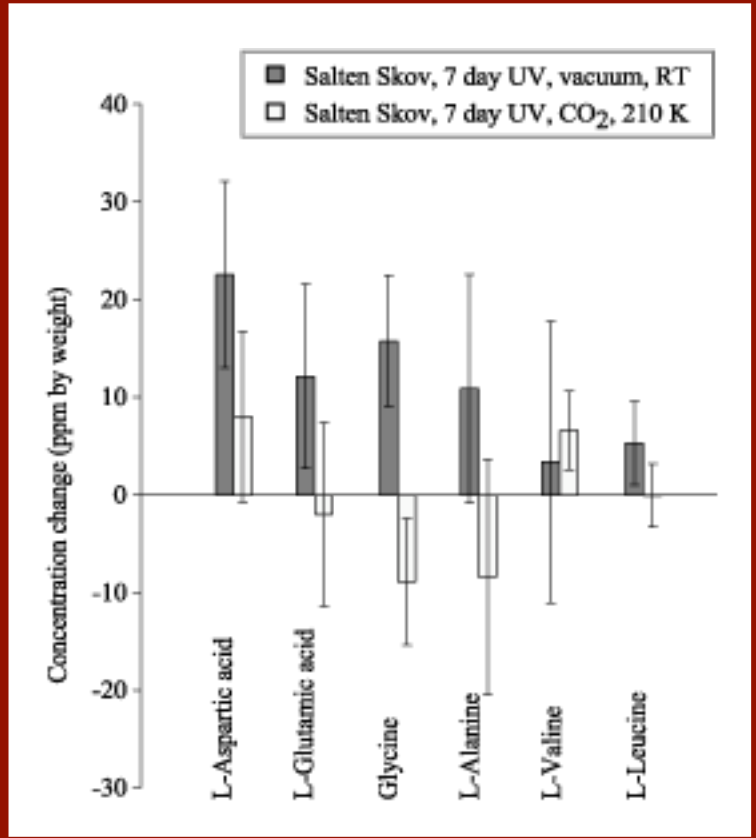
Results II - effect on amino acid concentrations





Results II - effect on amino acid concentrations

Irradiation with UV in vacuum at 294 K:

MORE amino acids than in unirradiated sample

→ **photolysis of intrinsic bacteria in the soil samples**

Garry *et al.* 2006

Results II - effect on amino acid concentrations

Irradiation with UV in vacuum at 294 K:

MORE amino acids than in unirradiated sample

→ photolysis of intrinsic bacteria in the soil samples

After irradiation with UV in CO_2 atmosphere at 210 K:

LESS amino acids than in unirradiated sample

→ **H_2O adsorbed on soil grains at 210 K, produced radicals lead to destruction**

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Overall conclusion

amino acids

not stable on martian surface: half life of 24 hrs

stable in soil: 10^7 years
(soil chemistry not taken into account)

future missions should be looking for small organic compounds exclusively beneath the surface

Acknowledgments

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