Does organic carbon hold micrometeoroids together?

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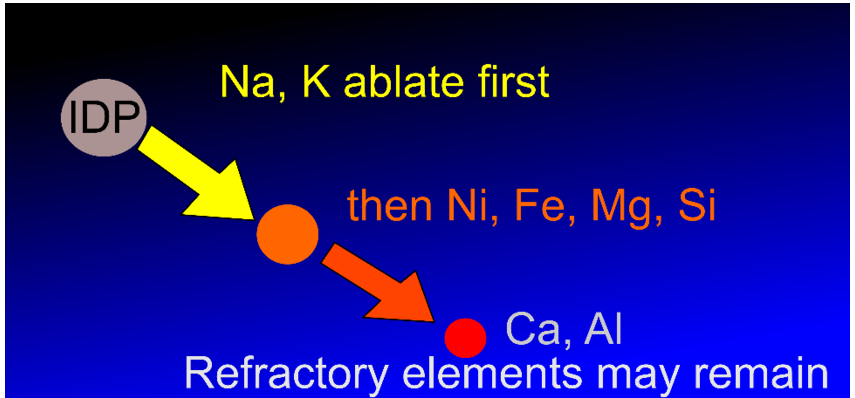
- About 28 tonnes/day of dust enters the Earth's atmosphere
- Meteoroids ranging in size from 10 microns up to 1 mm (plus occasional more massive objects)
- As they heat up on entry, they start to evaporate
- This leaves layers of metal atoms and ions in the Earth's mesosphere
- Produce meteoric smoke, potentially nucleate noctilucent clouds
- Constant flux of matter to the Earth's surface



- Meteors have also been observed to **fragment** on entry
- This changes their size distribution and the resultant meteoric input
- Also could provide **nucleation sites** e.g. for **polar stratospheric clouds**
- **MeteorStrat** project: does fragmentation result in nucleation sites?
- Questions: when, where and why do they fragment?
- Hypothesis: the hydrocarbon compounds in these meteoroids are acting as a glue. At a certain temperature this glue fails, meteoroid fragments.

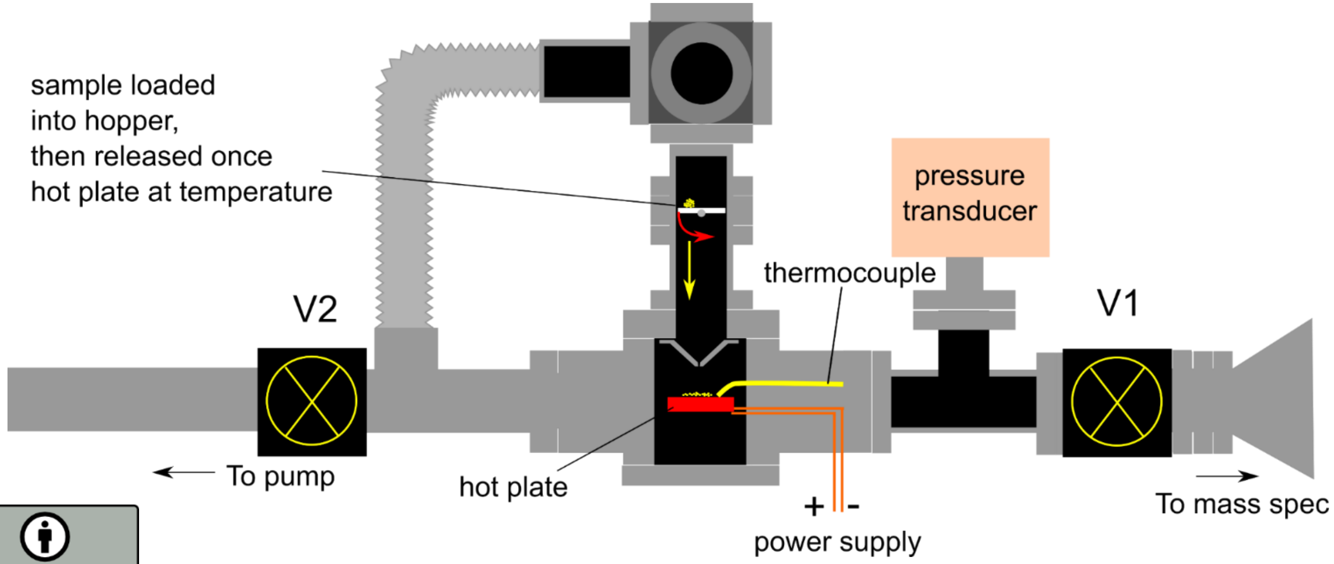
Aims:

- Measure the rate of ablation of carbon compounds from meteoroid proxies as a function of **temperature**
- Measure the tensile strength of meteoroid proxies before and after heating (also as a function of maximum temperature)
- Produce a fragmentation model to predict the meteoric fragment input to the stratosphere

MASI 2 - Vacuum chamber attached to mass spectrometer

Temperature range: 293 – 1273 K

Organic carbon expected to ablate at ~ 900 K



Experiment:

- Pre-heat surface e.g. to 900 K
- Measure temperature with thermocouple
- Drop particles onto surface
- Turn off heat

→ Particles flash heated

- CO_2 production measured with mass spectrometer

Meteoroid proxies

Carbonaceous chondrites:

- Jbilet Winselwan (CM2)
- Allende (CV3)

Ordinary chondrite Chergach (H5)

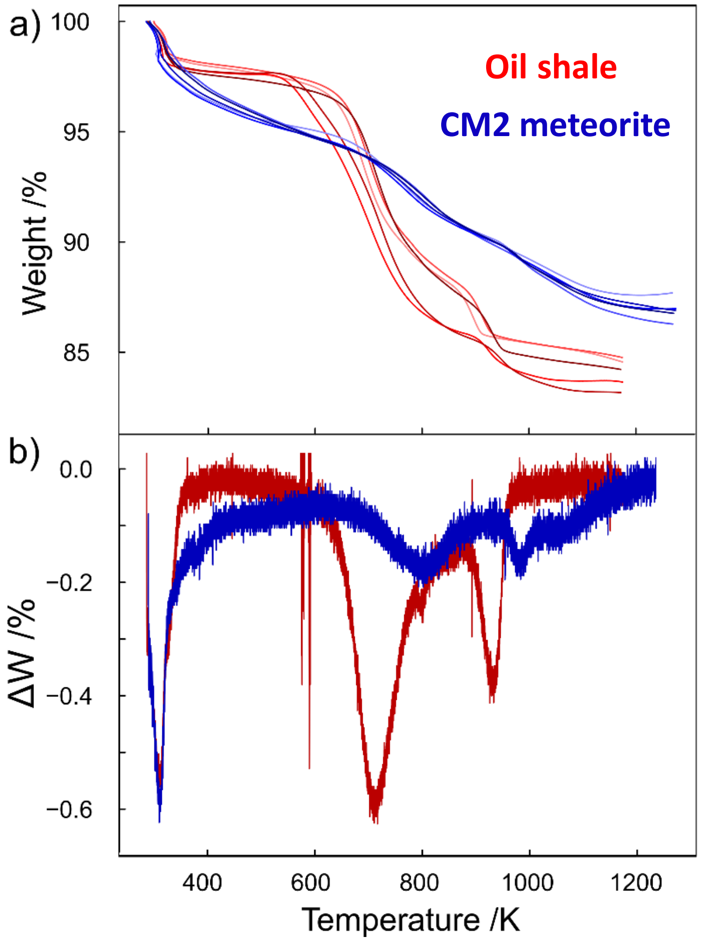
Oil shale

CM chondrites are the (available) terrestrial meteorites closest to cometary dust.

Samples are powdered then size sorted (Endecott test sieve)

Linear temperature ramps

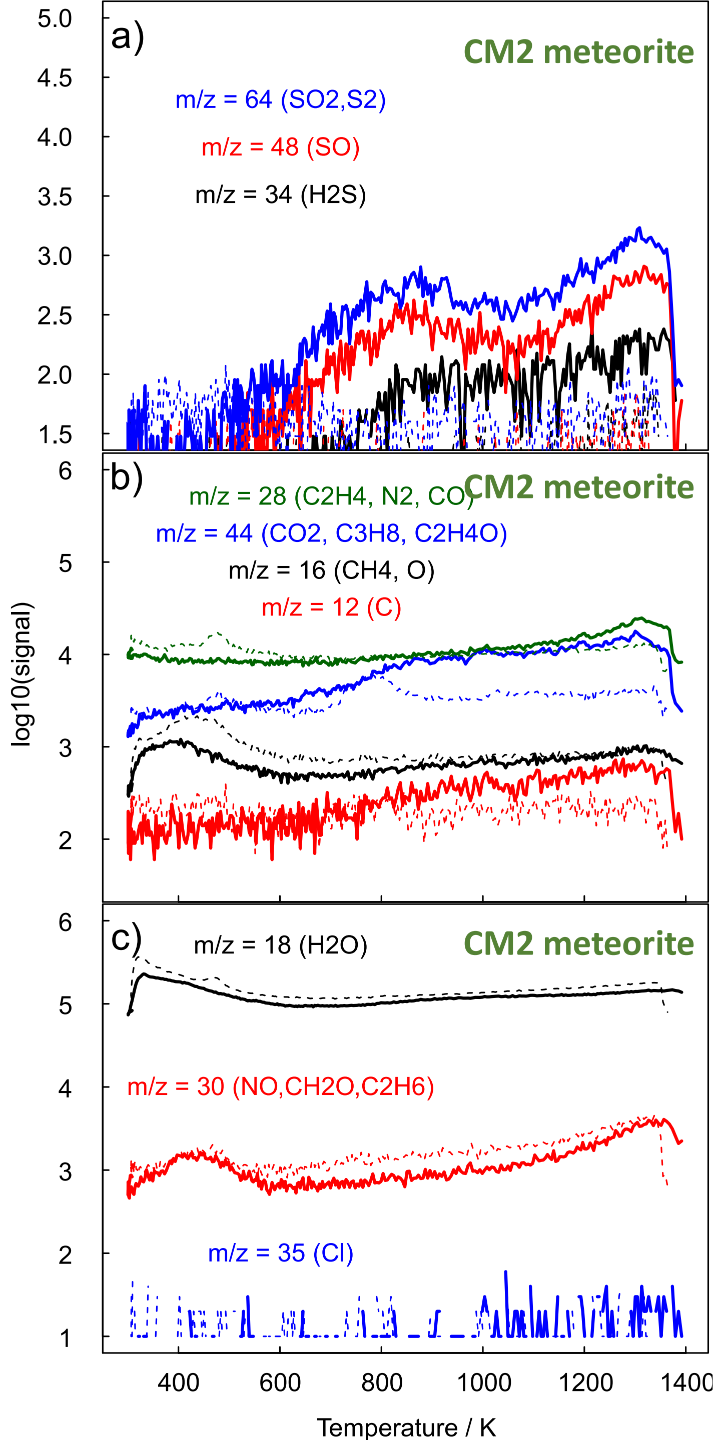
Thermogravimetric analysis; mass spectrometry



S ablates above 500 K

C ablates above 700 K

Ablated C (total) to ablated S (total): 7:1 (CM2 meteorite ratio about 1:1.5)



Oil shale: Clear pyrolysis steps
-> steep temperature dependence
CM2 meteorite: poorly defined steps
-> shallow temperature dependence

Still exploring the kinetics,
But some observations can be made:

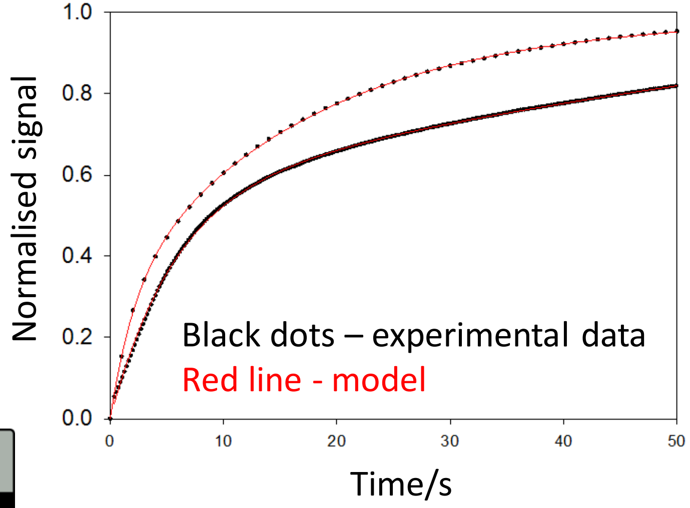
Models suggest that ablation kinetics can be explained by two components of very different volatility

- Organic C in CM meteorites is 5-30% soluble, volatile and 70-95% insoluble, refractory.

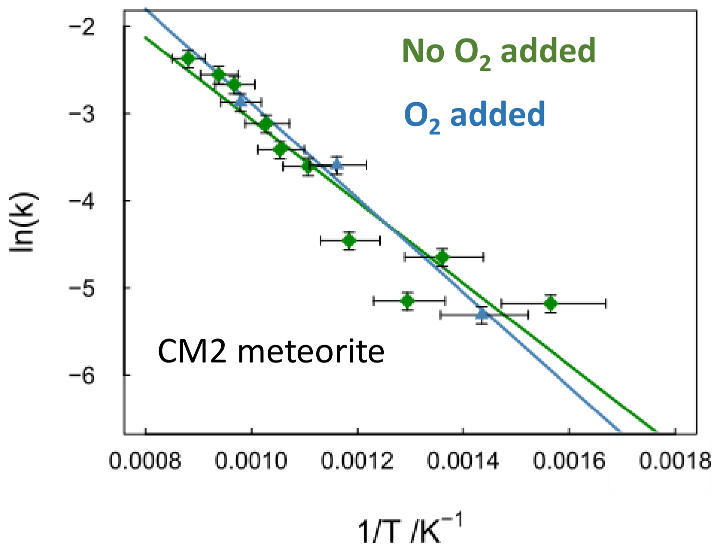
May also need to consider rate of heat transfer in particle

Diffusion out of the particle can help explain rate of CO_2 release

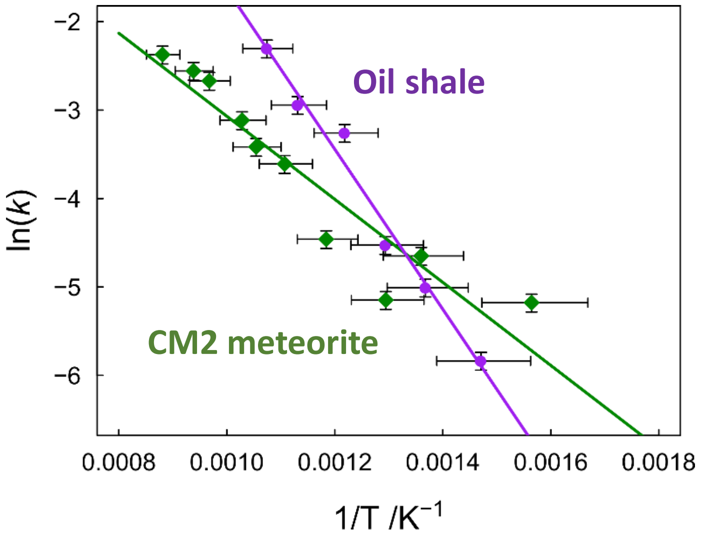
Modelling CO_2 ablation



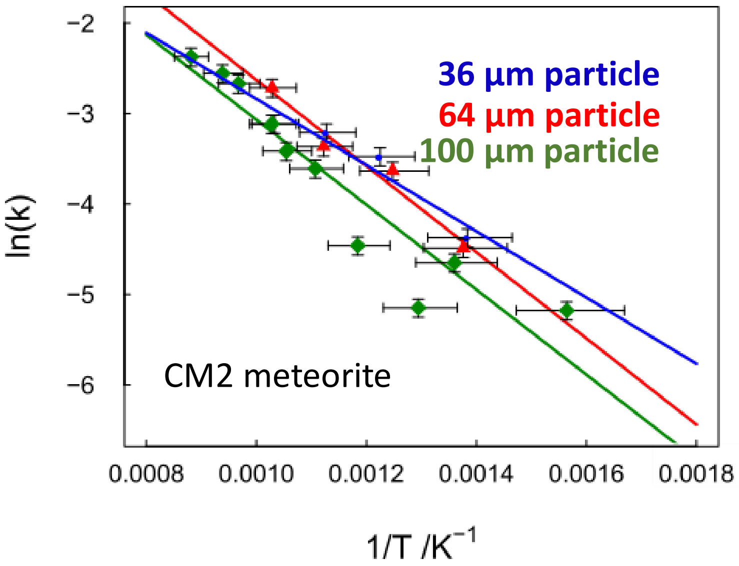
Adding O_2 has no effect



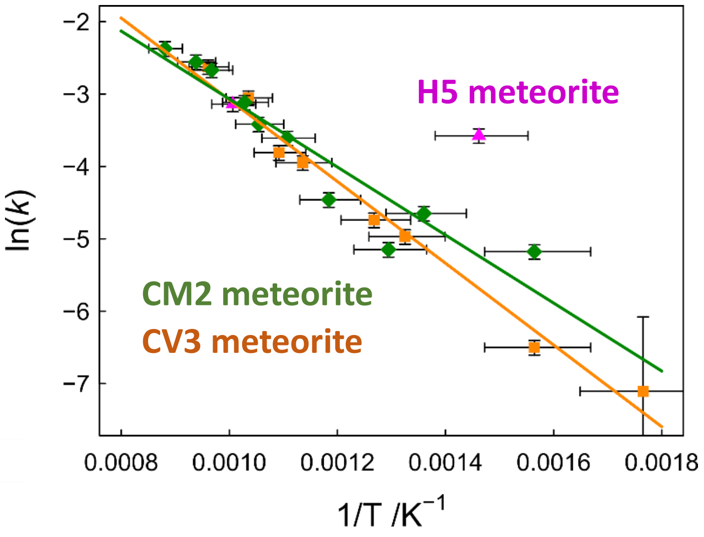
Oil shale shows more temperature dependence than meteorite



Size of particles makes little difference



Type of meteorite does not make much difference



AFM yield stress tests

SEM image of particle in epoxy

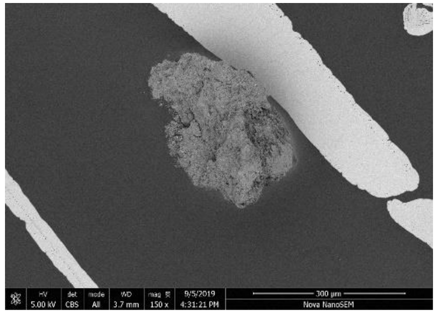
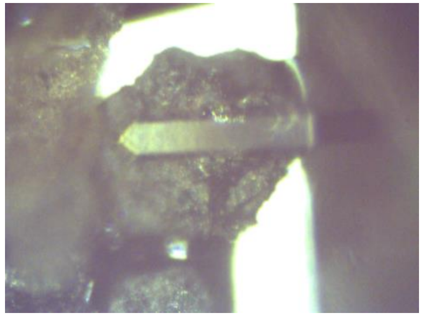
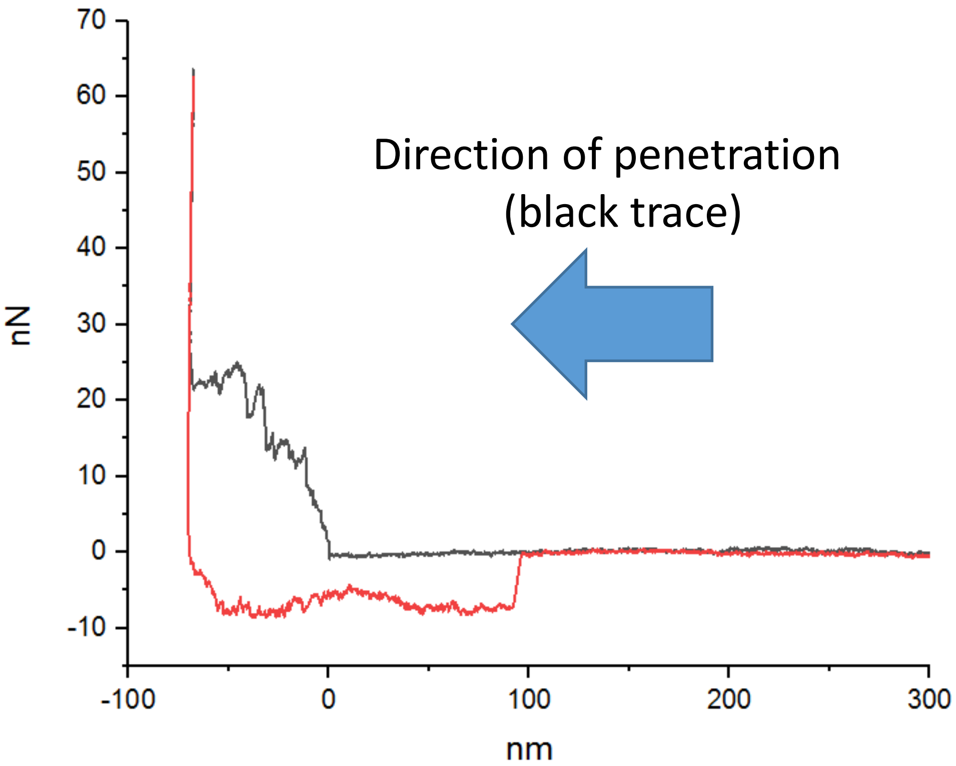


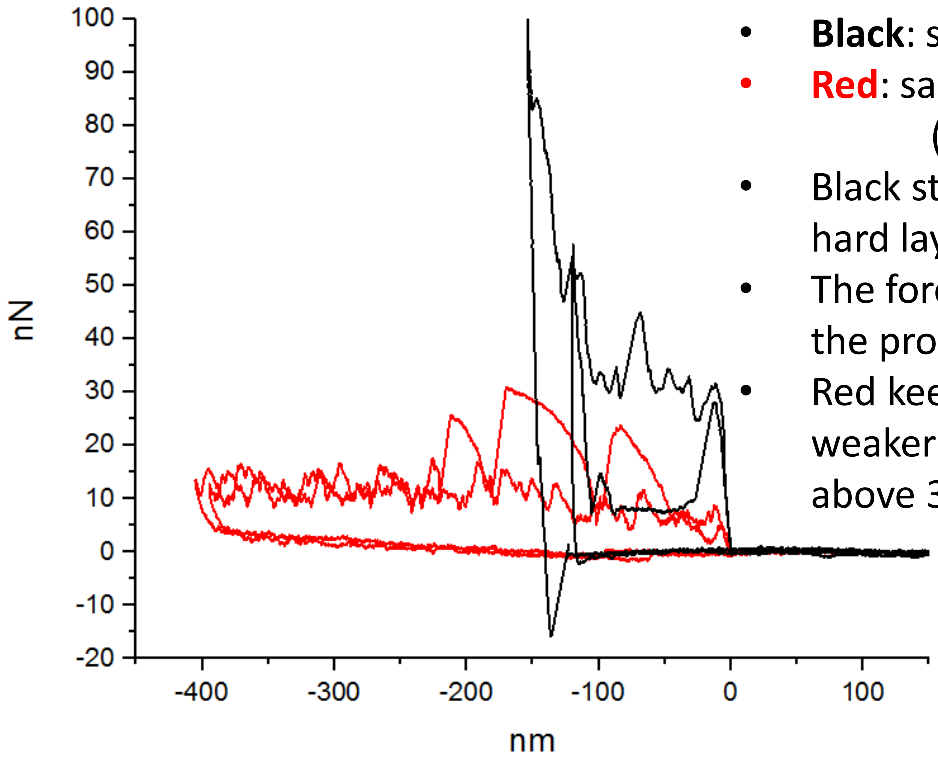
Photo (from above) of cantilever and particle



Single AFM force profile



Overlaid AFM force profiles – heated and unheated oil shale



- **Black**: sample 1 – unheated oil shale
- **Red**: sample 3 – heated oil shale
  (two tests each)
- Black stops penetrating when it hits a hard layer at 150 nm.
- The force goes up to 100 nN, then the probe retracts.
- Red keeps pushing through the weaker layers, force doesn't get above 32 nN

Heating weakens the particles – but tensile strength is too high (~10^6 Pa) for fragmentation

Conclusions

- At temperatures above 1000 K, all carbon is ablated in seconds
- Oil shale and CM2 meteorite particles are not weak enough even after heating to fragment at atmospheric pressures (e.g. 1000 Pa)
- Cosmic dust consists of:
  - 10% Oort cloud comets – very fast, could ablate completely
  - 80% Kuiper belt (Jupiter family comets) – fragile, high in carbon - may fragment to large extent
  - 10% asteroid belt dust - dense, does not fragment, recovered as terrestrial micrometeorites