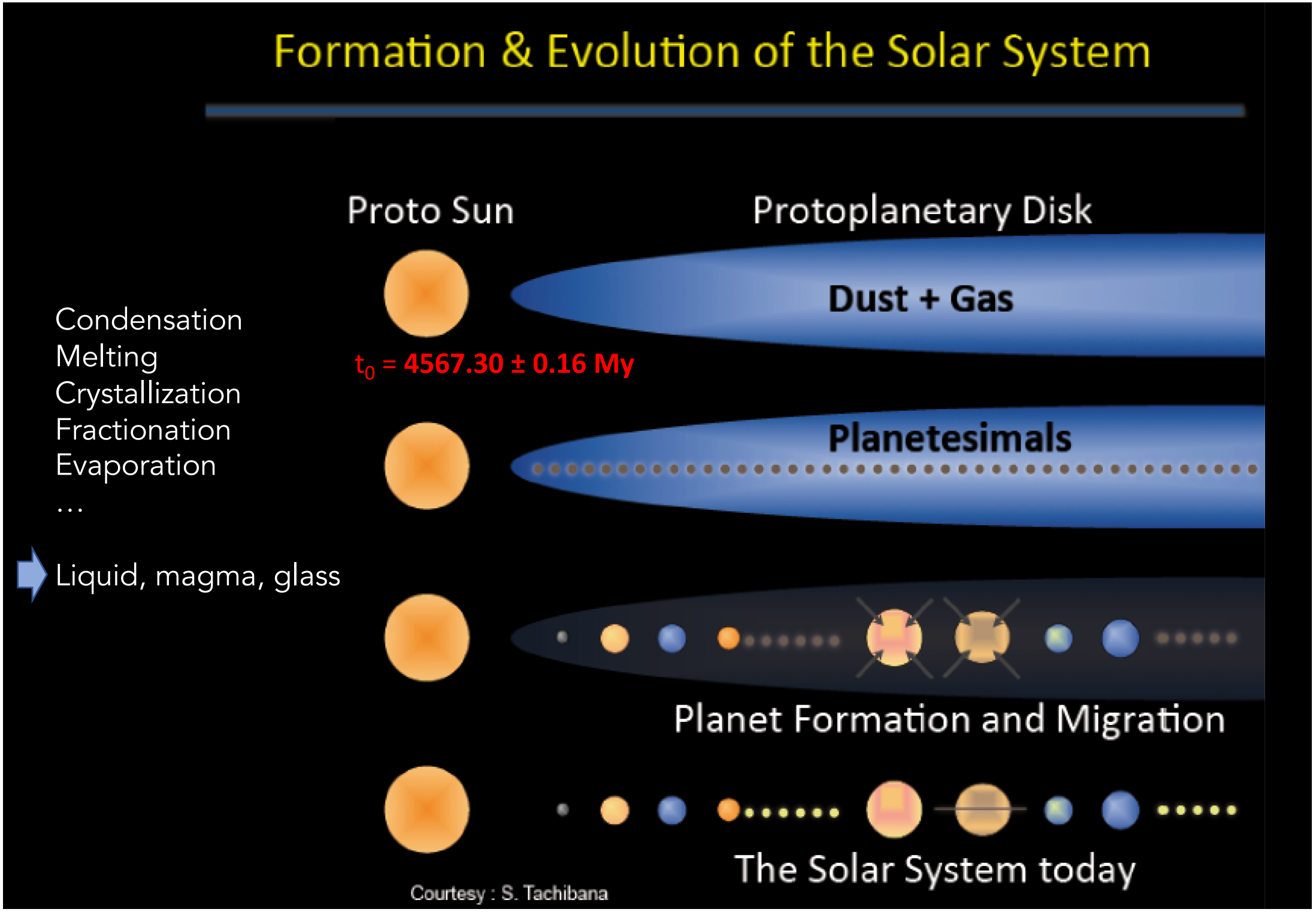
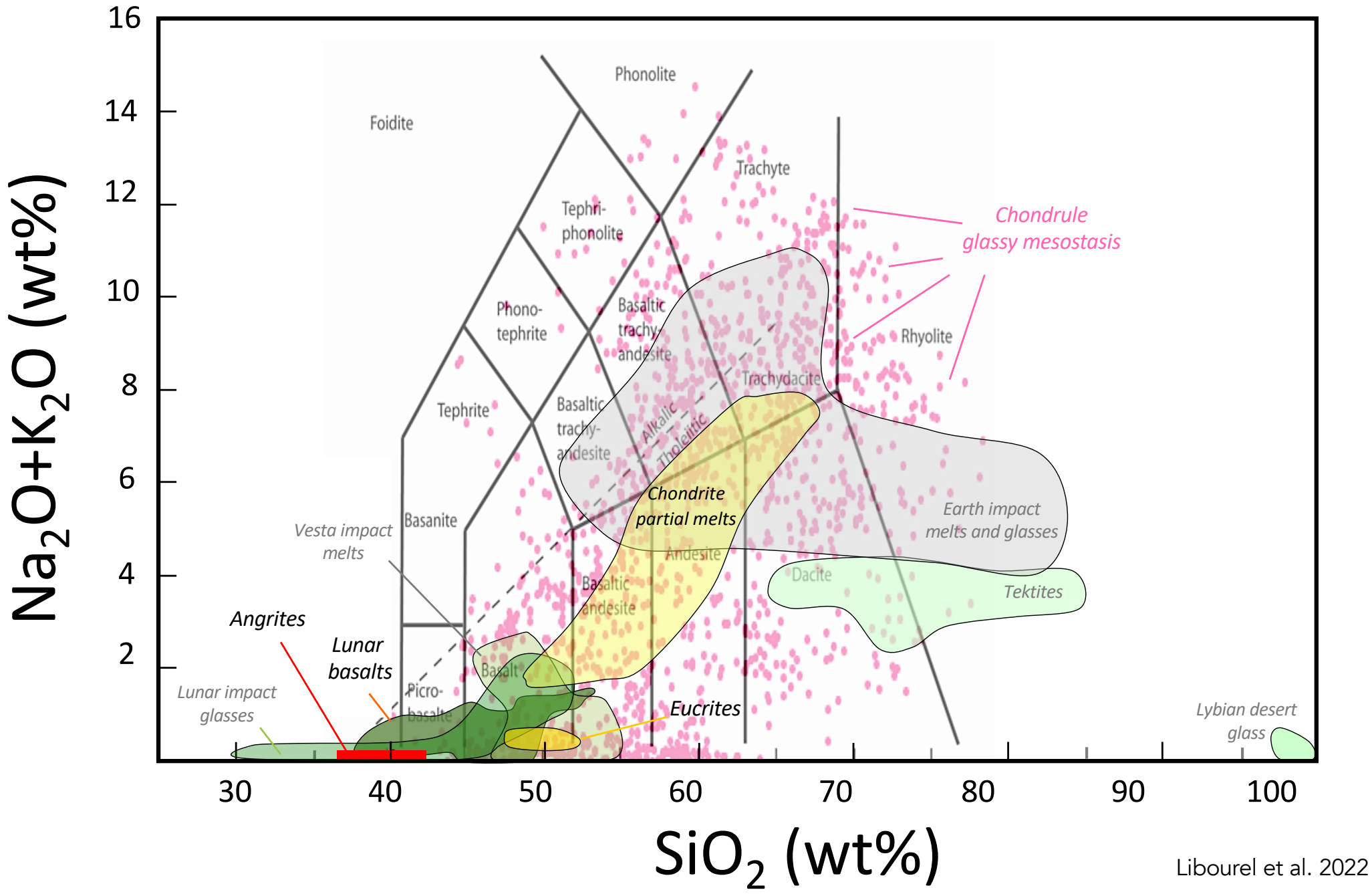
Verres extraterrestres

Guy Libourel,
Université Côte d'Azur,
Observatoire de la Côte d'Azur
Laboratoire Lagrange

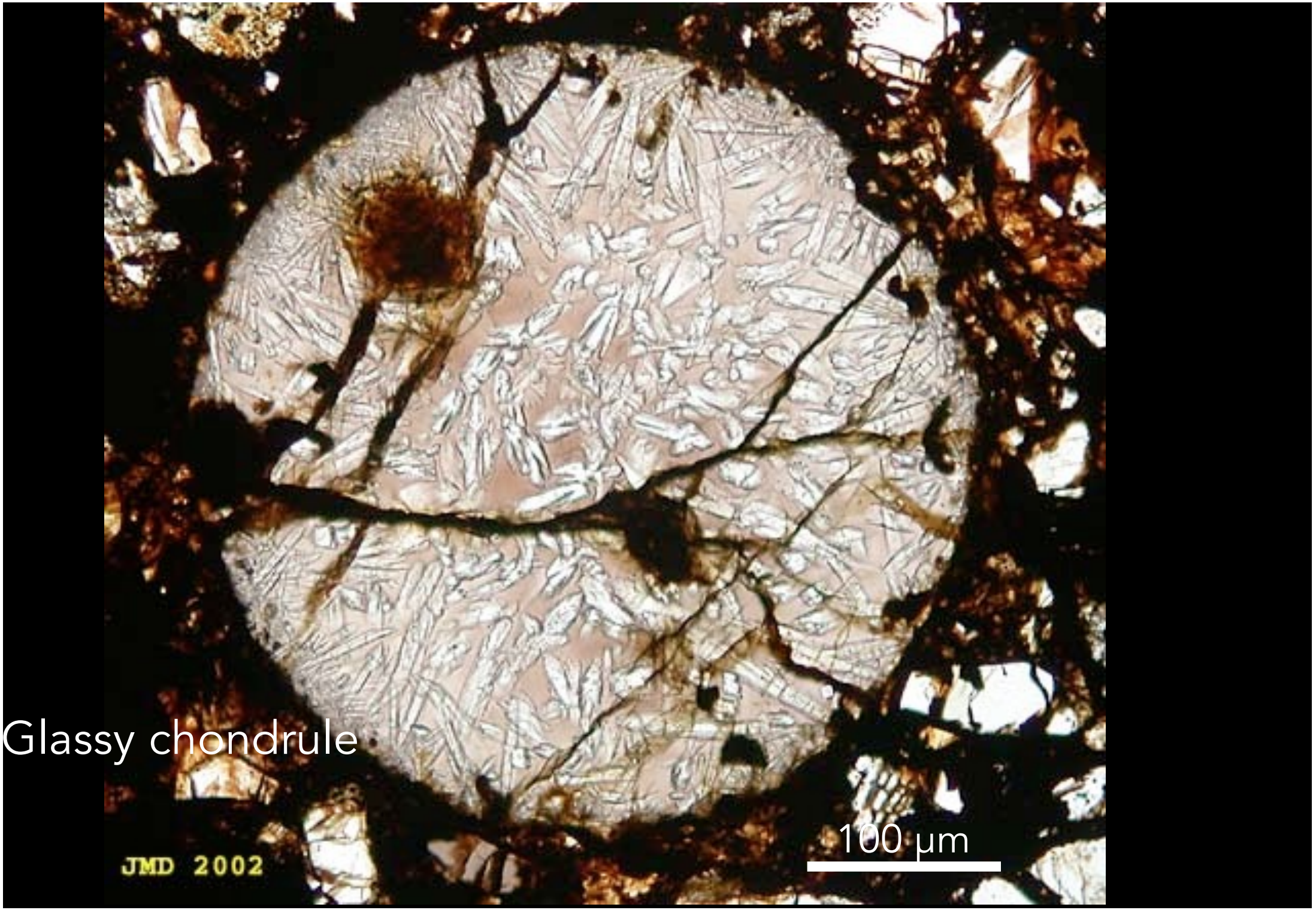
December 6th, 2020, Woomera desert, Australia


Formation & Evolution of the Solar System
Proto Sun
Protoplanetary Disk
Dust + Gas
Condensation
Melting
Crystallization
Fractionation
Evaporation
…
t_0 = 4567.30 ± 0.16 My
Planetesimals
Liquid, magma, glass
Planet Formation and Migration
The Solar System today
Courtesy : S. Tachibana

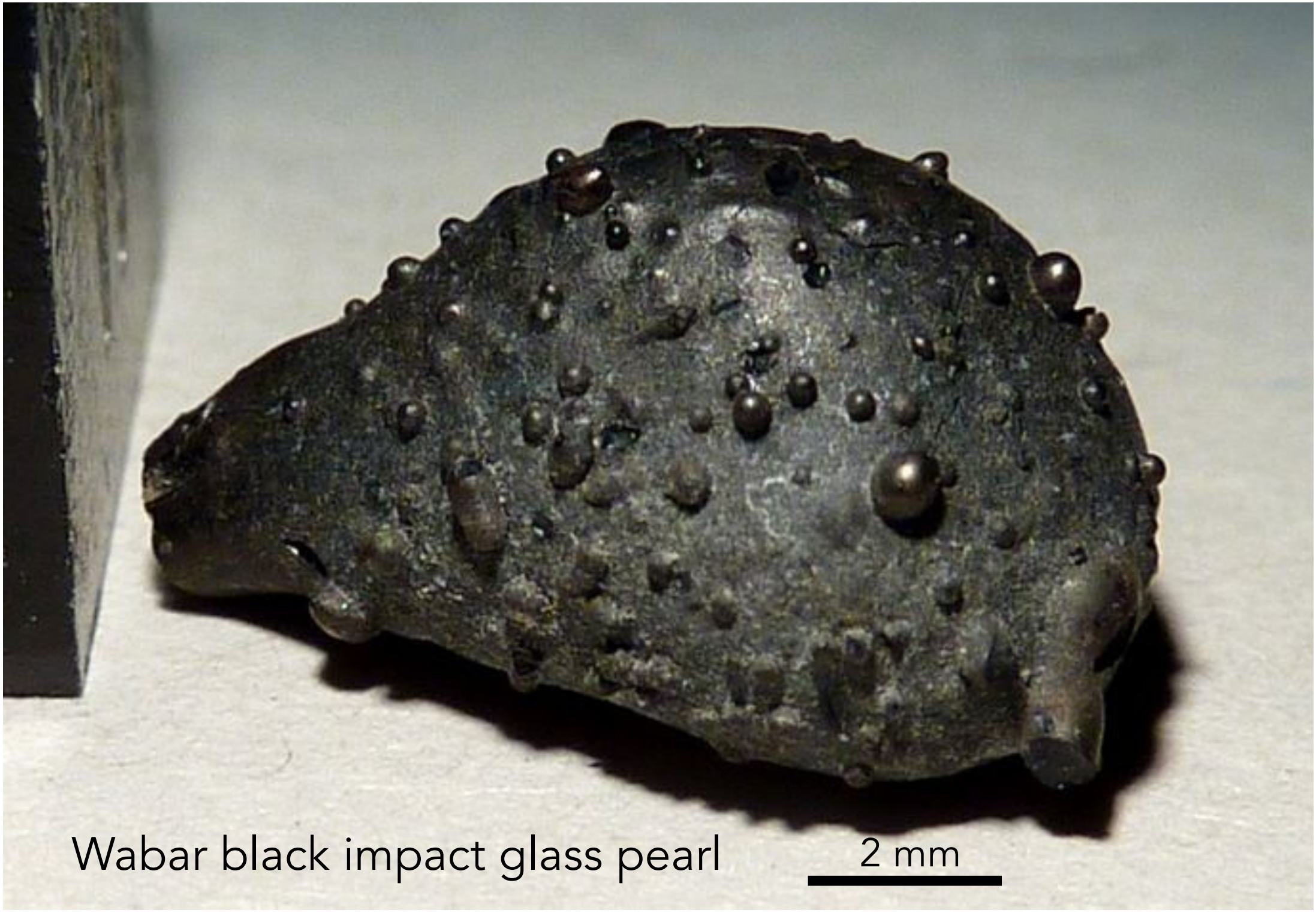
Verres extraterrestres

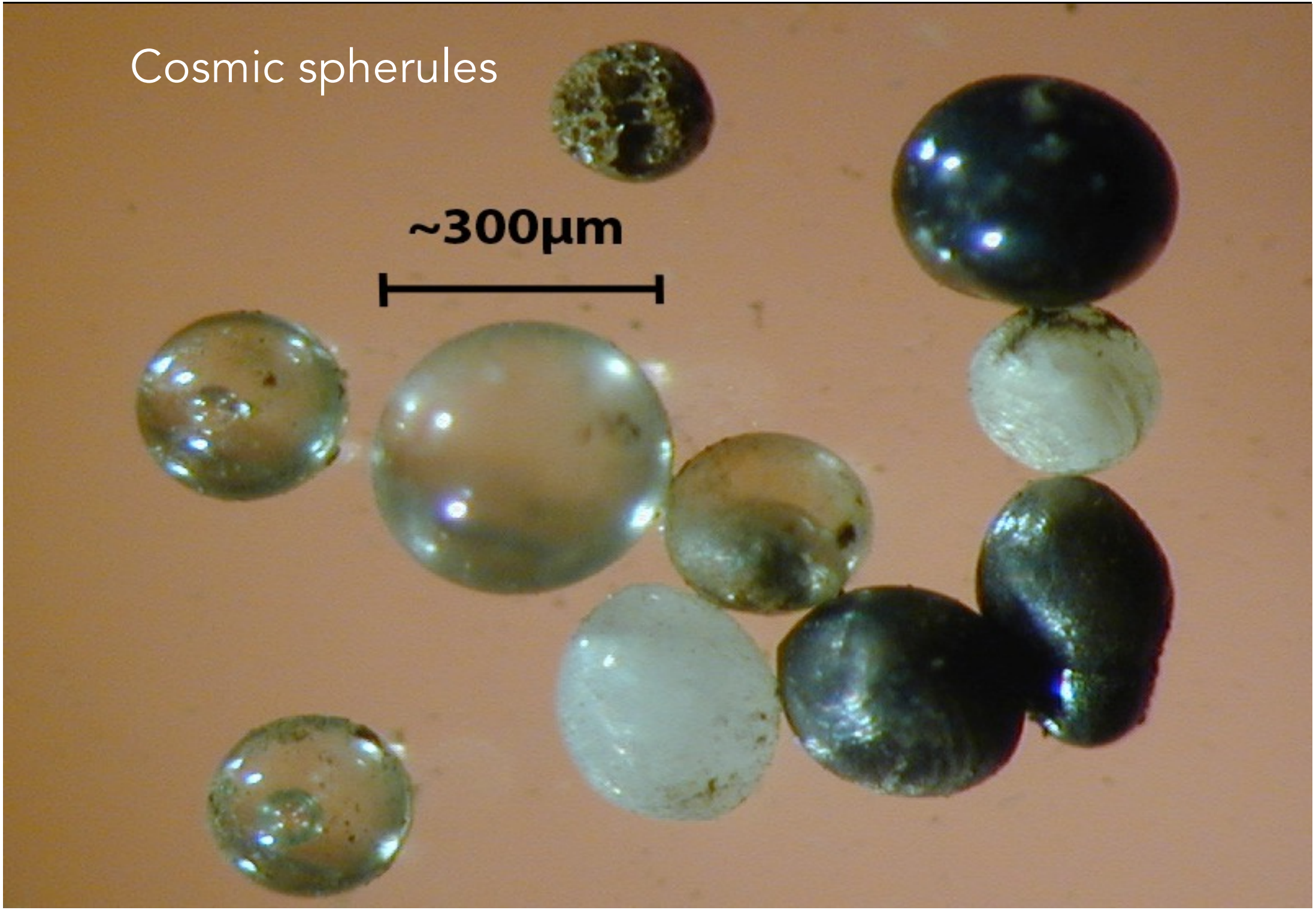


Libourel et al. 2022

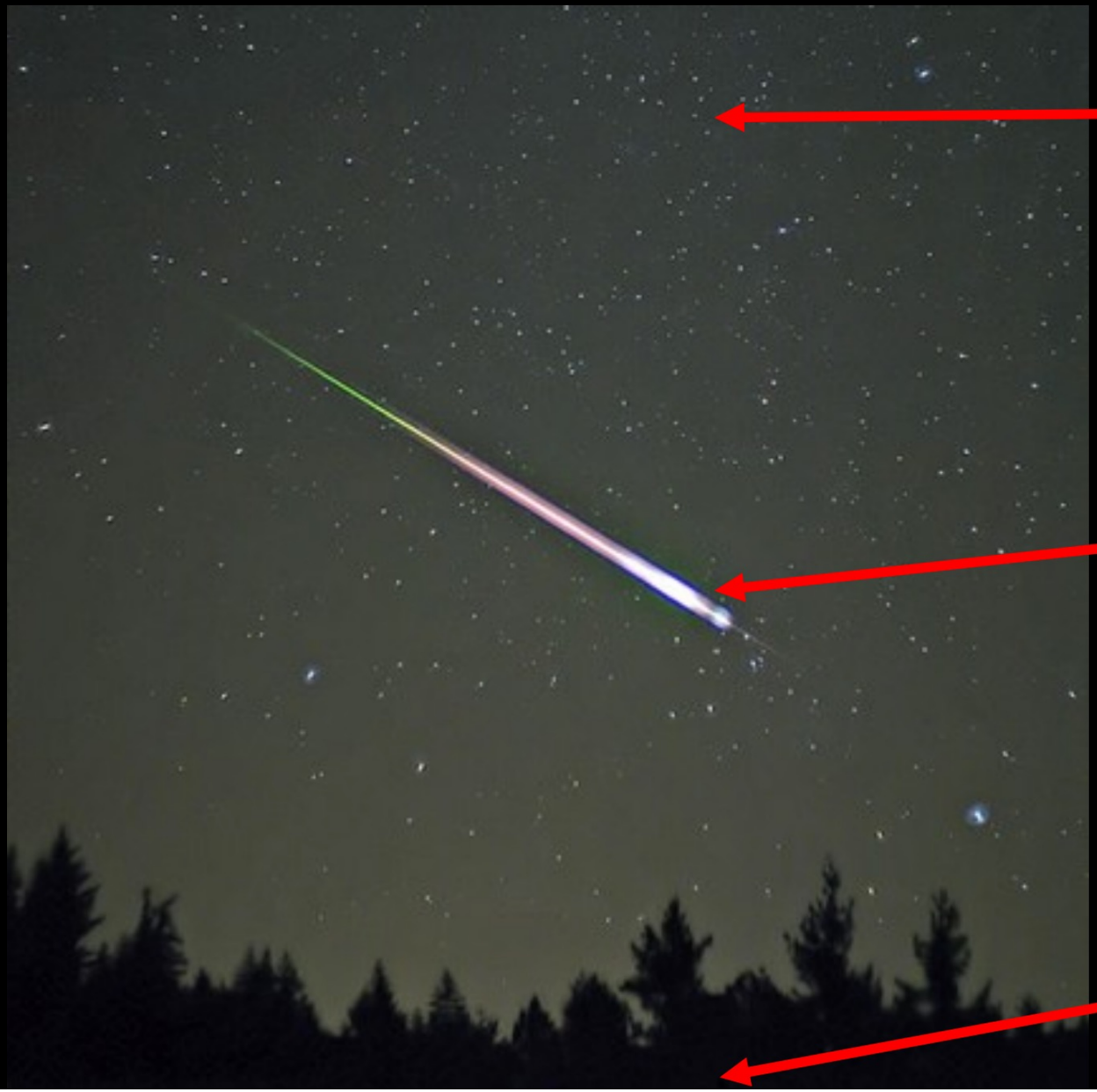

Glassy chondrule
100 μm
JMD 2002


Libyan desert glass
5 cm


Wabar black impact glass pearl
2 mm


Cosmic spherules
~300µm

Meteors?



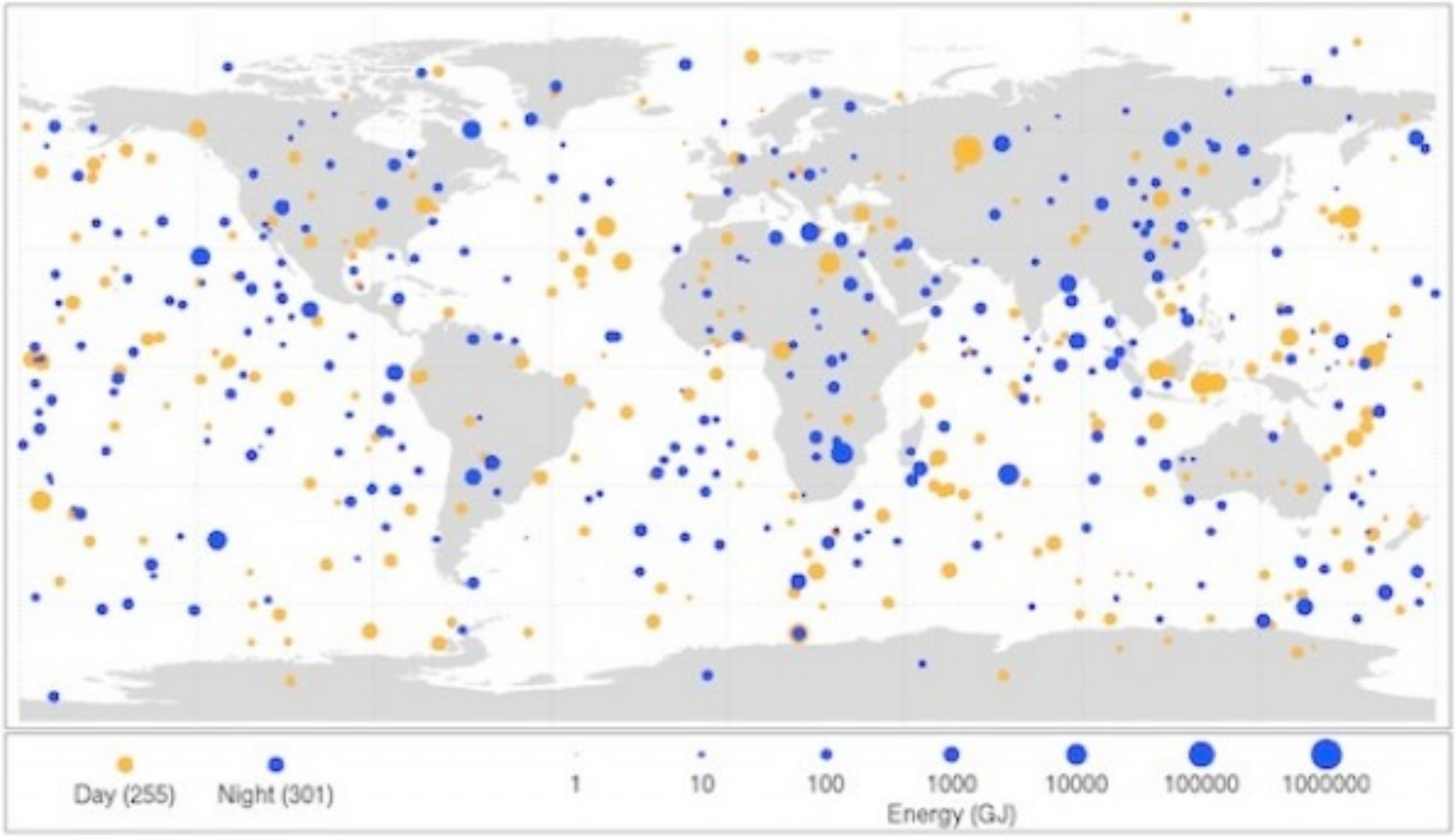
Meteoroid
in space

Meteor
in atmosphere

Meteorite
on Earth

Bolide Events 1994 – 2013

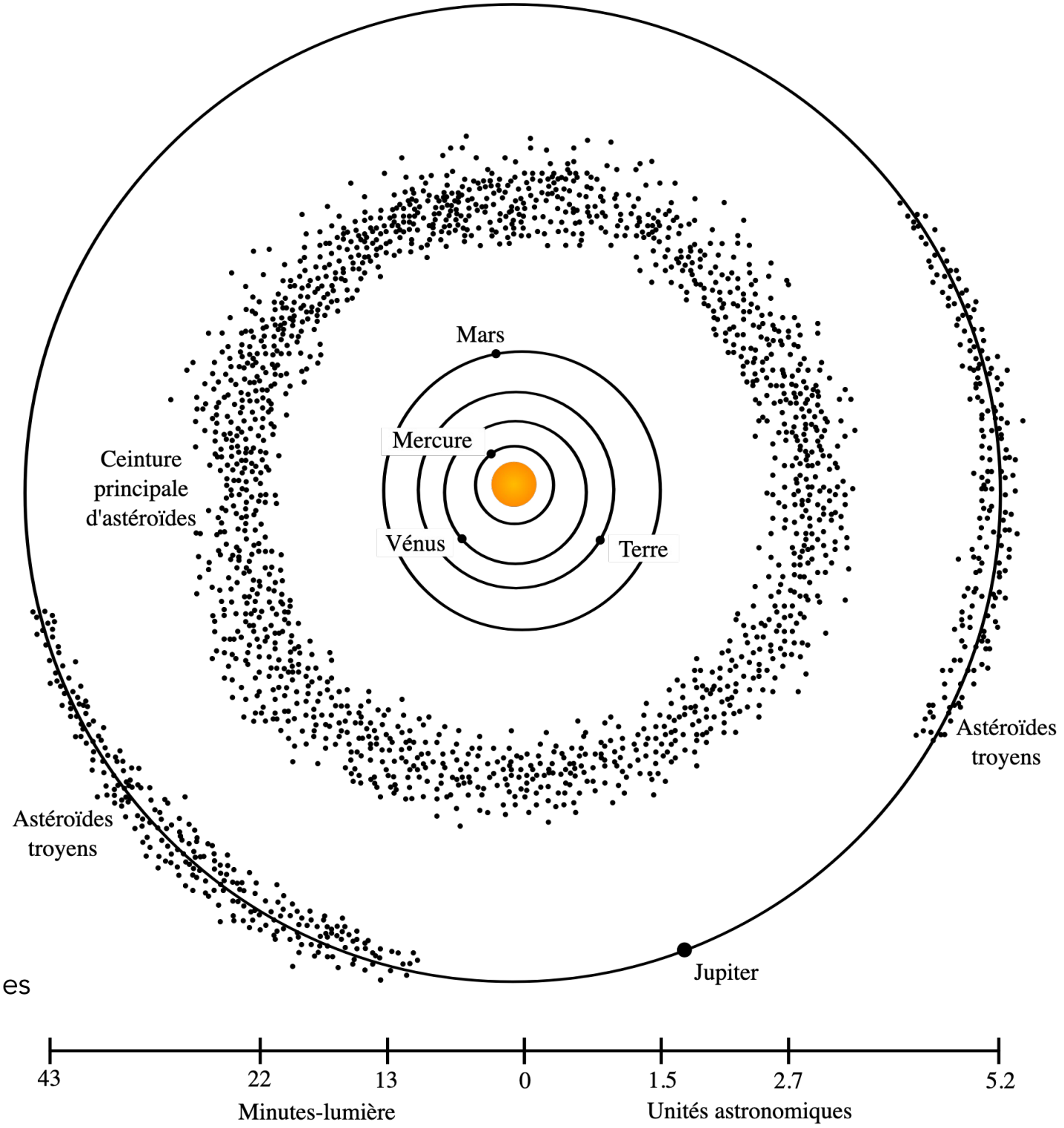
Small Asteroids that Disintegrated in Earth's Atmosphere



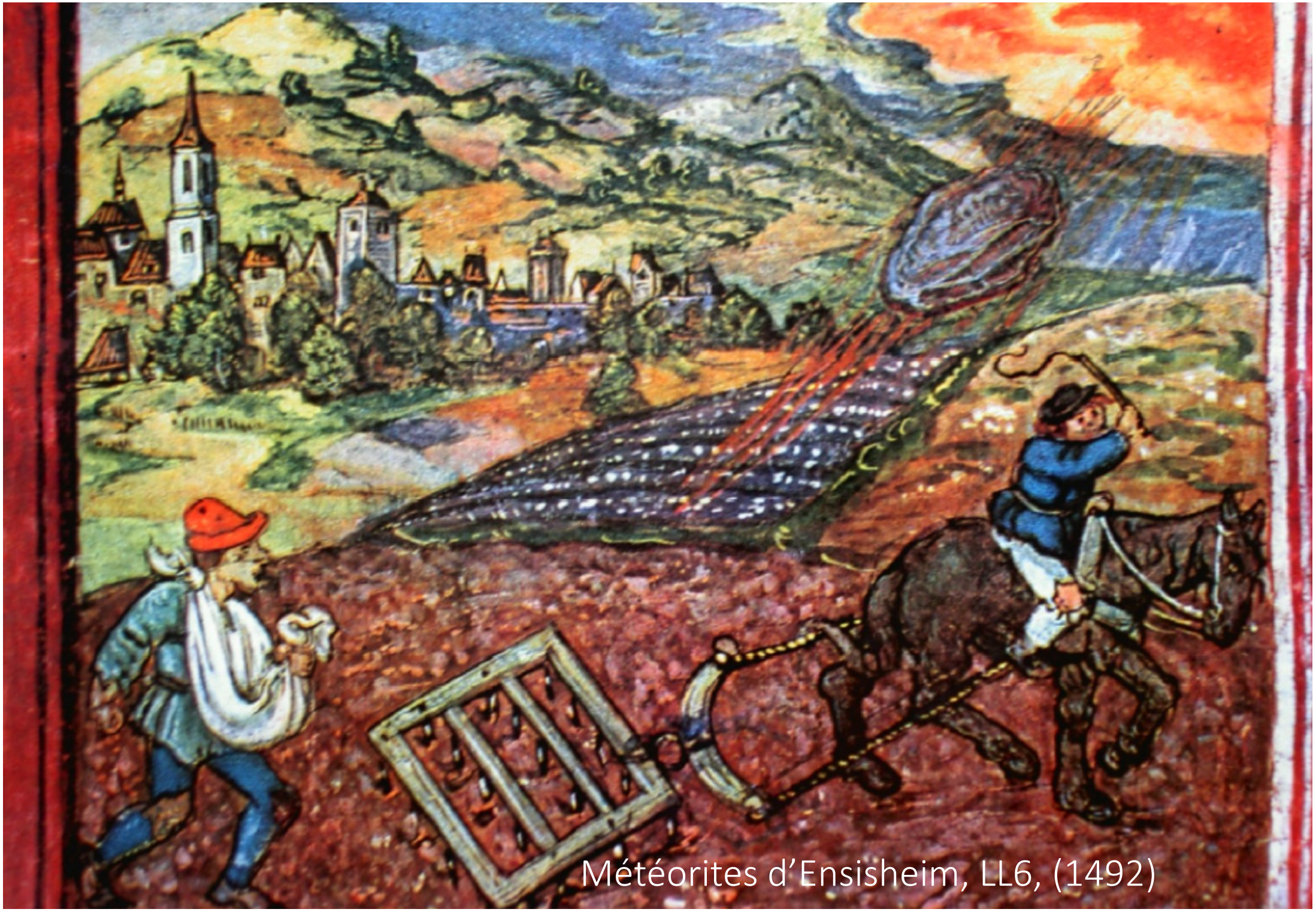
Flux of extraterrestrial matter on the surface of the Earth

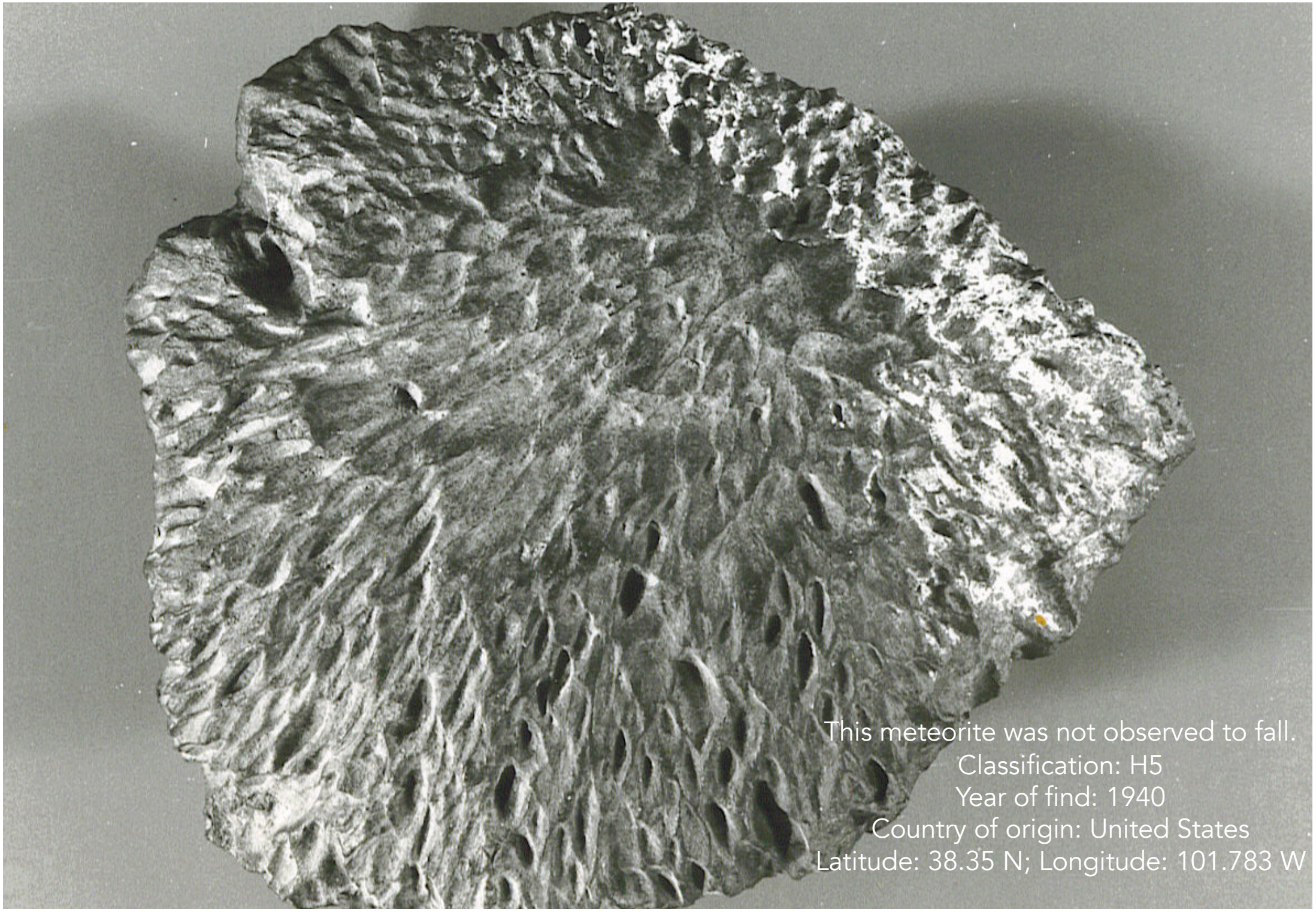
Mass	Flux	
[1µg – 1mg]	30 000	ton per year
[10g – 1kg]	7	ton per year
[10g – 100 kg]	54	ton per year
> 1000 kg	–	

Gounelle, 2017

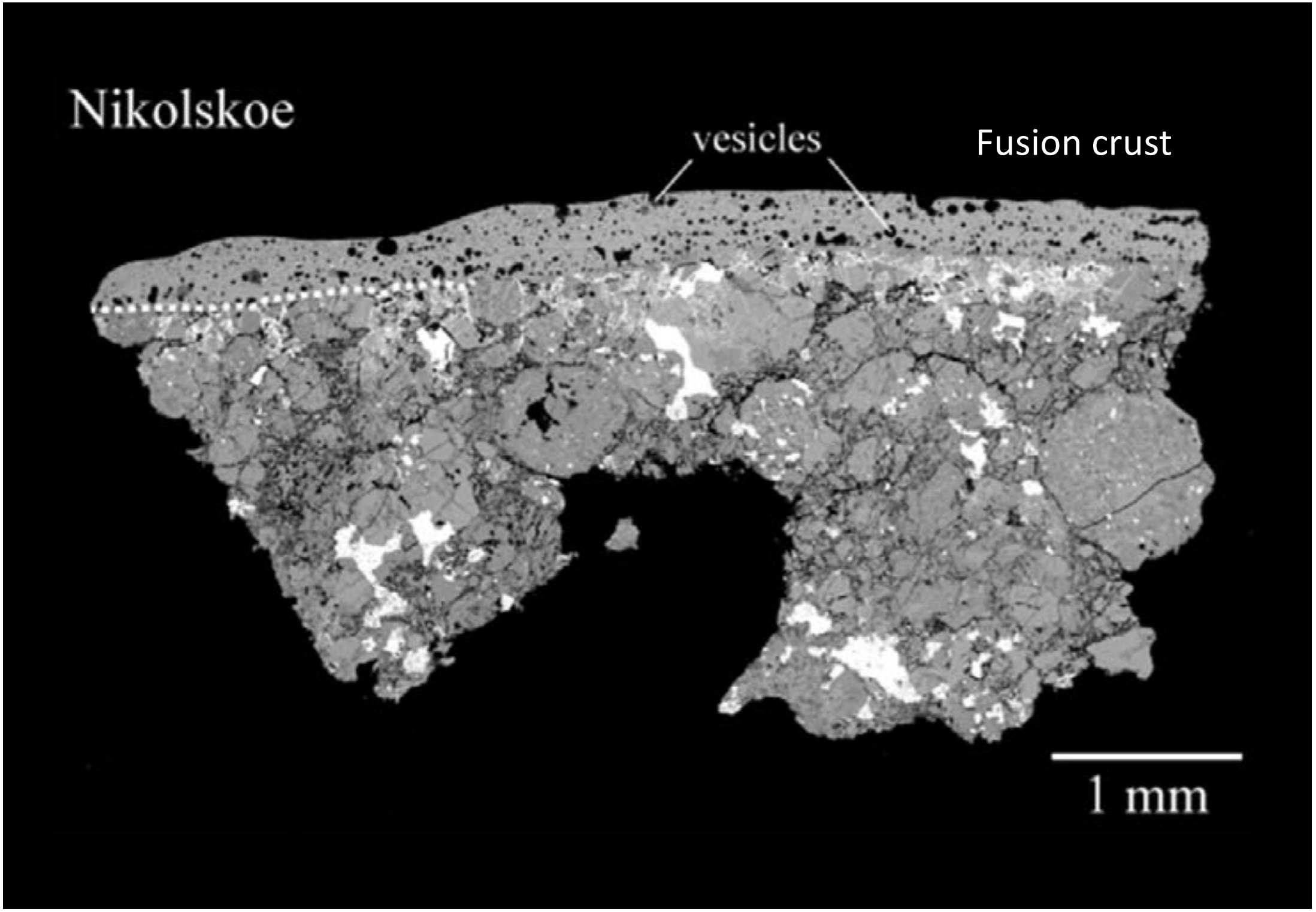


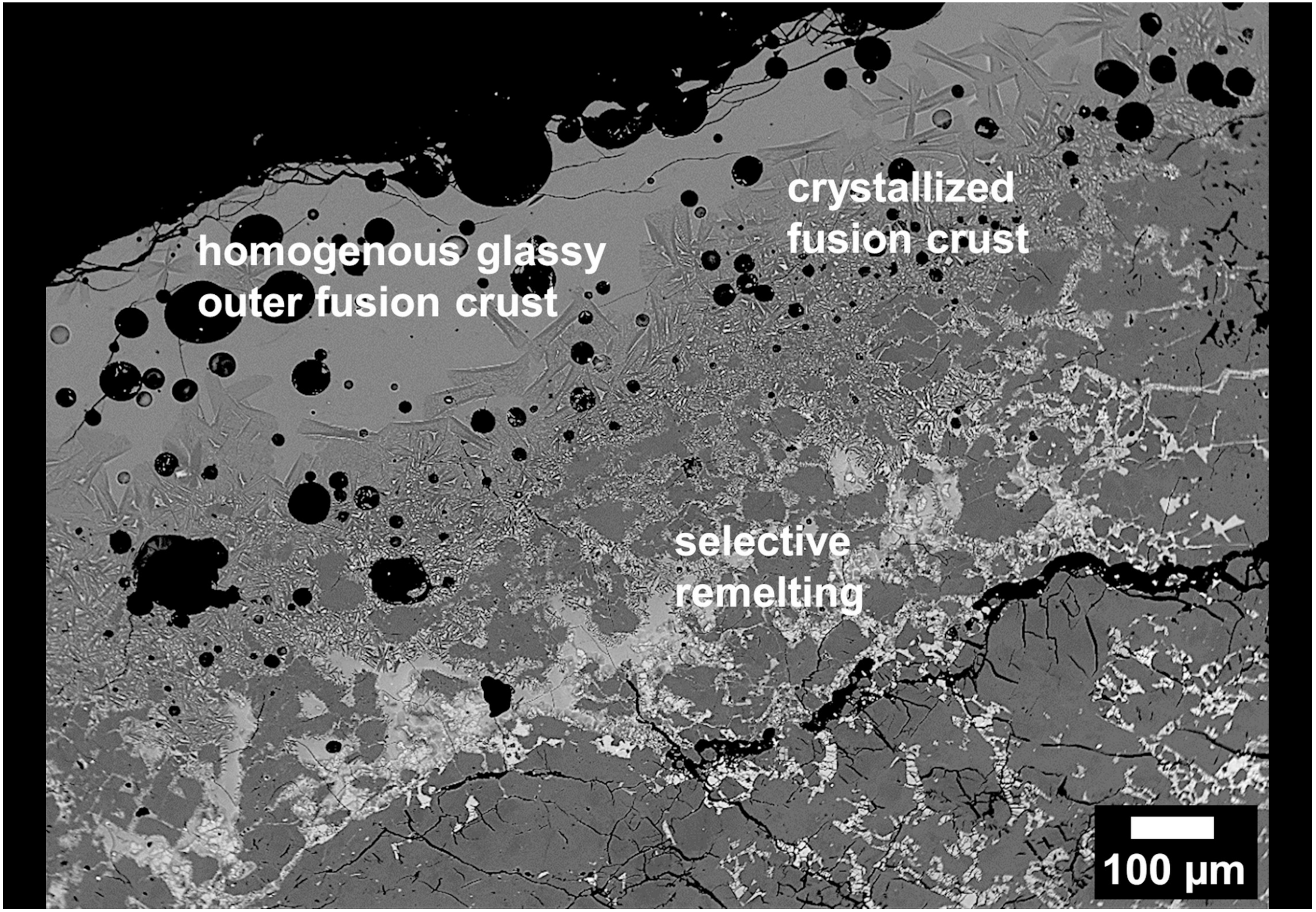
Résonances orbitales
Collisions

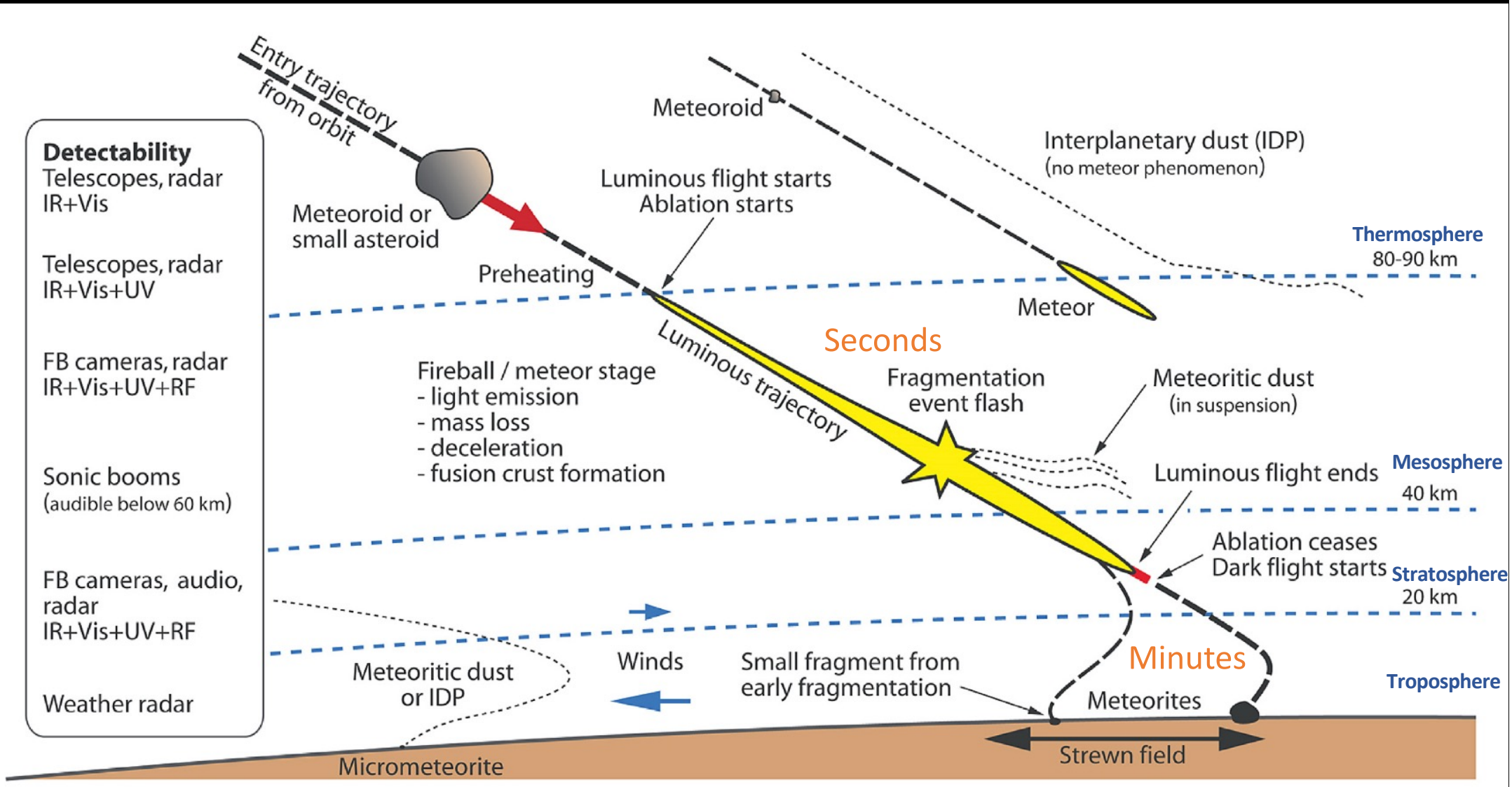

Météorites d’Ensisheim, LL6, (1492)



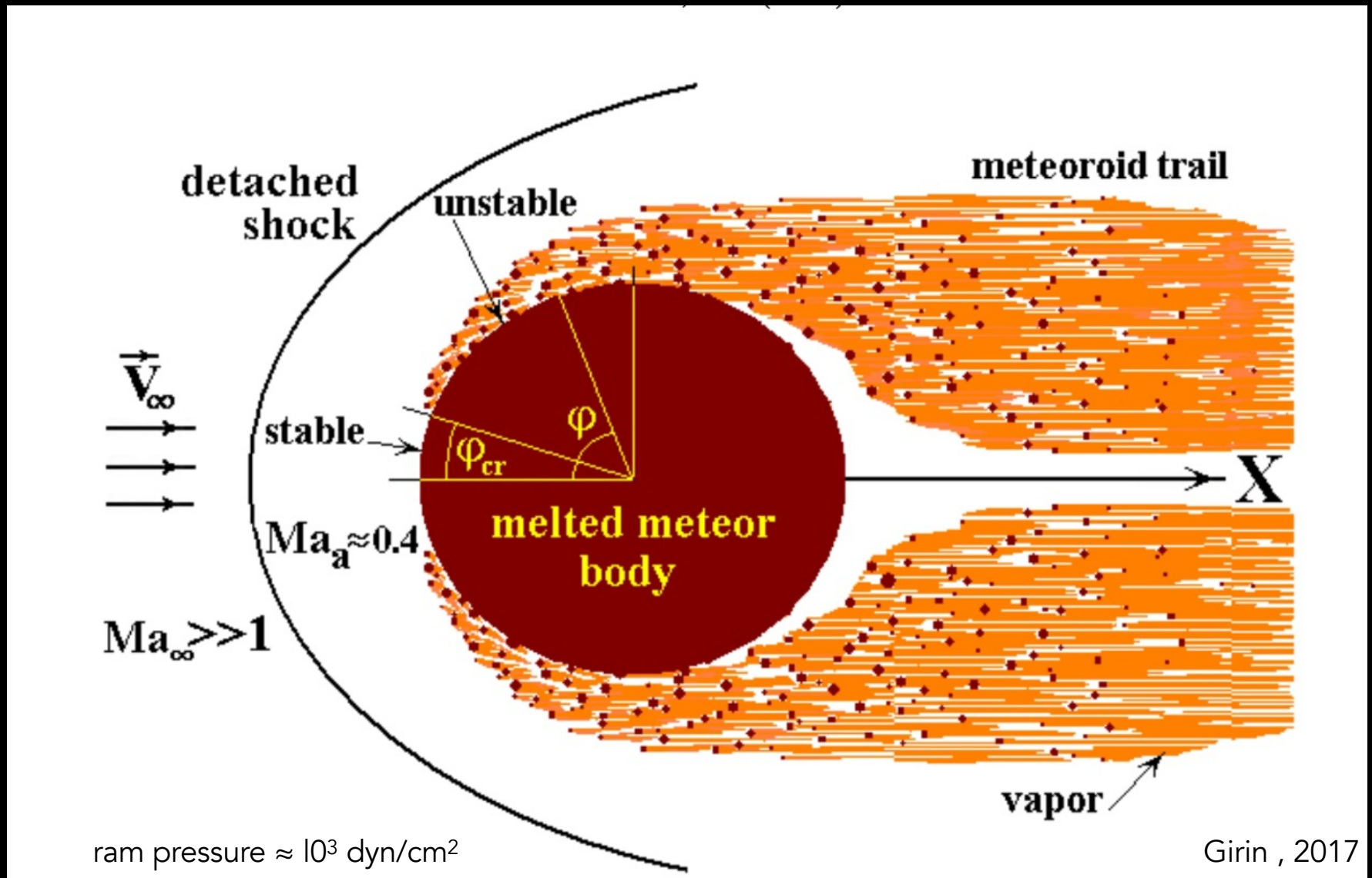
This meteorite was not observed to fall.
Classification: H5
Year of find: 1940
Country of origin: United States
Latitude: 38.35 N; Longitude: 101.783 W


Nikolskoe
vesicles
Fusion crust
1 mm


homogenous glassy
outer fusion crust
crystallized
fusion crust
selective
remelting
100 µm


Detectability
Telescopes, radar
IR+Vis
Telescopes, radar
IR+Vis+UV
FB cameras, radar
IR+Vis+UV+RF
Sonic booms
(audible below 60 km)
FB cameras, audio,
radar
IR+Vis+UV+RF
Weather radar
Entry trajectory
from orbit
Meteoroid
Interplanetary dust (IDP)
(no meteor phenomenon)
Meteoroid or
small asteroid
Luminous flight starts
Ablation starts
Thermosphere
80-90 km
Preheating
Meteor
Seconds
Luminous trajectory
Fireball / meteor stage
- light emission
- mass loss
- deceleration
- fusion crust formation
Fragmentation
event flash
Meteoritic dust
(in suspension)
Luminous flight ends
Mesosphere
40 km
Ablation ceases
Dark flight starts
Stratosphere
20 km
Minutes
Winds
Meteoritic dust
or IDP
Small fragment from
early fragmentation
Troposphere
Meteorites
Strewn field
Micrometeorite

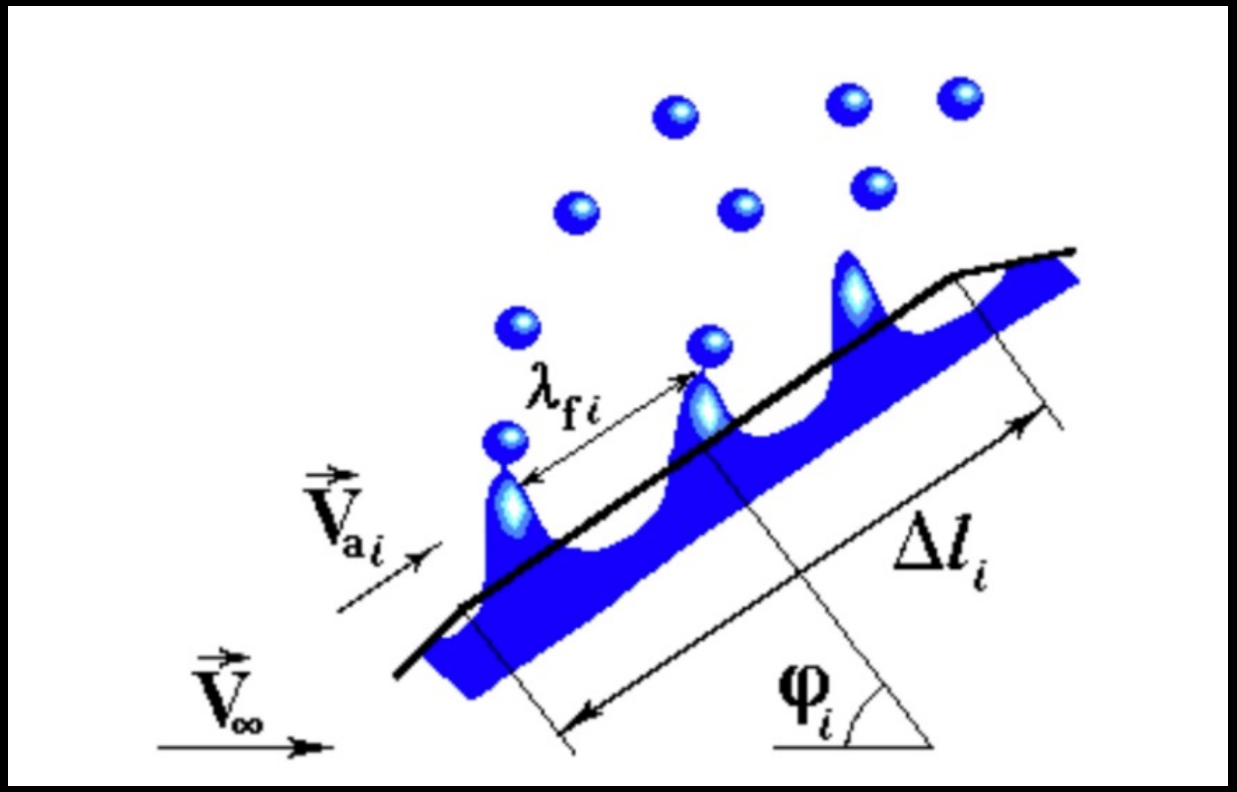
Meteor ablation: melt spraying model



ram pressure ≈ 10^3 dyn/cm^2

Girin , 2017

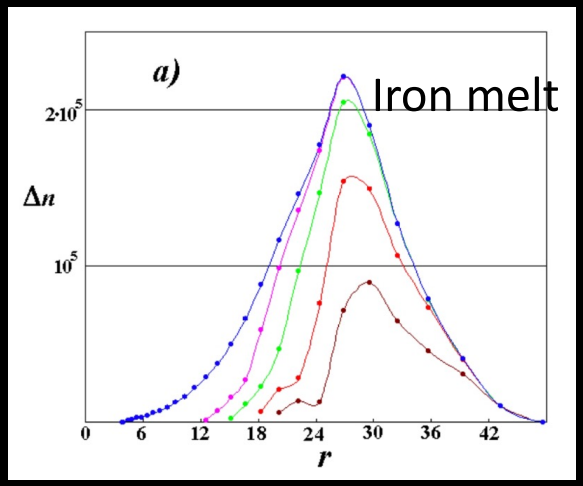
Meteor ablation: melt spraying model



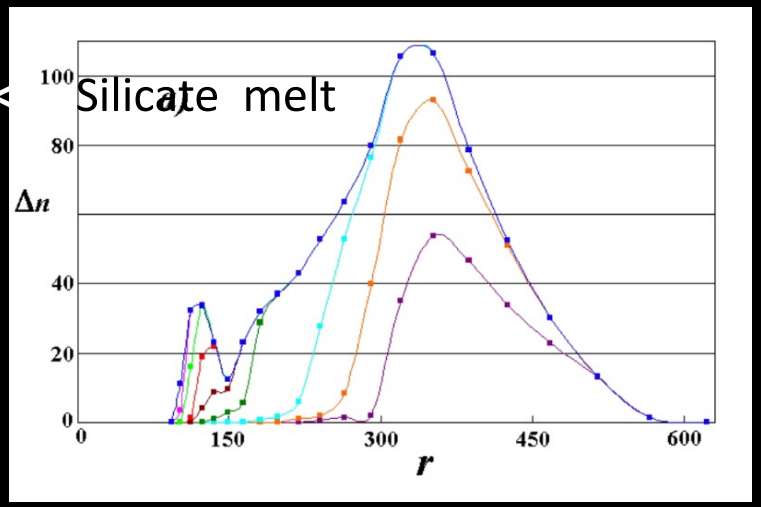
Weber number

$$We = \frac{\rho v_f^2 l}{\sigma}$$

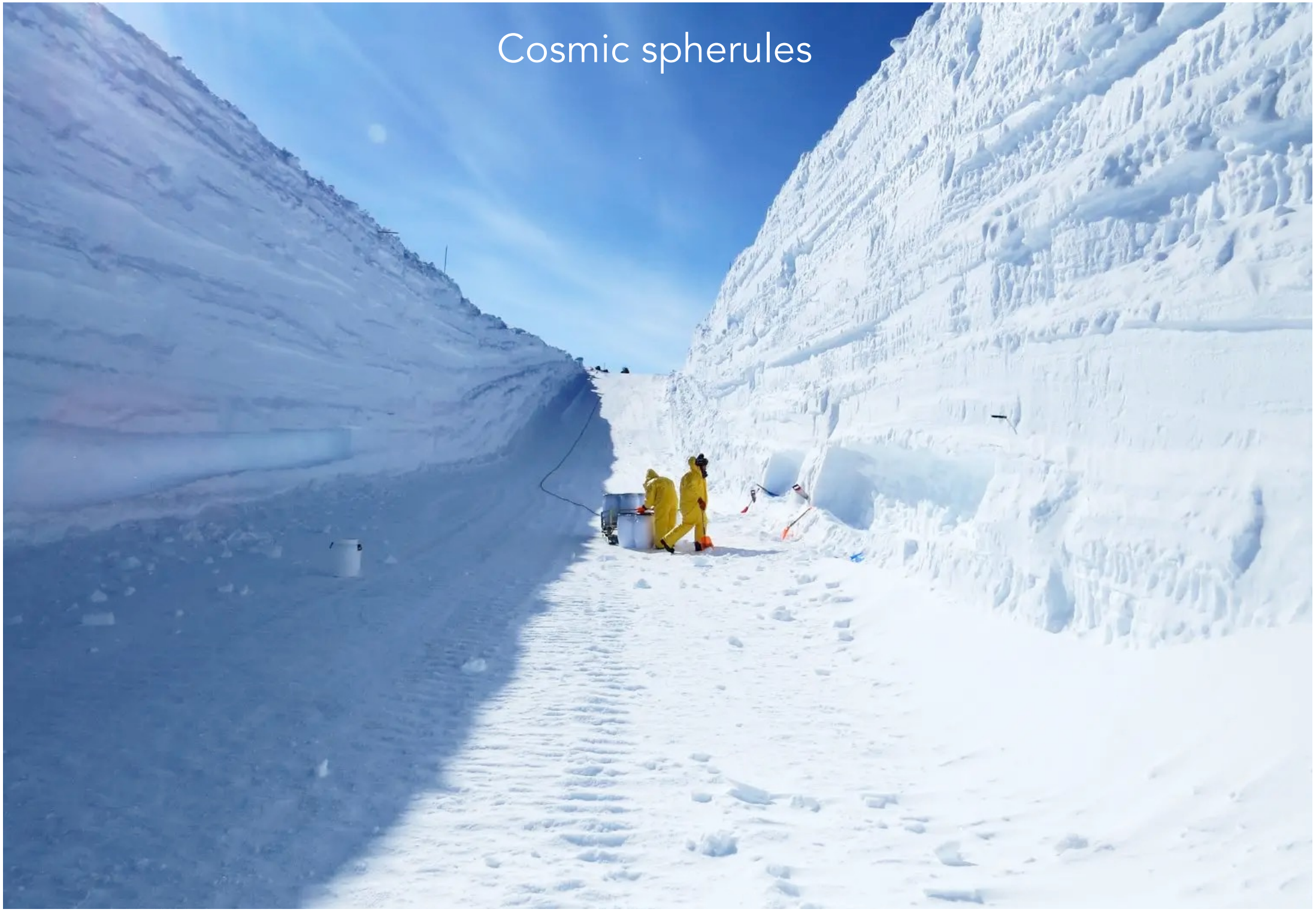
Ratio of the momentum in the vapor layer divided by the surface tension force restraining the liquid



<< Spherule size <<



Cosmic spherules



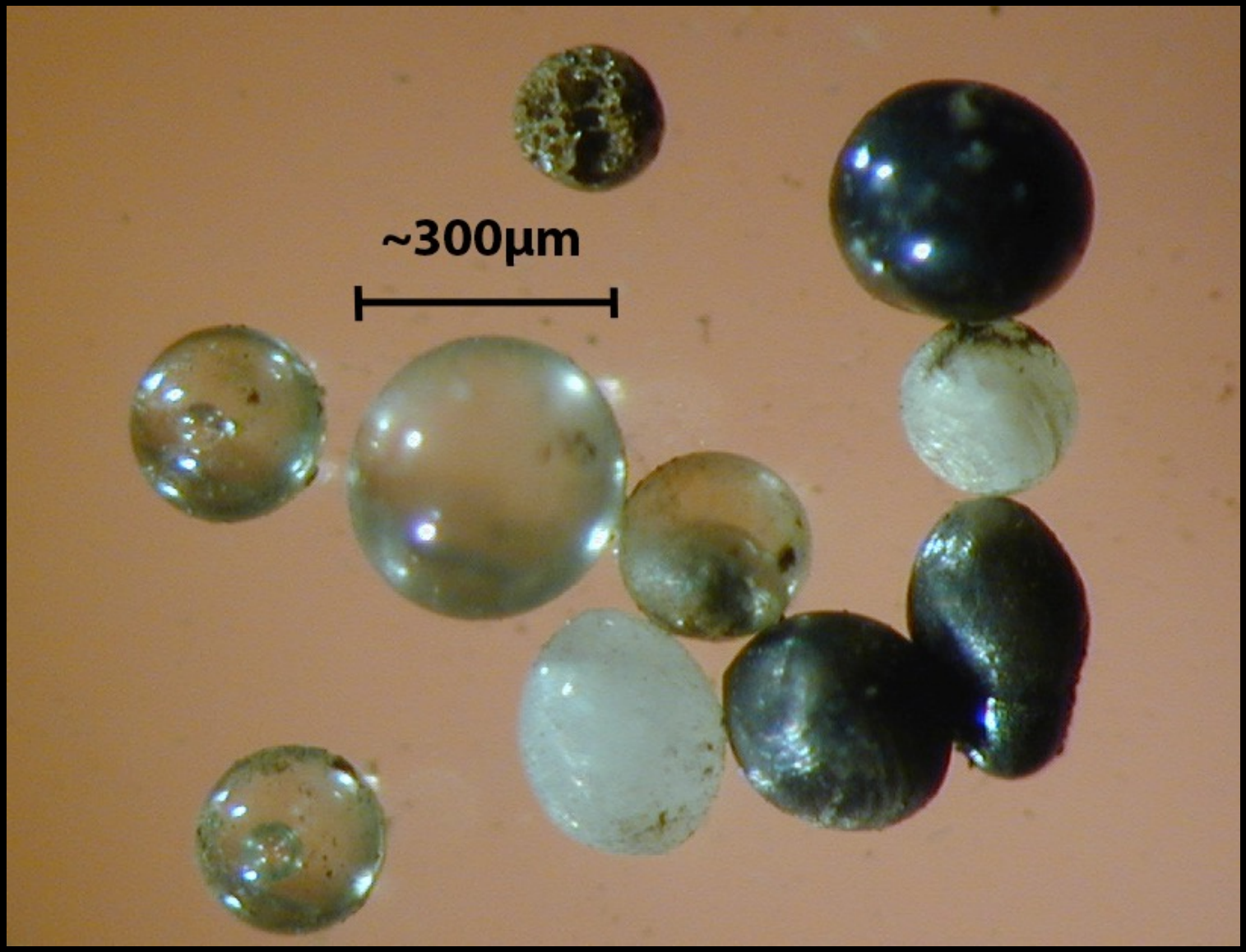
Cosmic spherules

National Institute of Oceanography,

Dona Paula, Goa, India

Cosmic spherules are predominantly found in ocean floor deposits on Earth and are mainly produced by frictional heating, melting, and ablation of meteoroids upon atmospheric entry.

Cosmic spherules



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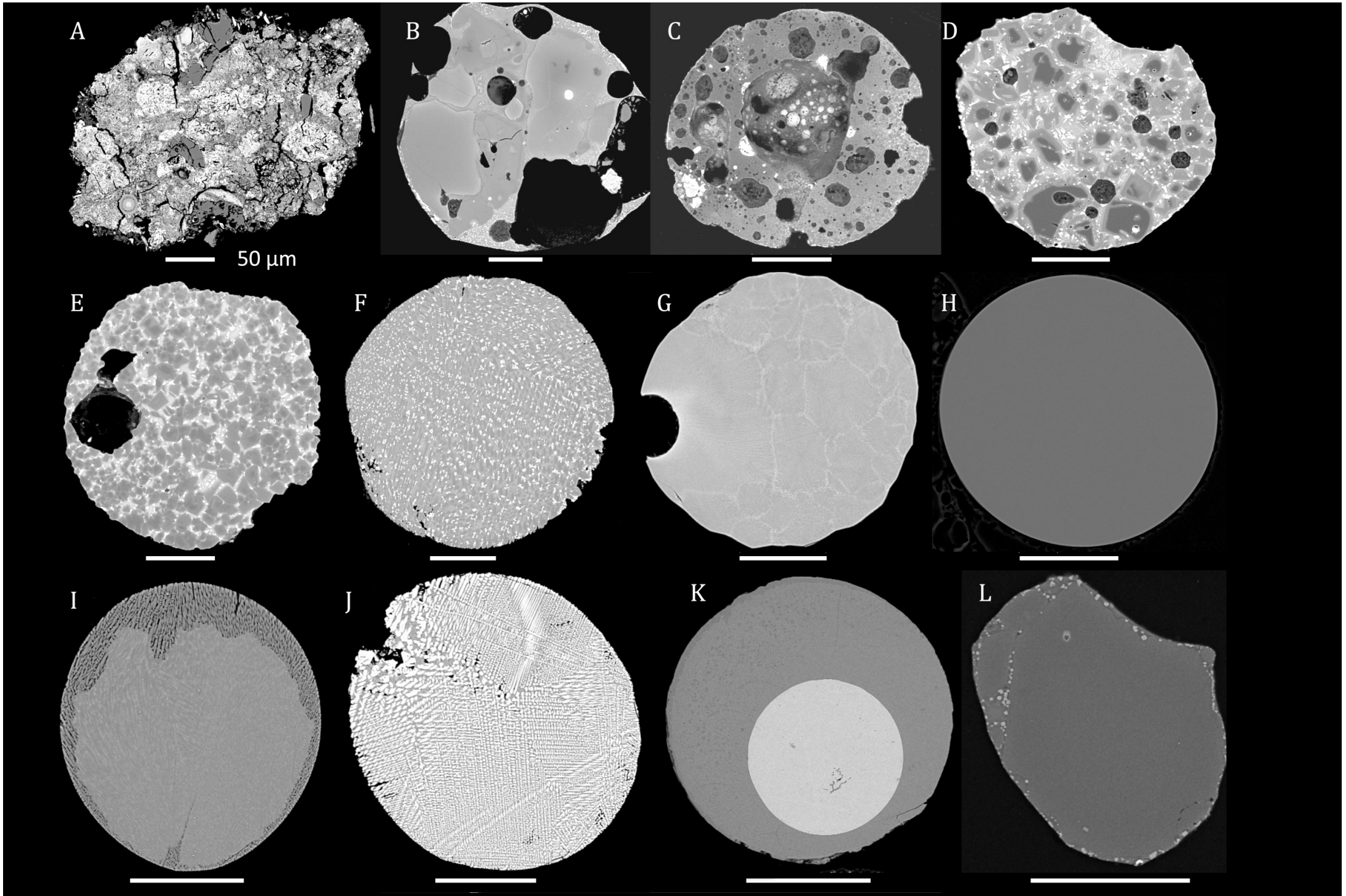
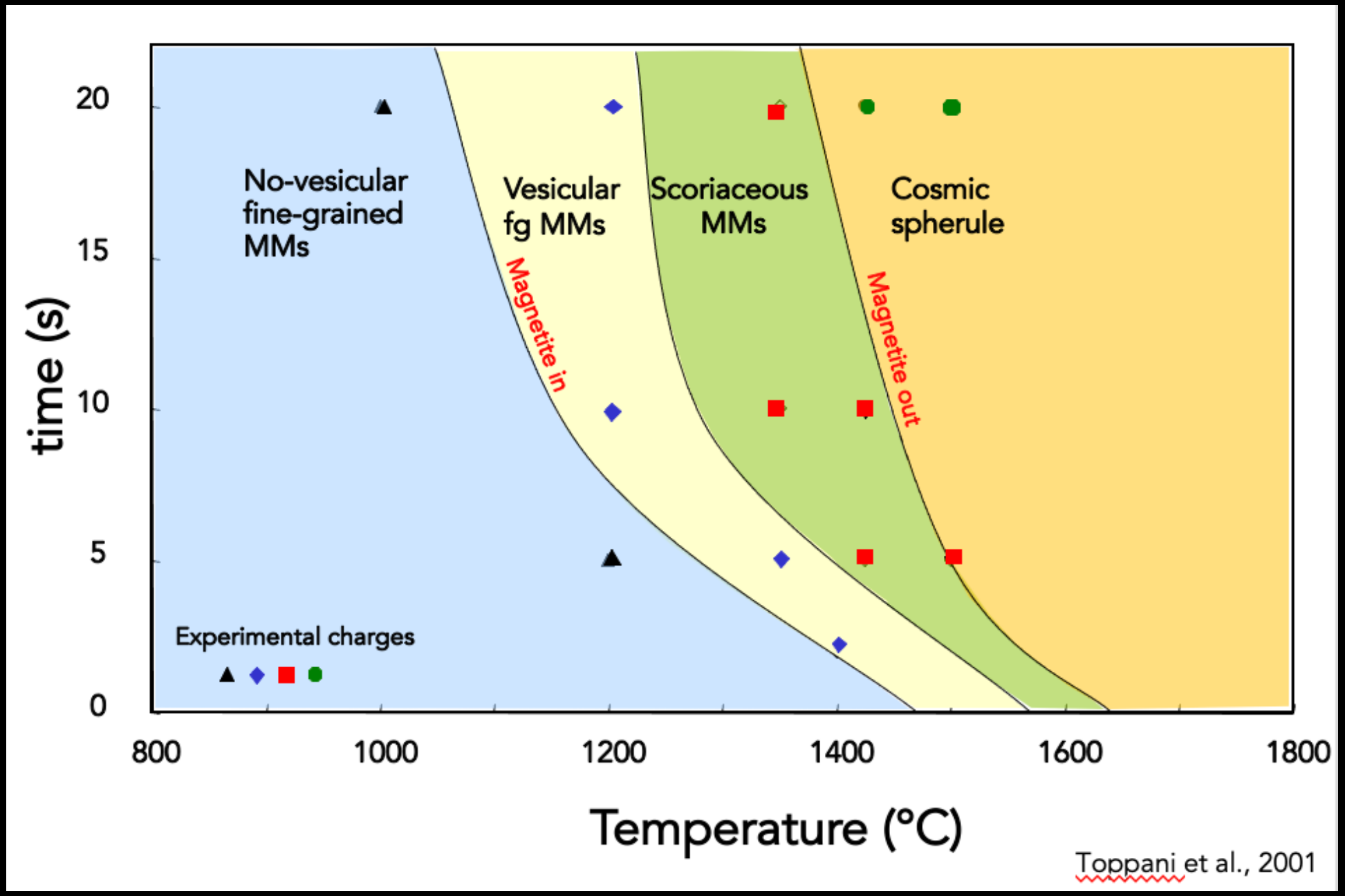
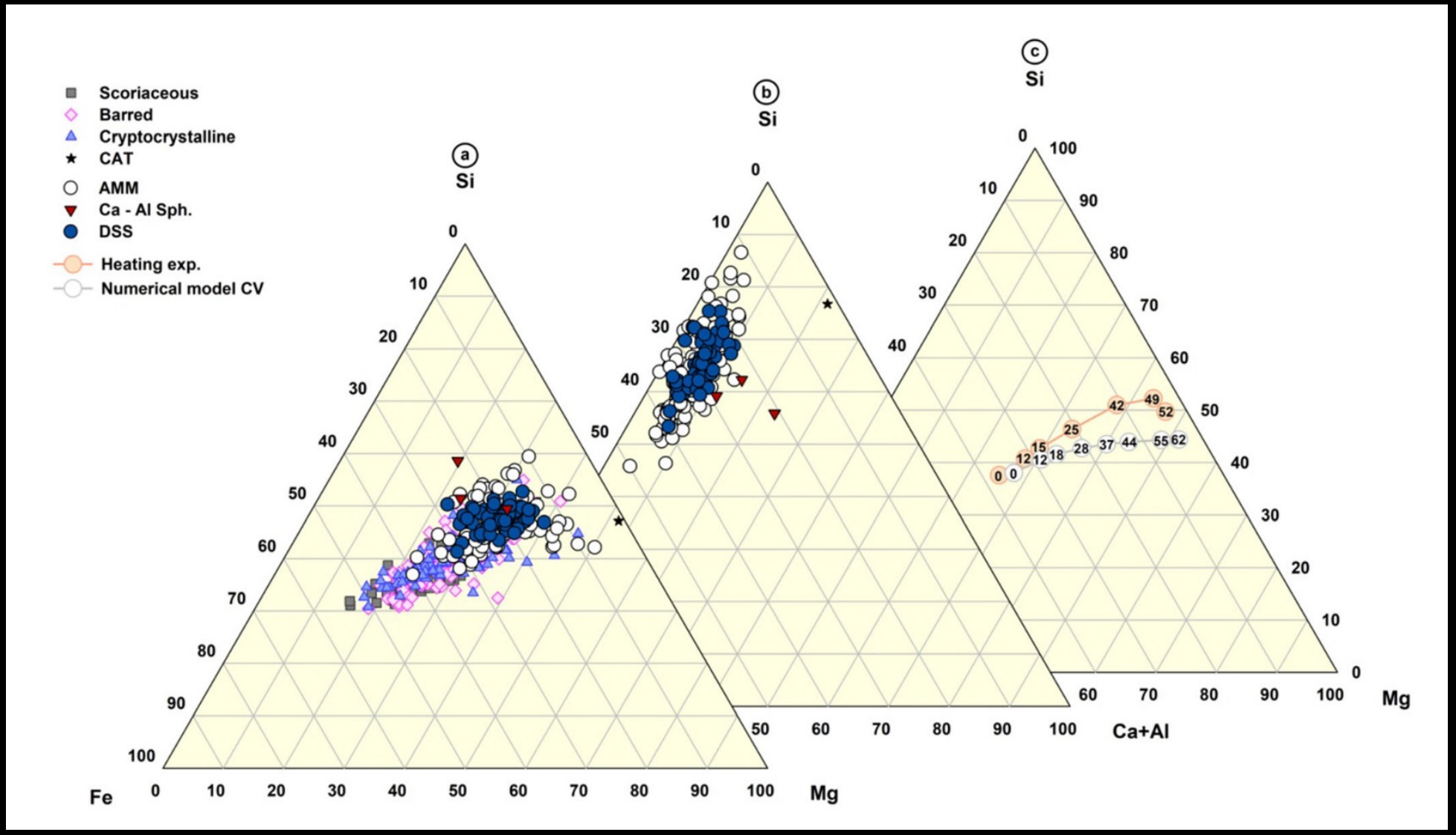


Cross sections of several micrometeorites - Image Credit: Shaw Street via Wikimedia Commons - CC BY-SA 3.0

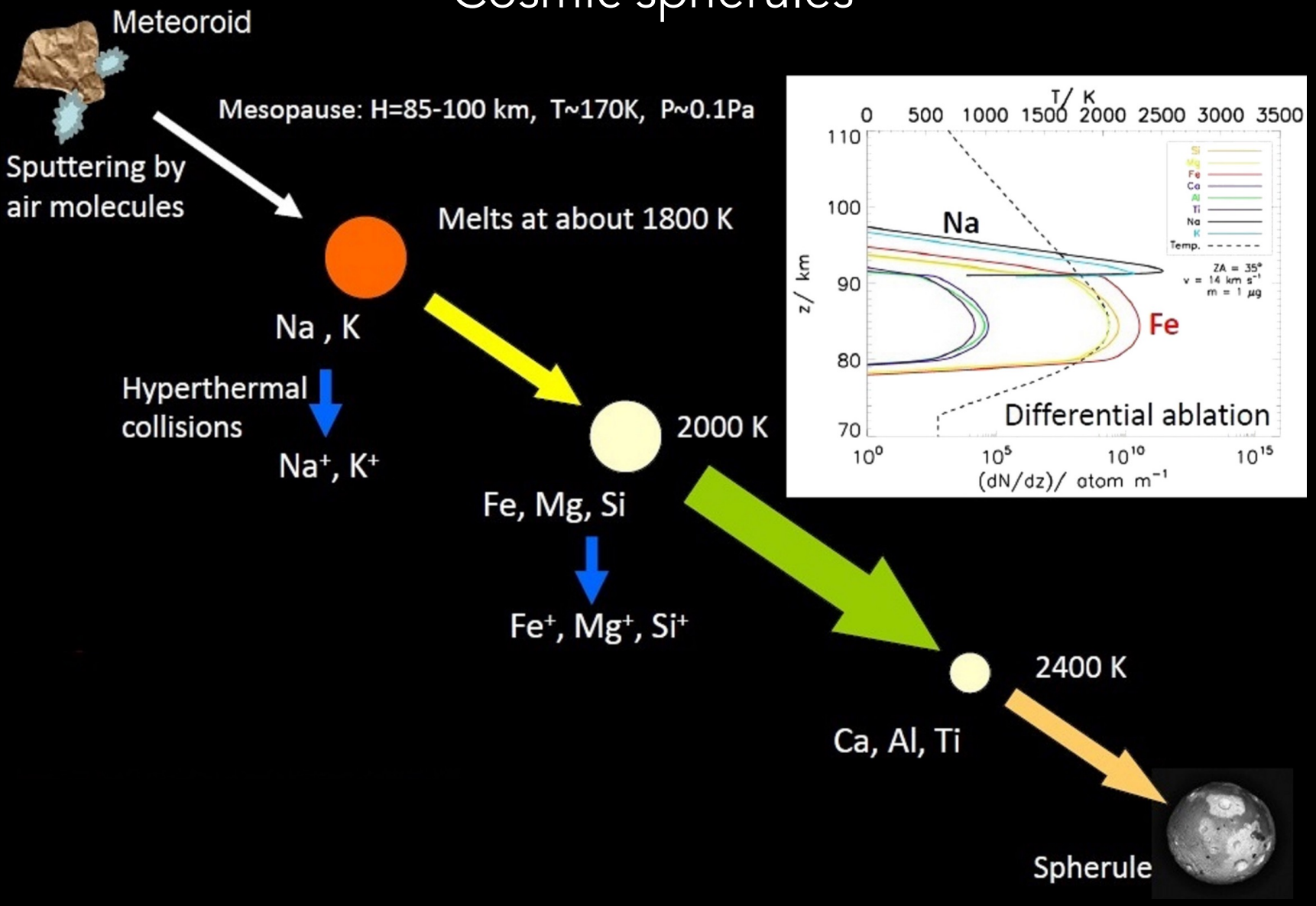

No-vesicular fine-grained MMs
Vesicular fg MMs
Scoriaceous MMs
Cosmic spherule
Magnetite in
Magnetite out
Experimental charges
time (s)
0
5
10
15
20
800
1000
1200
1400
1600
1800
Temperature (°C)
Toppani et al., 2001

Cosmic spherules



Cosmic spherules show a large range of composition with clear depletion in volatile and moderately volatile element (Fe, Na).

Cosmic spherules



Trigo-Rodriguez et al. 2019

Differential ablation is a direct consequence of the selective ablation at different heights of meteoroid minerals having different vaporization temperatures

Cosmic spherules

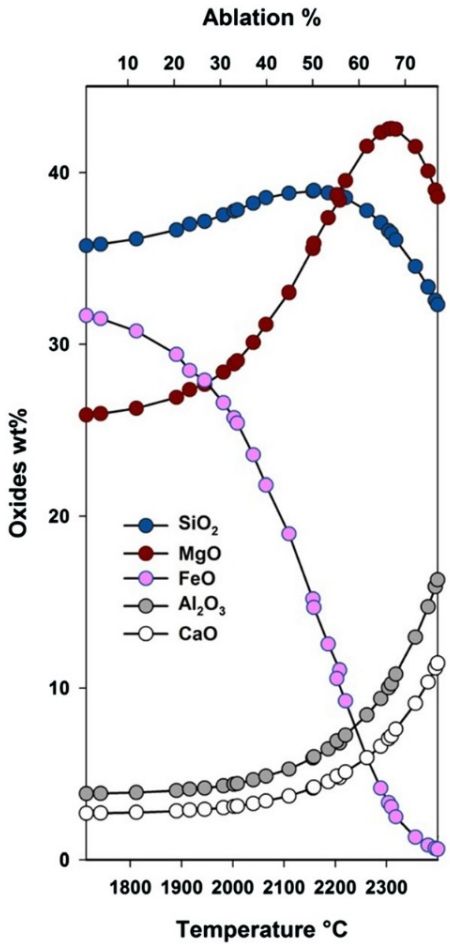
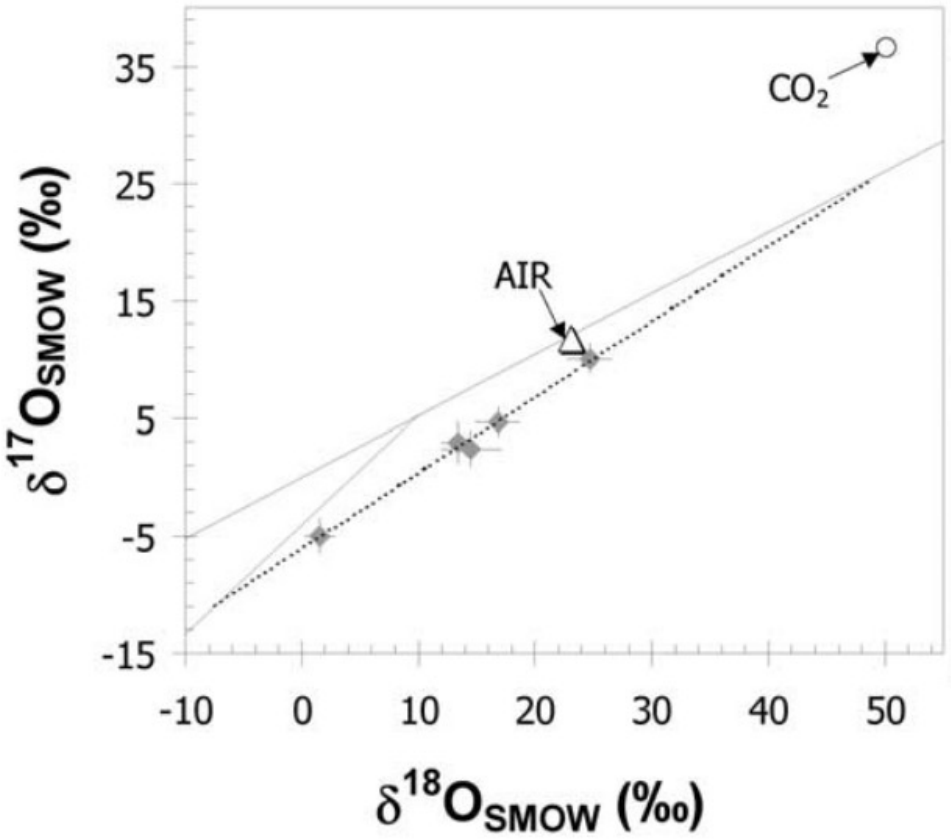
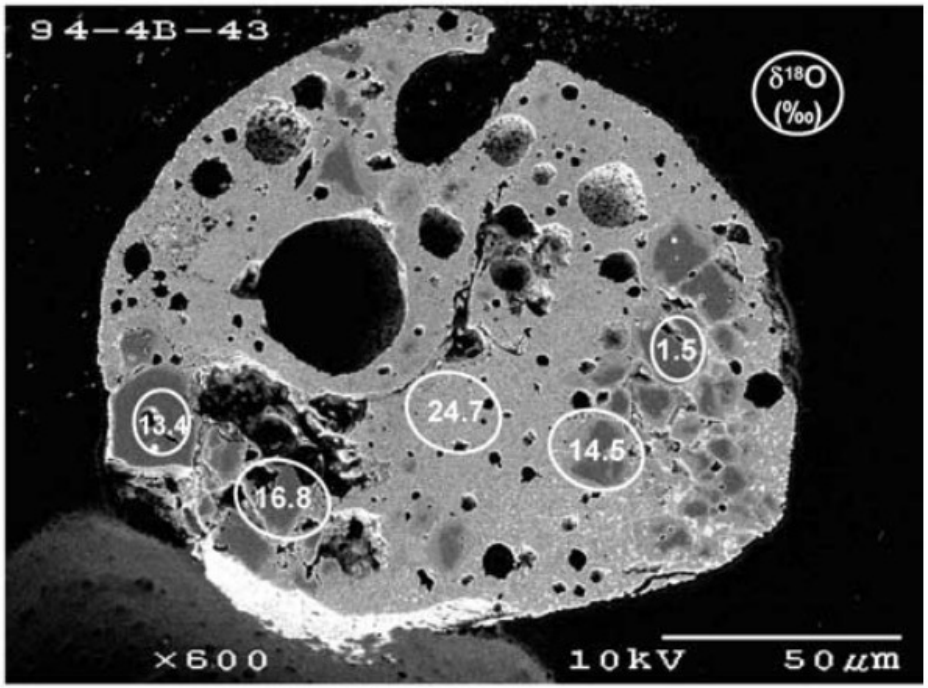


Figure 5. Variation in oxide composition wt% of SiO_2, MgO, FeO, Al_2O_3, and CaO with respect to temperature in °C and with corresponding ablation percentages for CV chondrite at entry velocity of 11 km/s for particle sizes between 100 and 500 µm at zenith angles 0°–70° (model data source Rudraswami *et al.* 2018a, b).

Cosmic spherules are predominantly found in ocean floor deposits on Earth and are mainly produced by frictional heating, melting, and ablation of meteoroids upon atmospheric entry.

Tracing the oxygen isotope composition of the upper Earth's atmosphere using cosmic spherules

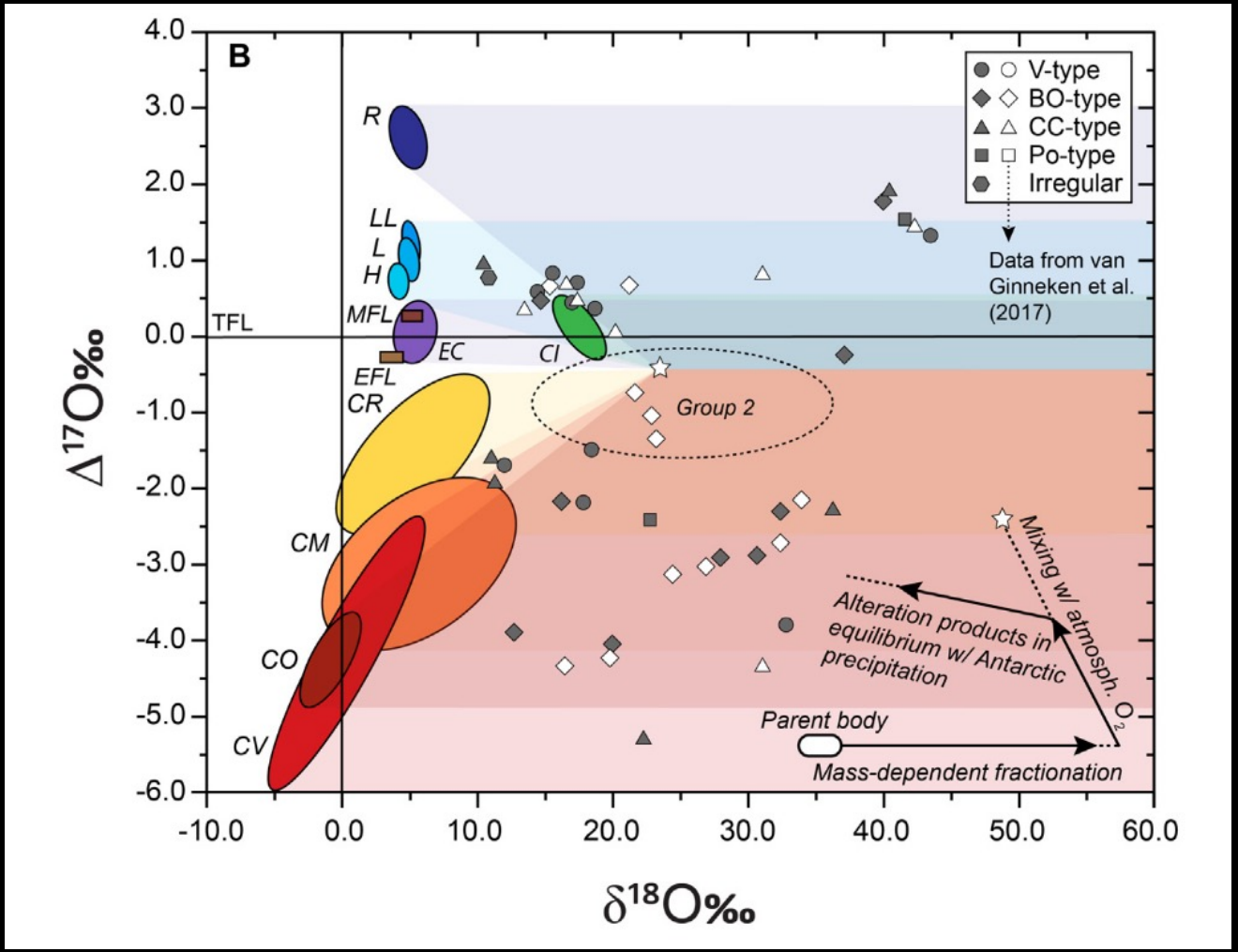




Engrand et al., 2005

Cosmic spherules

S. Goderis et al. / Geochimica et Cosmochimica Acta 270 (2020) 112–143



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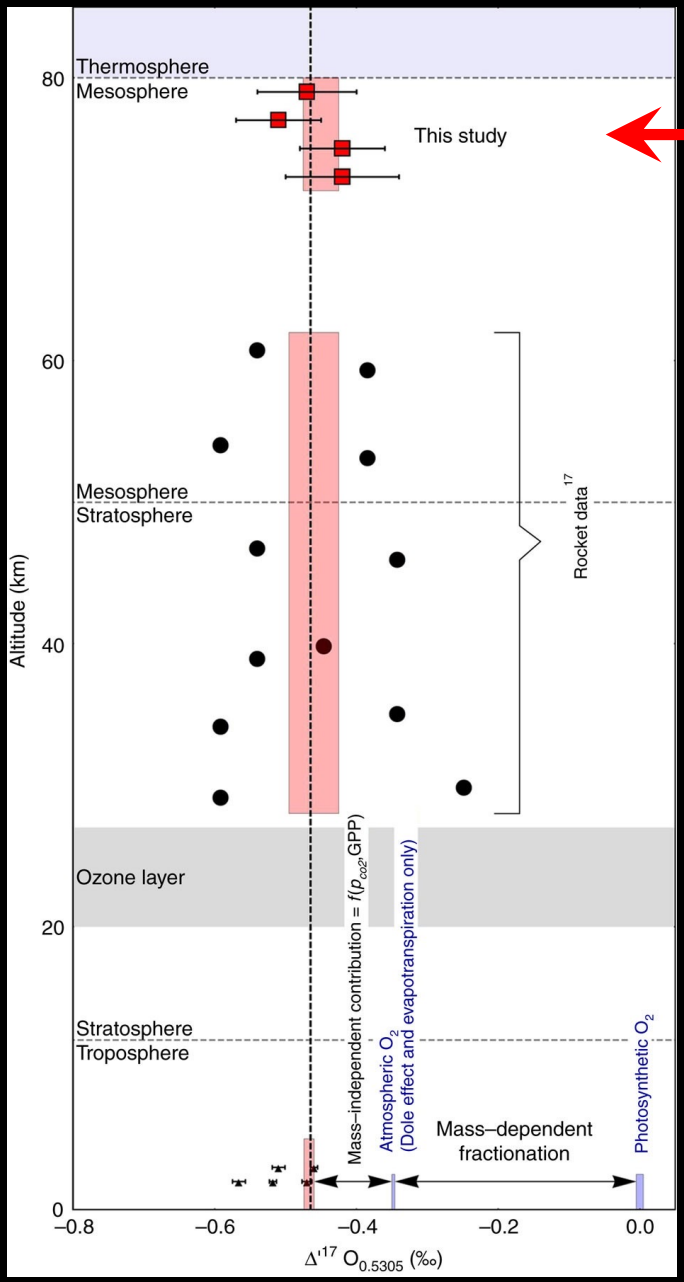
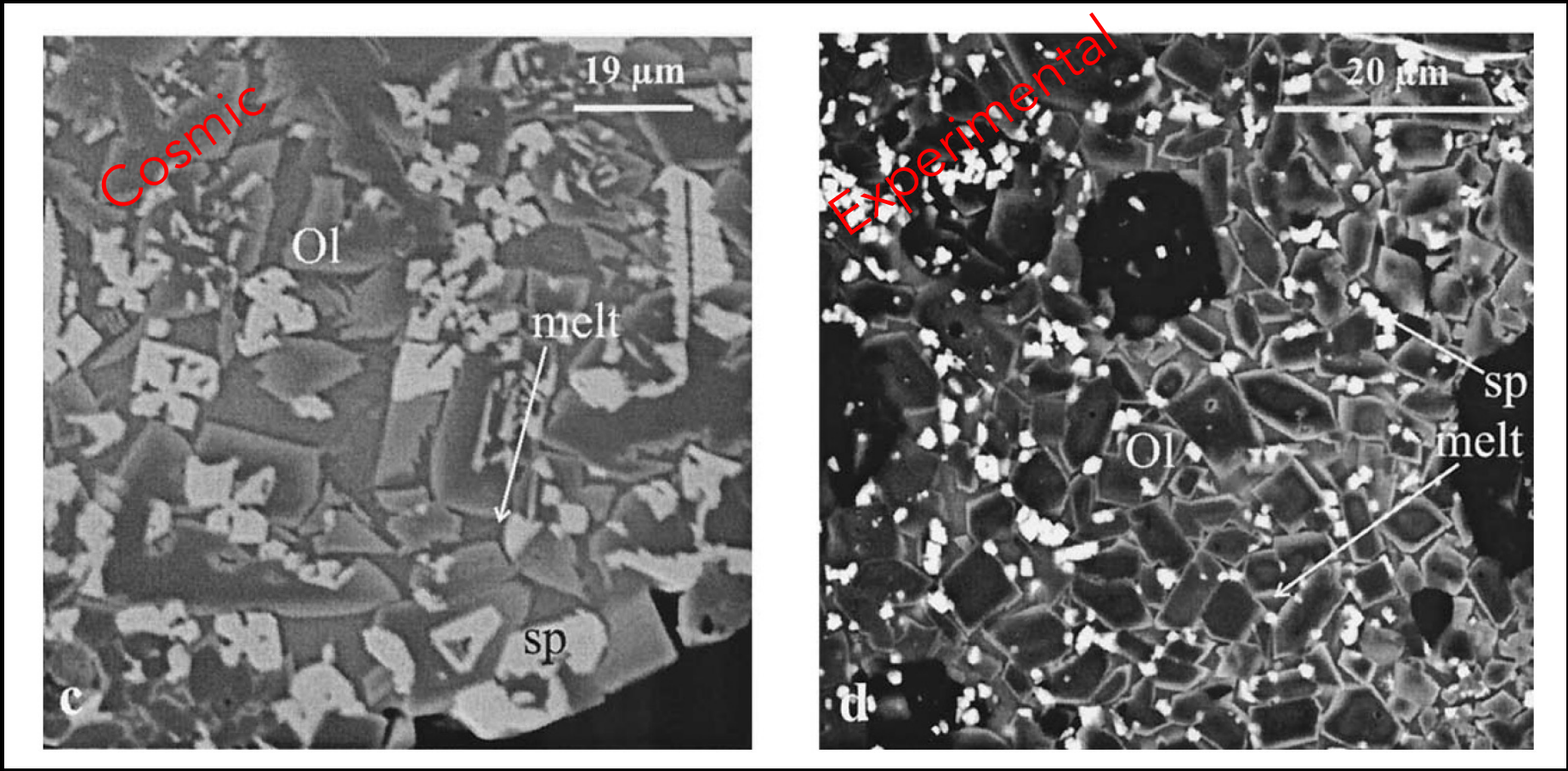


Cosmic spherules collected in Antartica

Pack et al., 2017

Constraints on entry angles and incident velocities of extraterrestrial objects during their atmospheric entry

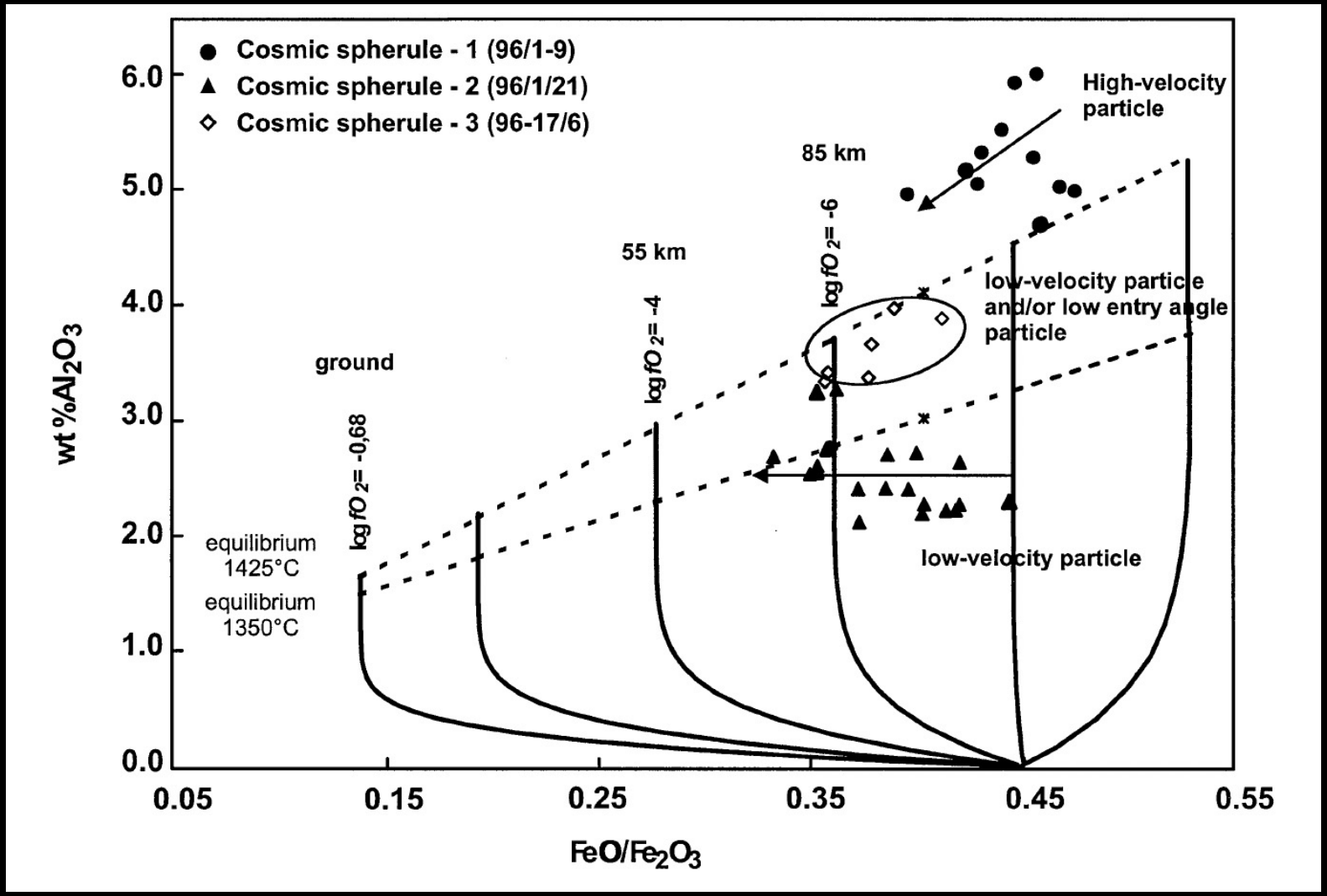


Magnetite ($FeFe_2O_4$), magnesioferrite ($MgFe_2O_4$), trevorite ($NiFe_2O_4$), ulvospinel (Fe_2TiO_4), hercynite ($FeAl_2O_4$), spinel sensu stricto ($MgAl_2O_4$), chromite ($FeCr_2O_4$), magnesiochromite ($MgCr_2O_4$)

- FeO/Fe_2O_3 = Redox (fO_2)

- Al_2O_3 = Degree of heating (t and T)

Constraints on entry angles and incident velocities



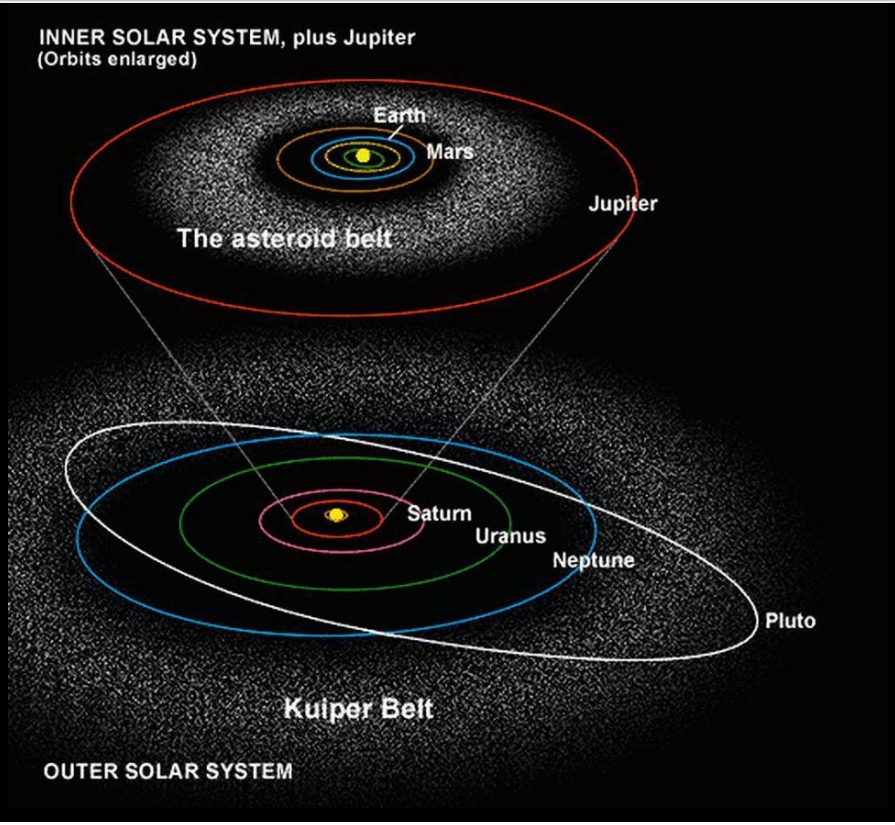
Increase degree of heating

Increase altitude of deceleration

Toppani and Libourel, 2003; 2013

The cosmic spinel composition is found to be dependent on two main parameters: degree of heating (temperature and time) and altitude of deceleration of the meteoroid.

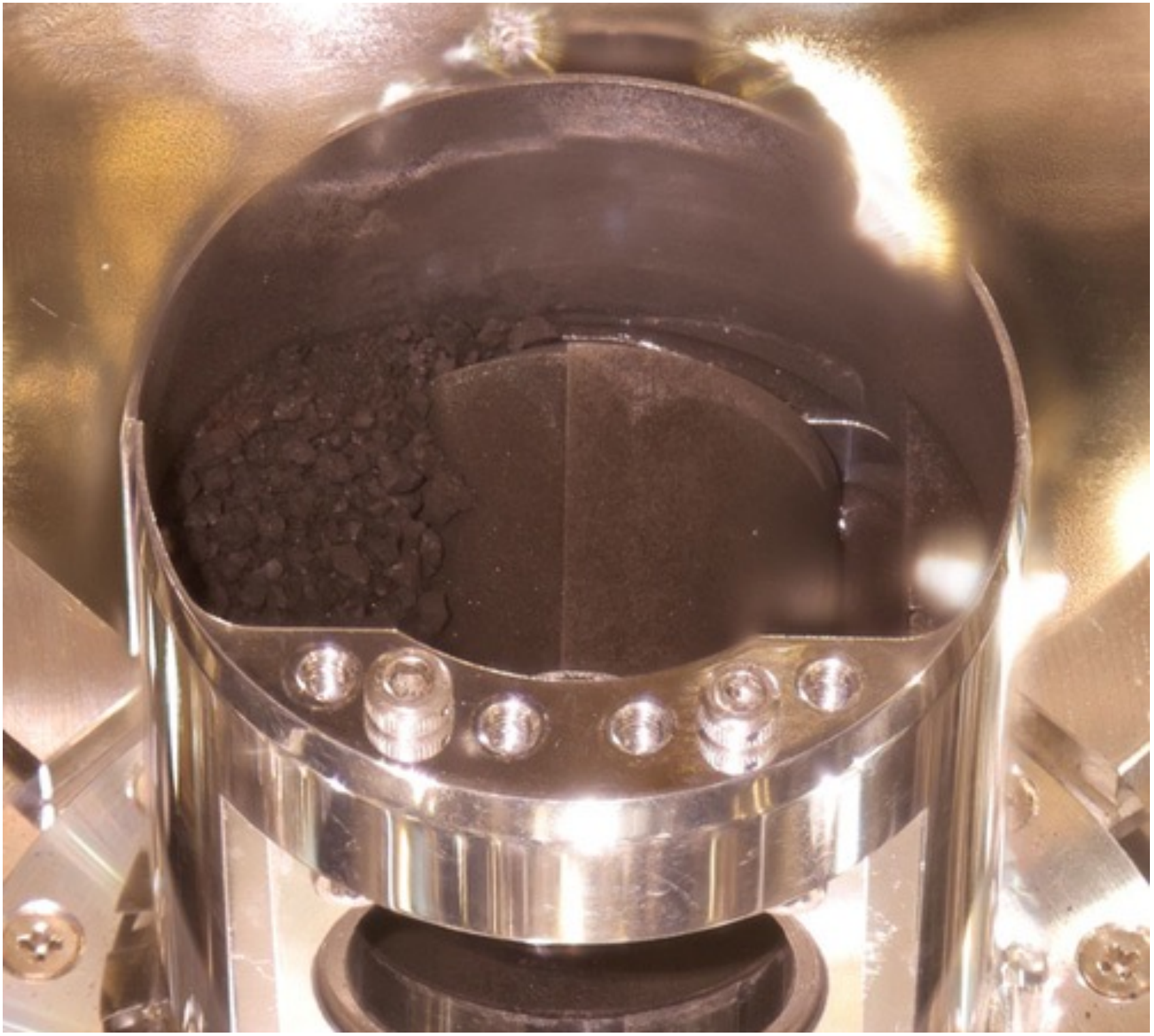
Cosmic spherules



December 6th, 2020, Woomera desert

Hayabusa2 (JAXA) capsule re-entry

Ryugu (870m)




Unfortunately, no glasses !!

Terre vue de Saturne à une distance de 1,44 milliard de km. Image: NASA/JPL-Caltech/Space Science Institute