SEIS *on* Mars @ School :

EGU GIFT 2016 :

An example of hands-on activity focused on martian meteorite craters: for teachers … and for their pupils

Diane Carrer

Science teacher : Biology & geology teacher at:

« Moutain's High School »

« Lycée de la Montagne »,

Valdeblore, Alpes Maritimes, France

SEIS *on* Mars @ School :

InSight

SEIS

to the heart of worlds

EGU GIFT 2016 :

An example of hands-on activity focused on martian meteorite craters

EUROPEAN GEOSCIENCES UNION

General Assembly 2016

An investigation into the physics of meteorite crater formation

Plan :

1. **Why studying meteorites @ school ?**
2. **Link in between Meteorites ⟺ Solar System ?**
3. **Link in between Meteorites ⟺ Mars Exploration *(InSight mission*) ?**
4. **Let's start 4 investigation experiments !**
5. **Pedagogical exploitation:** *when Geosciences, Physics & mathematics have a « rendez-vous » …*

seis

InSight

1. Why studying meteorites @ school ?

5 good reasons to study meteorites

a) Because it creates so nice geological objects on Earth: **craters** !

b) It is often seen as « **bolides** » …. And often on the **press** !

c) We (**Mammals**) are on Earth « *thanks to* » the -65 My meteorite (**Chixculub)**

d) We (entire Biosphere) are on Earth thanks to meteorites: **Panspermia theory**

e) Our **Moon** results from a giant impact with « **Theia** », a giant asteroid**.**

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Namibia
ROTER KAMM Crater

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USA
Meteor Crater

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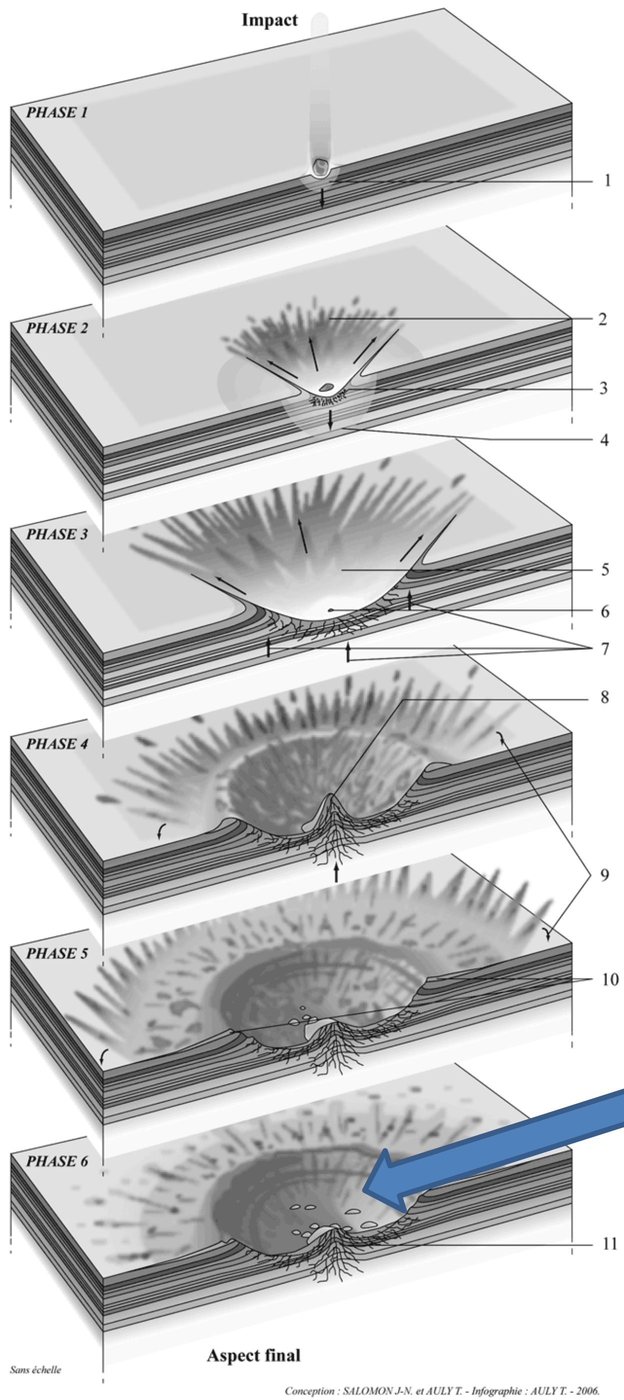
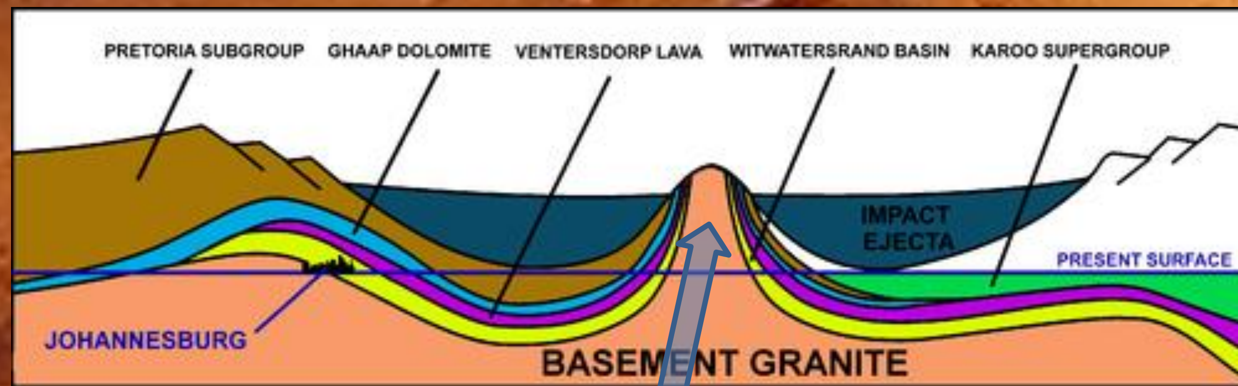
SOUTH AFRICA
Vredefort Crater
VREDEFORT ASTROBLEMA
2.023 Billion years (+/-4 My)

1. Why studying meteorites @ school ?





Central peak Uplift (called Dome)

COMPLEX IMPACT CRATER FORMATION

SOUTH AFRICA
Vredefort Crater
2.023 Billion years (+/-4 My)

Impact Melt rocks
(kind of *breccias*)
from the ASTROBLEMA of
VREDEFORT .

1. Why studying meteorites @ school ?

SOUTH AFRICA
Vredefort Crater

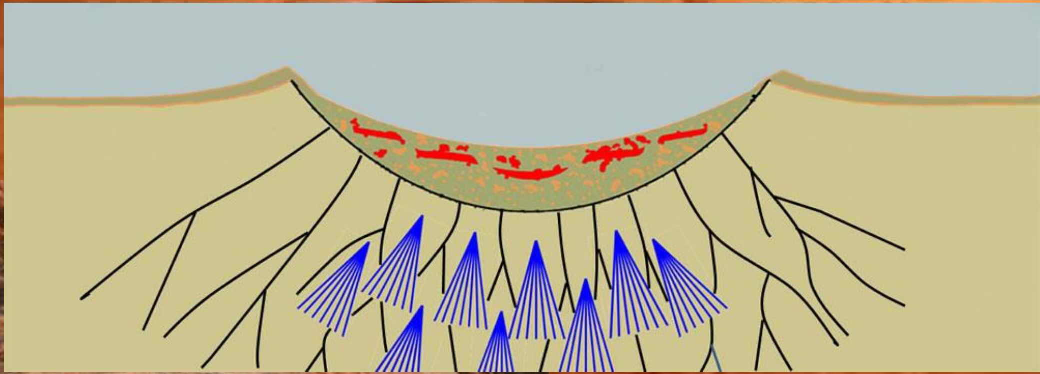
Impact Melt rocks
(kind of *breccias*)
from the ASTROBLEMA of VREDEFORT
(brèches d'impact pseudotachylitiques)

1. Why studying meteorites @ school ?

Photographie : Pierre Thomas

SOUTH AFRICA
Vredefort Crater

1. Why studying meteorites @ school ?



SHATTER CONES of Vredefort Crater SOUTH AFRICA

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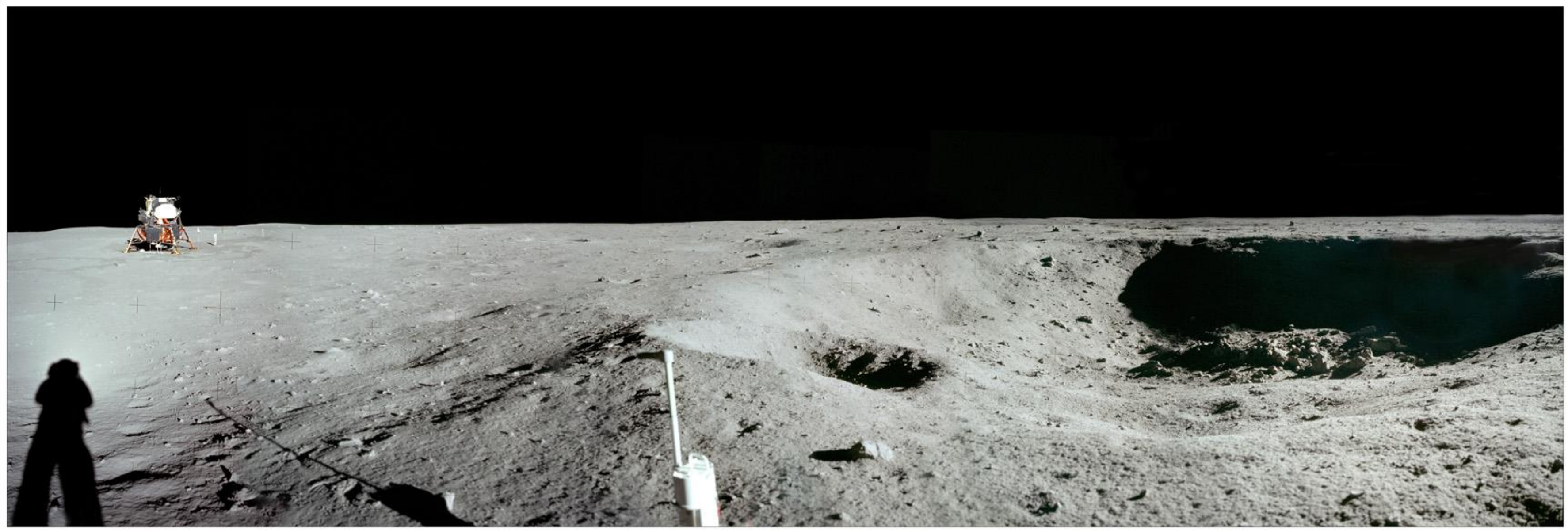


Apollo 11 - Commander Neil Armstrong's pan of East Crater, with LM Eagle in the background

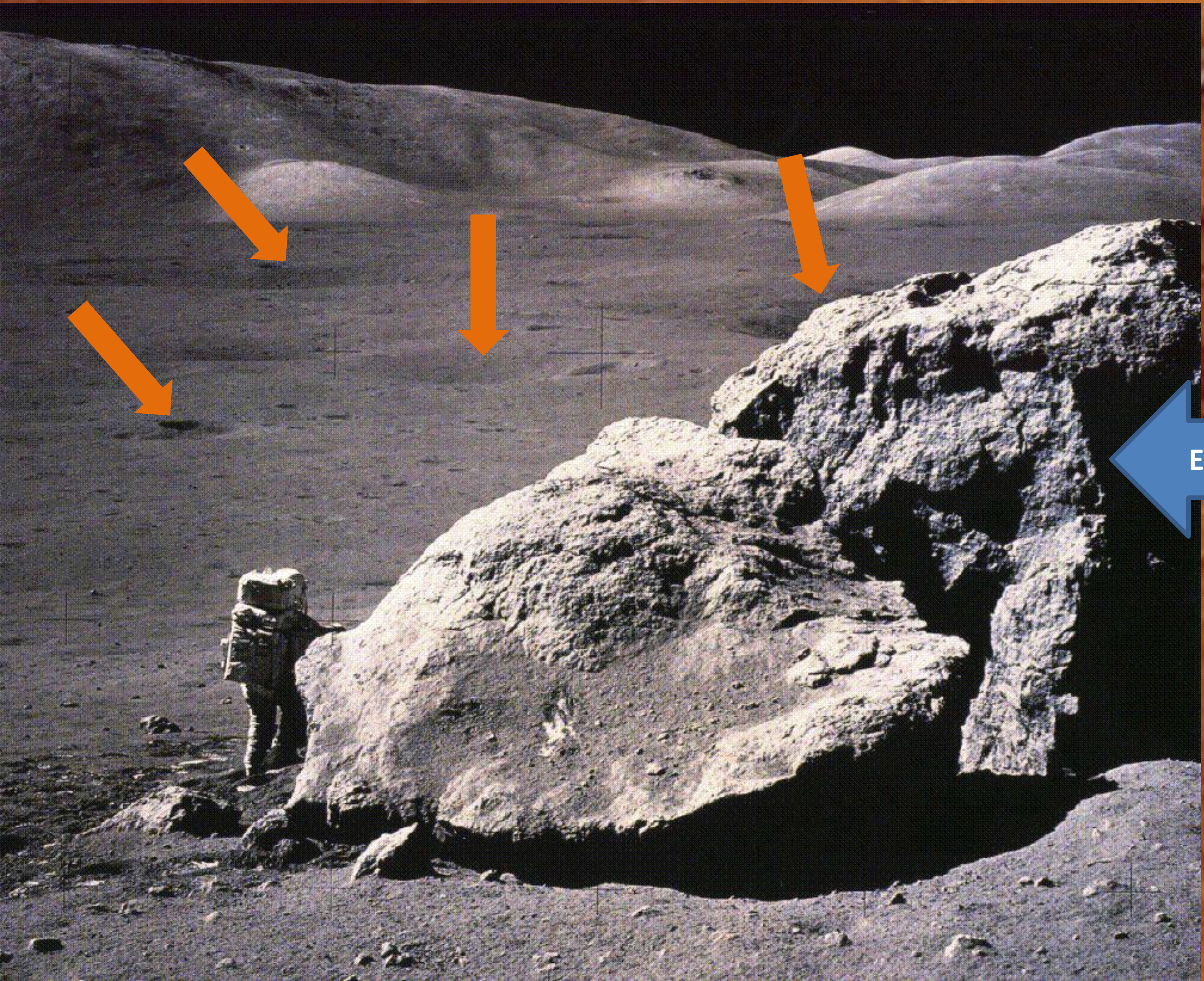
© moonpans.com

MOON Craters

NASA APOD pictures

Apollo 11 mission

1. Why studying meteorites @ school ?



MOON Ejecta and Craters

Credits : NASA APOD pictures

Apollo 11 mission

1. Why studying meteorites @ school ?

MOON Copernicus and Tycho Craters

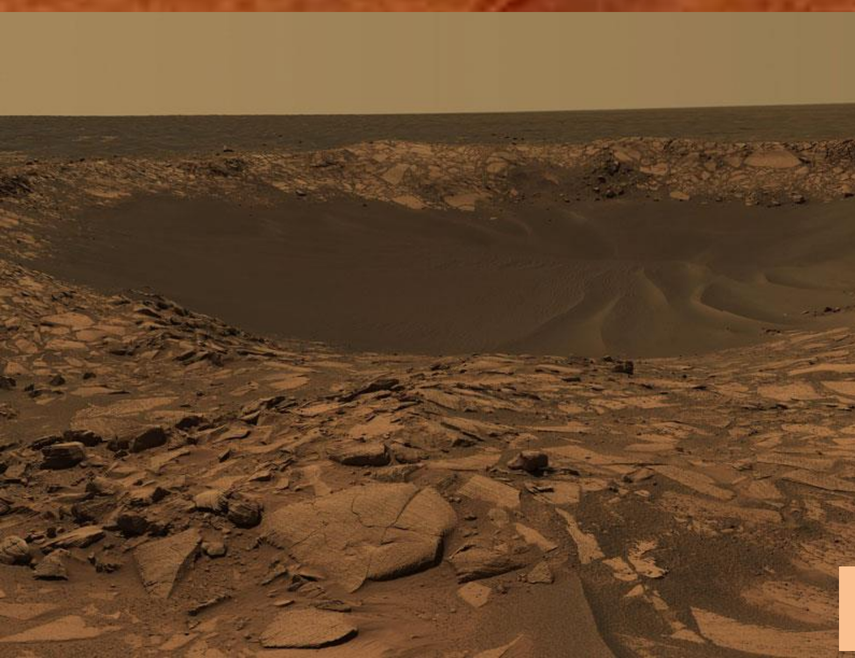
Credits : NASA APOD pictures

the full Moon features two prominent ray craters, Copernicus (upper left) and Tycho (lower right), each with extensive ray systems of light colored debris **blasted out** by the crater-forming impacts

1. Why studying meteorites @ school ?

Endurance crater , MARS (Opportunity)

Credits : NASA APOD pictures and JPL



Beagle Crater on Mars (Opportunity rover)

www.passc.net/EarthImpactDatabase/reportcrater.html

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Earth Impact Database

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- RPIF
- Missions
- Meteorites
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Report a Crater

*** At this time, we are unable to respond to the large number of crater reports we receive by email. Please review the Criteria for confirming an impact crater and only email us if all, or at least 80%, of the criteria are met, and provide the analytical microscope data and/or a peer-reviewed journal publication to back it up (publications that are "Accepted with Revisions" or "In Press" are acceptable) ***

Facts about Reporting a Crater

- We get an average of 3 reports a week from people who have spotted while on a plane (including pilots). The PASSC team is currently invo large time delay in responding to crater report emails, we apologize for t

  - The Mars Science Laboratory Curiosity Rover mission
  - The Manicouagan Impact Research Program (MIRP)
  - The High-speed Impact Research and Technology Facility

You can even

REPORT a crater

with your pupils if you

find every criteria !!

assc.net/EarthImpactDatabase/Criteria.html

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Earth Impact Database

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Please review criteria below before reporting a possible impact crater to PASSC. We would be happy t answer any questions.

Criteria for the identification of an impact structure

The principal criteria for determining if a geological feature is an impact structure formed by the hypervelocity impac of a meteorite or comet are listed below. The criteria can be divided into **megascopic** (overview – bird's eye satellite scale), **macroscopic** (can be seen easily seen with the naked eye) and **microscopic** (requires microscope to see) features, as follows:

1. Presence of shatter cones that are in situ (macroscopic evidence).

2. Presence of multiple planar deformation features (PDFs) in minerals within in situ lithologies (microscopic evidence).

3. Presence of high pressure mineral polymorphs within in situ lithologies (microscopic evidence and requiring proof via X-ray diffraction, etc.).

4. Morphometry. On other planetary bodies, such as the Moon and Mars, we rely on the shape of the impac structure to determine its presence and type (simple versus complex, etc.). This is a megascopic quality (i.e., too bi to be seen unaided by the human eye, thus requiring remote sensing, aerial photography, detailed mapping o multiple outcrops to assemble and view the typically km- or multiple km-size structure). On Earth, recognizin

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Chelyabinsk Bolide Russia

February , 15th, 2013

https://www.youtube.com/watch?v=ztrU90Ub4Uw

Blast of the bolide
=>
shock waves
=>
Big Sounds + windows crash

seis

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Peekskill Meteorite,

USA ,
New Jersey
Sept, 10th, 1992

(falled on Miss Michelle Knapp red car !)

https://www.youtube.com/watch?v=AOU3r3Q4-eY

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Wisconsin Bolide
(fireball)

April, 14th, 2010

https://www.youtube.com/watch?v=-BCh5Y3-KdM

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*On **every newspaper** and even **outreach magazines** (Sciences&Vie) **last February** !!!*

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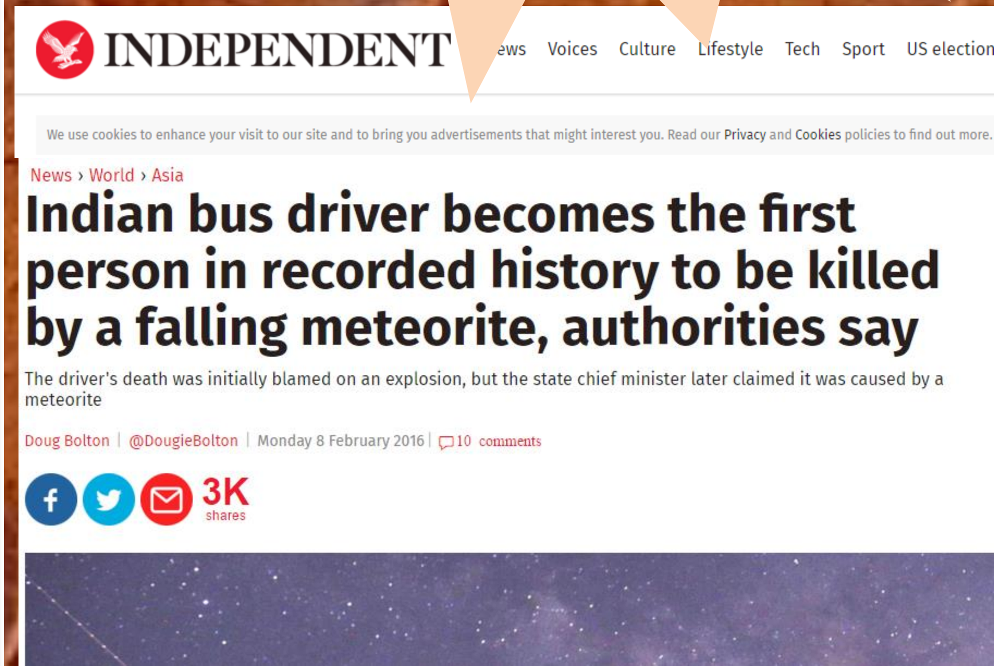
Indian bus driver 'killed by meteorite strike'

Tamil Nadu chief minister says man named as Kamaraj killed by meteorite

788 0 10 798 Email



INDEPENDENT

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Indian bus driver becomes the first person in recorded history to be killed by a falling meteorite, authorities say

The driver's death was initially blamed on an explosion, but the state chief minister later claimed it was caused by a meteorite

Doug Bolton | @DougieBolton | Monday 8 February 2016 | 10 comments

3K shares

1. Why studying meteorites @ school ?

b) It is often seen as « **bolides** » …. And often on the **press** !

ASIA PACIFIC

That Wasn't a Meteorite That Killed a Man in India, NASA Says

By CHRISTINE HAUSER FEB. 9, 2016

Thank you NASA !

For your pupils :
a good way to work on **critical sense** and learn how to **step back from what medias tell us**

NASA: Meteorite didn't kill man in India

By Dana Ford, CNN
Updated 0339 GMT (1139 HKT) February 11, 2016

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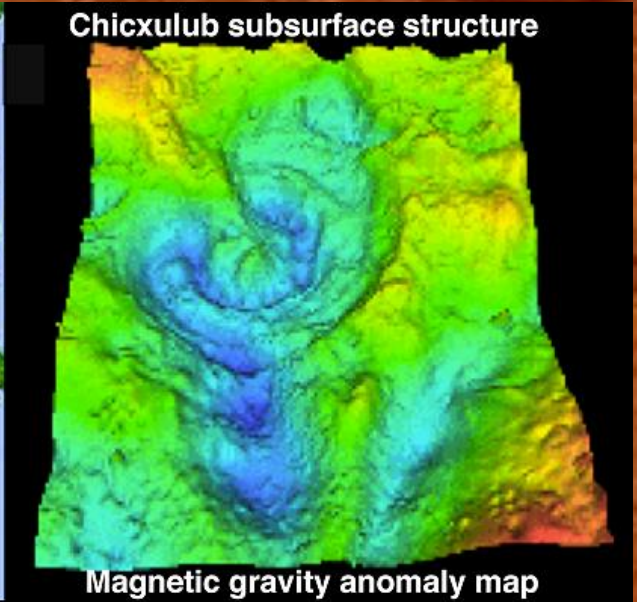

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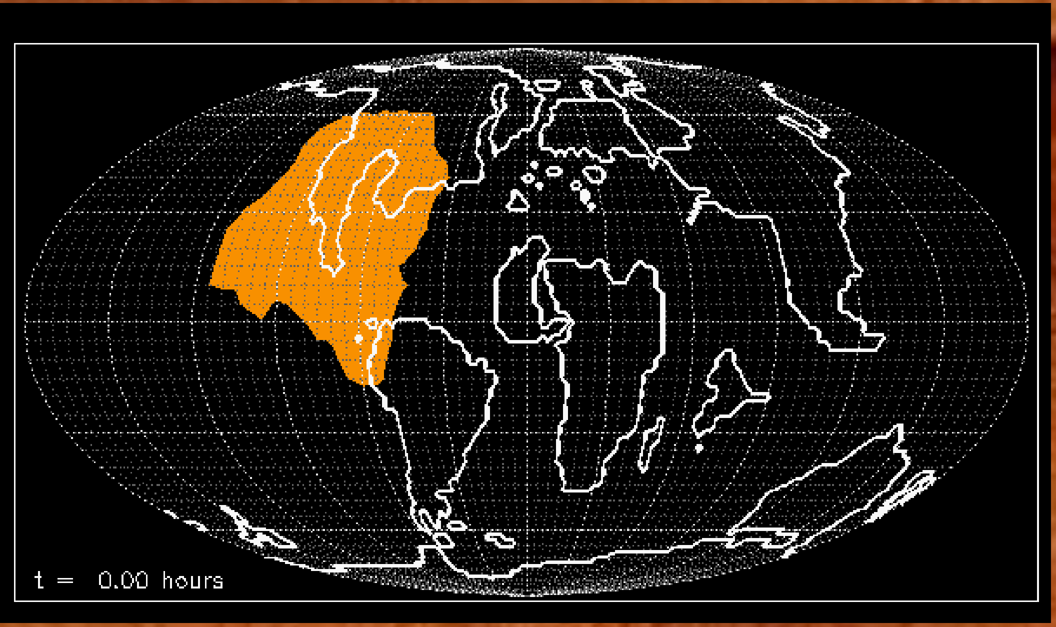

Simulation of IMPACT GENERATED WILDDFIRES after Chicxulub

Wildfires => ***plumes of smoke into that atmosphere => darkened the planet => Nuclear winter => 76 % of marine species extincted***

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SEIS

InSight

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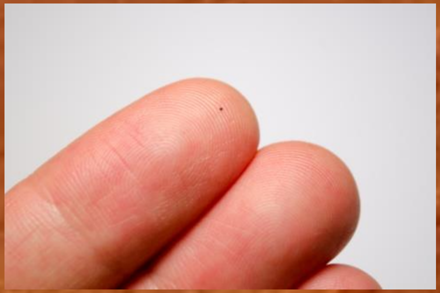


Meteoritic rate on Earth :

100 000 tons/ year !

99.9 % are micro-meteorites !

Organic molecules found on Chondrites:

2.5% to **4 % of their mass is Organic Matter !!**

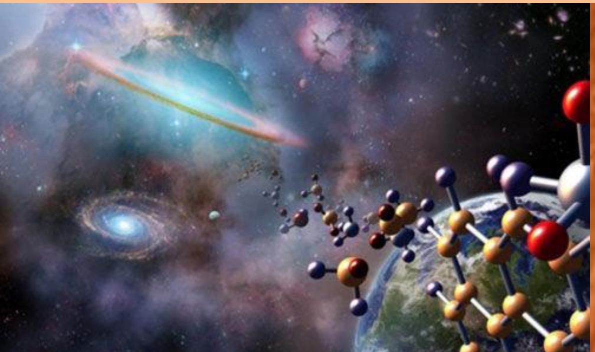
1. Why studying meteorites @ school ?

d) We (entire Biosphere) are on Earth thanks to meteorites: **Panspermia theory**

What do we find in a chondrite (C) meteorite ? :

- **H_20**
- **amino acids**
- **Sugars**
- **aromatic compounds**
- **simple hydrocarbons** (methan)

All those molecules are also found in comets, in cosmic dust, in nebula (Horsehead Nebula)



This is why scientists think **PREBIOTIC MOLECULES** have been transported by meteorites until Earth => this is called « **Panspermia** » theory (greek : « ***PAN*** » : « all », and « ***SPERMA*** »: seed)

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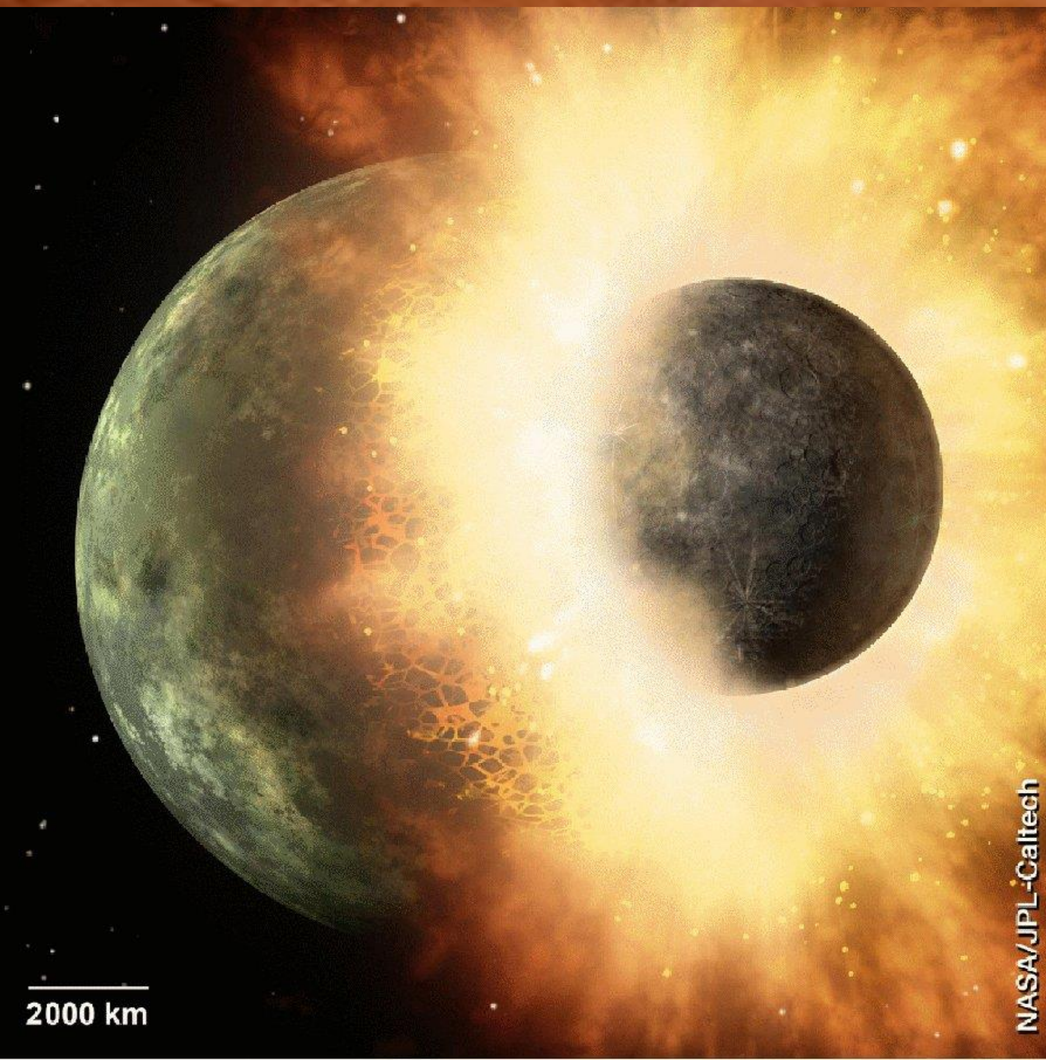
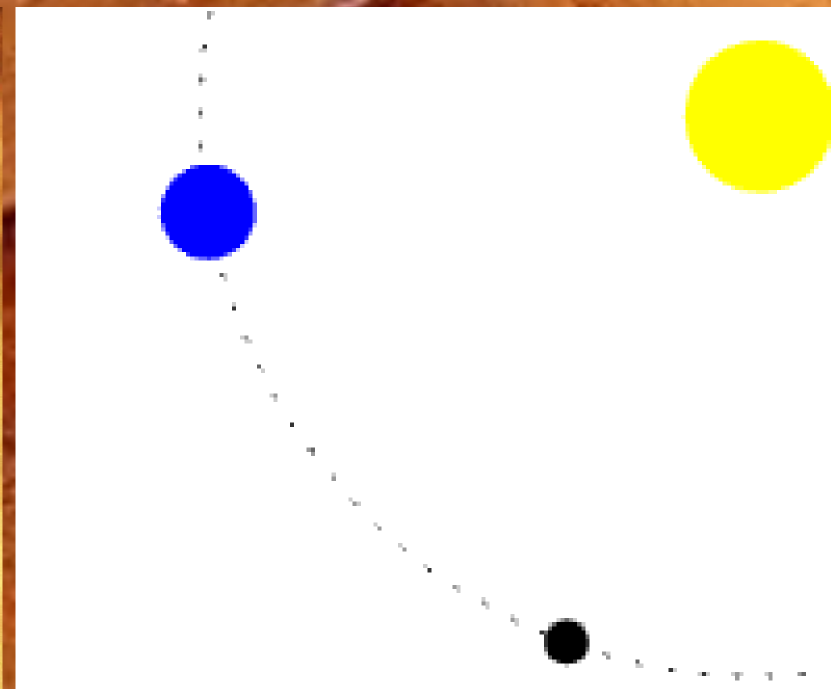
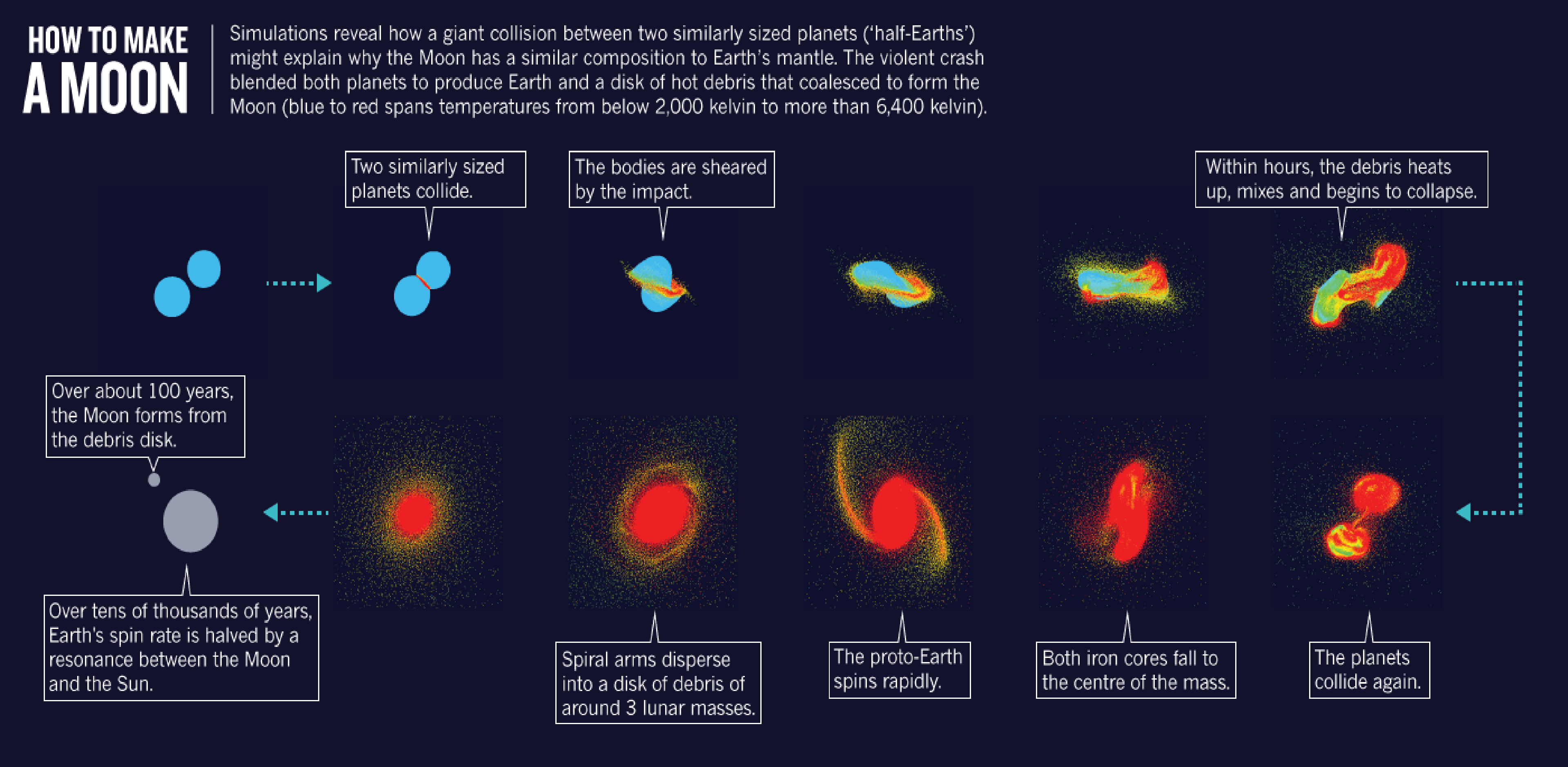




The Big Splat , impact with Theia :
At the very beginning of Solar Sytem creation (around **-4.5 Gy**)

THE « BIG SPLAT » ,
Credits : NASA CALTECH



http://www.nature.com/news/planetary-science-lunar-conspiracies-1.14270

NATURE December 2013 : How to make a moon ?

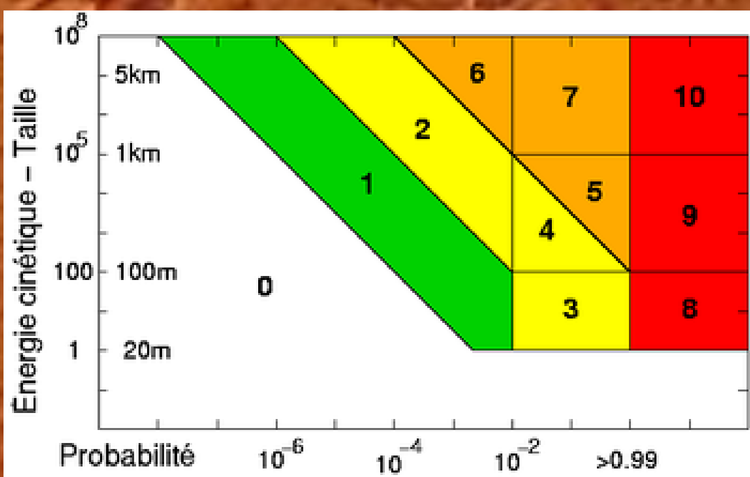
Three-dimensional simulations show how a collision between early Earth and a similar sized planet could mix their materials within a day.

Courtesy: Julien Salmon and Robin Canup/Southwest Res. Inst

Don't panic !!
Scientist have already estabilished a **« METEORITIC RISK SCALE » for us !!!**

ESA has 2 programs focused on how to avoid a NEO (near Earth Object) :

- ✓**AIDA :** Asteroid Impact & Deflection Assessment
- ✓**DART :** Double Asteroid Redirection Test



THE TORINO SCALE
Assessing Asteroid/Comet Impact Predictions

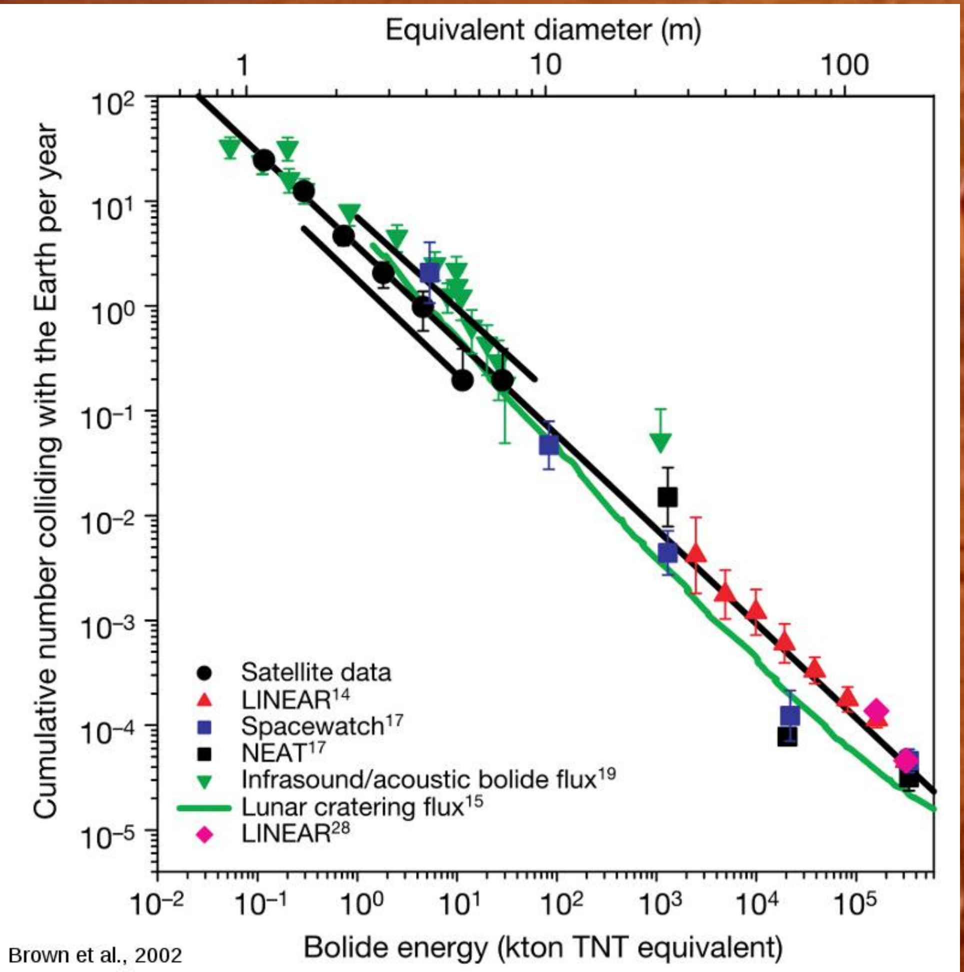
No Hazard	0	The likelihood of collision is zero, or is so low as to be effectively zero. Also applies to small objects such as meteors and bolides that burn up in the atmosphere as well as infrequent meteorite falls that rarely cause damage.
Normal	1	A routine discovery in which a pass near the Earth is predicted that poses no unusual level of danger. Current calculations show the chance of collision is extremely unlikely with no cause for public attention or public concern. New telescopic observations very likely will lead to re-assignment to Level 0.
Meriting Attention by Astronomers	2	A discovery, which may become routine with expanded searches, of an object making a somewhat close but not highly unusual pass near the Earth. While meriting attention by astronomers, there is no cause for public attention or public concern as an actual collision is very unlikely. New telescopic observations very likely will lead to re-assignment to Level 0.
	3	A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of localized destruction. Most likely, new telescopic observations will lead to re-assignment to Level 0. Attention by the public and by public officials is merited if the encounter is less than a decade away.
	4	A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of regional devastation. Most likely, new telescopic observations will lead to re-assignment to Level 0. Attention by the public and by public officials is merited if the encounter is less than a decade away.
Threatening	5	A close encounter posing a serious, but still uncertain threat of regional devastation. Critical attention by astronomers is needed to determine conclusively whether or not a collision will occur. If the encounter is less than a decade away, governmental contingency planning may be warranted.
	6	A close encounter by a large object posing a serious, but still uncertain threat of a global catastrophe. Critical attention by astronomers is needed to determine conclusively whether or not a collision will occur. If the encounter is less than three decades away, governmental contingency planning may be warranted.
	7	A very close encounter by a large object, which if occurring this century, poses an unprecedented but still uncertain threat of a global catastrophe. For such a threat in this century, international contingency planning is warranted, especially to determine urgently and conclusively whether or not a collision will occur.
Certain Collisions	8	A collision is certain, capable of causing localized destruction for an impact over land or possibly a tsunami if close offshore. Such events occur on average between once per 50 years and once per several 1000 years.
	9	A collision is certain, capable of causing unprecedented regional devastation for a land impact or the threat of a major tsunami for an ocean impact. Such events occur on average between once per 10,000 years and once per 100,000 years.
	10	A collision is certain, capable of causing a global climatic catastrophe that may threaten the future of civilization as we know it, whether impacting land or ocean. Such events occur on average once per 100,000 years, or less often.

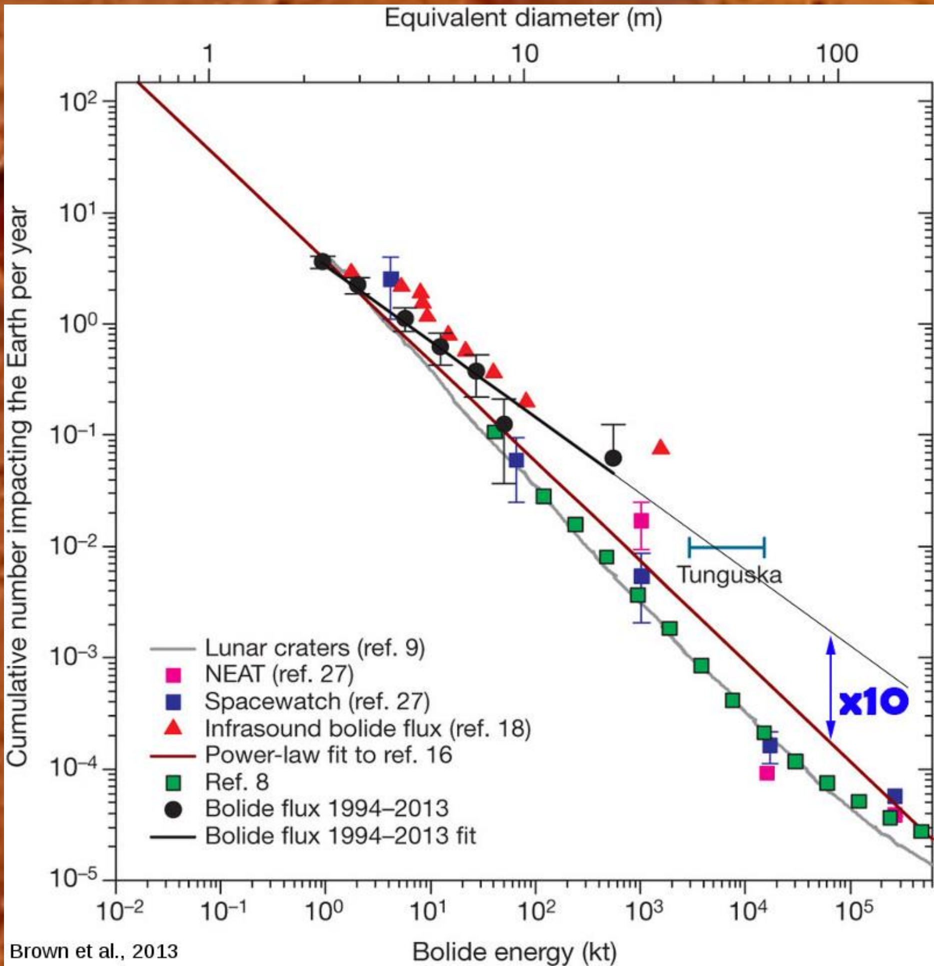
Fig. 2. Public description for the Torino Scale, revised from Binzel (2000) to better describe the attention or response that is merited for each category.

Don’t panic !! …..
BUT …..
After Tungunska … the estimation rate has been multiplied by 10 !!!!

Brown , et al. 2002

Brown , et al. 2013





2. How meteorites study is linked to the solar system exploration ?

Meteorites are precious objects for astronomers, exobiologists, geoscientists because their study reaveal :

-their content (Organic matter)

-their origin …

They help us to better understand the Solar System structure.

Where do meteorites come from ?

- **Asteroids belt**
- **Trojan bodies (in between each Kirkwood Gaps , on Jupiter orbit)**
- **Kuiper Belt** (more for comets)

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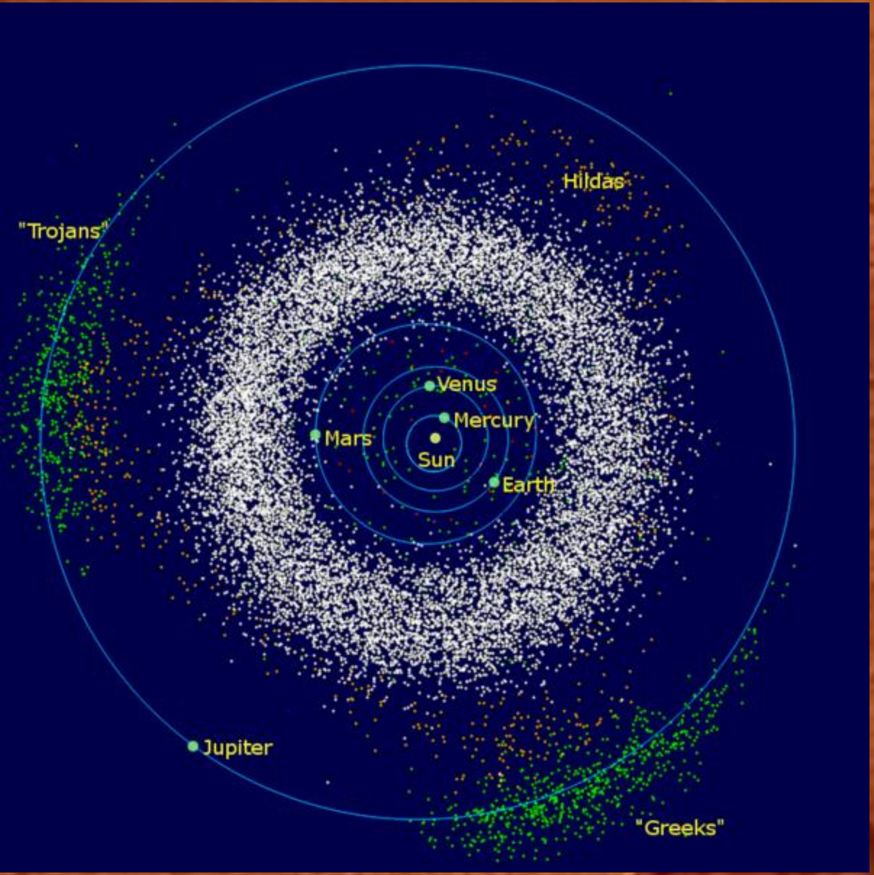
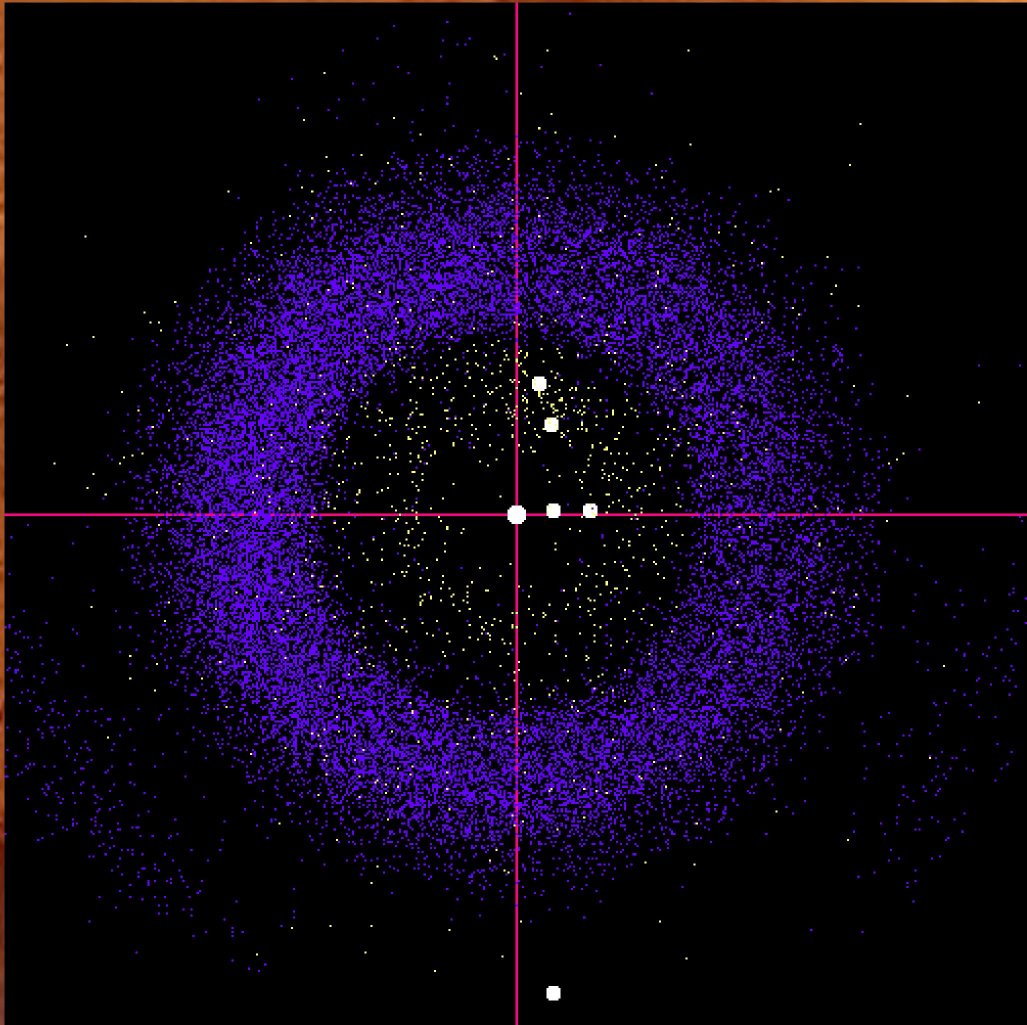
Where do meteorites come from ?





http://www.asterank.com/3d/

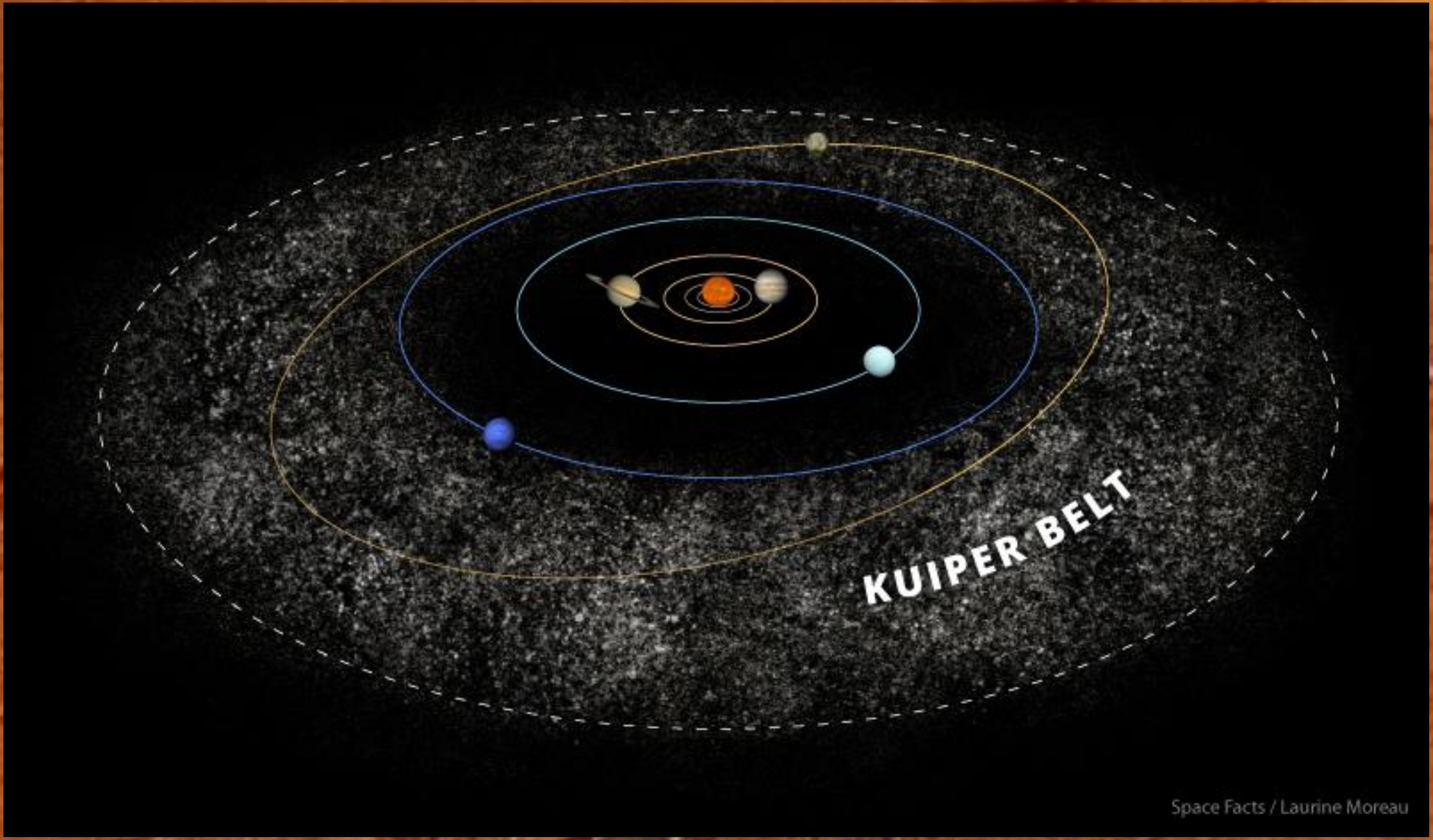
Some very rare meteorites :

The MARTIAN meteorites called SNC

SNC : Shergottites, Nakhlites and Chassignites

Only 34 SNC on 24 000 meteorites found on Earth !

Kuiper Belt : an other reservoir of asteroids (mostly comets)



3 . How meteorites are linked to the Martian exploration ?

Link in between Meteorites ⟷ Mars ?

Aim of the mission :

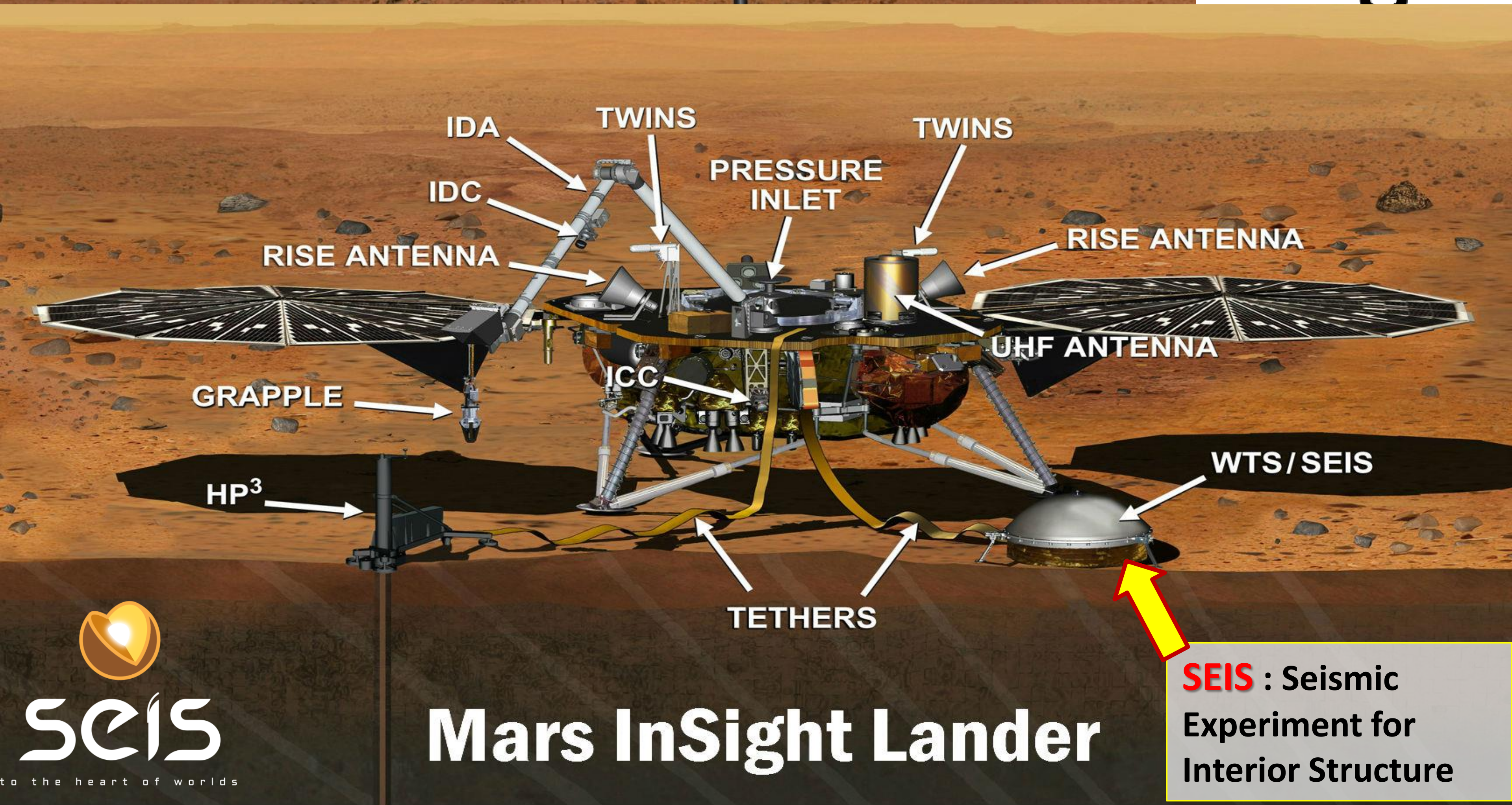
Discover the **inner structure** of Mars by measuring the planet's "vital signs":
Its "pulse" (**seismology**),
"temperature" (**heat flow probe**),

And

detecting the fingerprints of the **processes** of terrestrial **planet formation.**

3 . How meteorites are linked to the Martian exploration ?

In 2018, **SEIS**, the **SEISMOMETER** will be installed on MARS for the very first time , thanks to the InSIGHT lander .

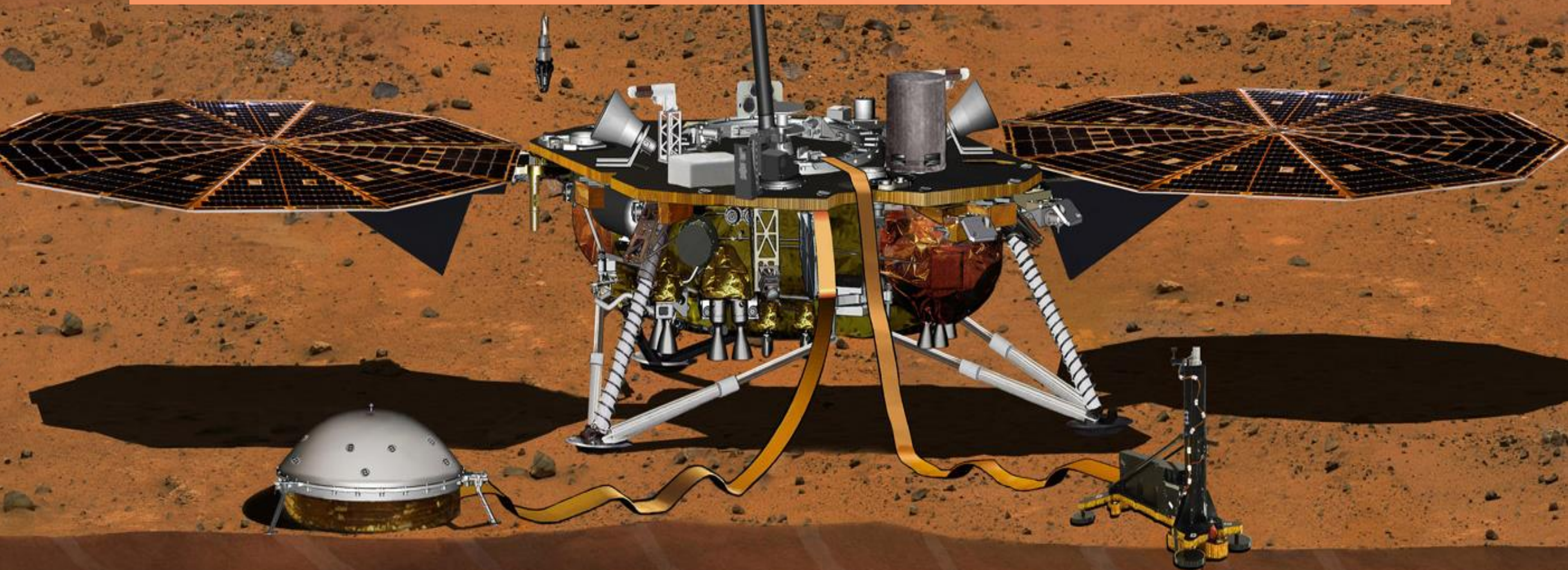


SEIS : Seismic Experiment for Interior Structure

https://insight.cnes.fr/fr/videos

InSight : Interior Exploration using *Seismic* Investigations, Geodesy and Heat Transport c

In 2018, SEIS (the french seismometer) will be recording seismic waves on the Martian surface...



But how do seismic waves can be produced on the Red Planet ?

3 main events that create seismic waves :

Dust Devils

3 main events that create seismic waves :

Dust Devils

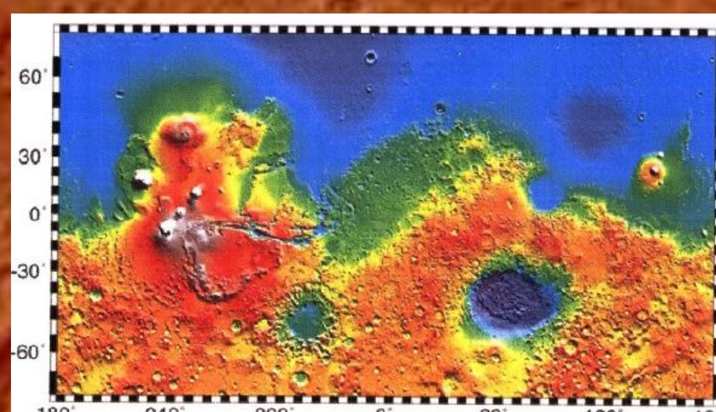
Thermic Contractions

3 main events that create seismic waves :

Dust Devils

Meteorite impacts

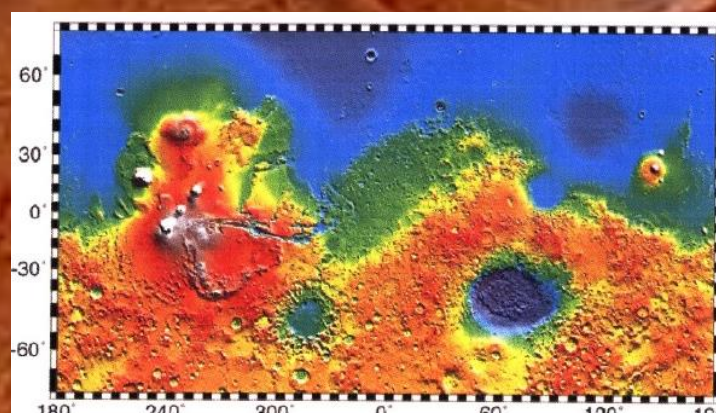
Thermic Contractions



3 main events that create seismic waves :

Dust Devils

Meteorite impacts



Thermic Contractions

Expected rate of impacts for interior structure analysis :

4 to 6 significant impacts / year !

4. Let's focus on meteorite impacts !

Ready for an investigation into the formation of craters ?

4. Let's focus on meteorite impacts !

**According to you ,
which parameters control
the
crater diameter ?**

4. Let's focus on meteorite impacts !

Size of impactor
Velocity of Impactor
Density of impactor

Investigation 1 :

Variable :

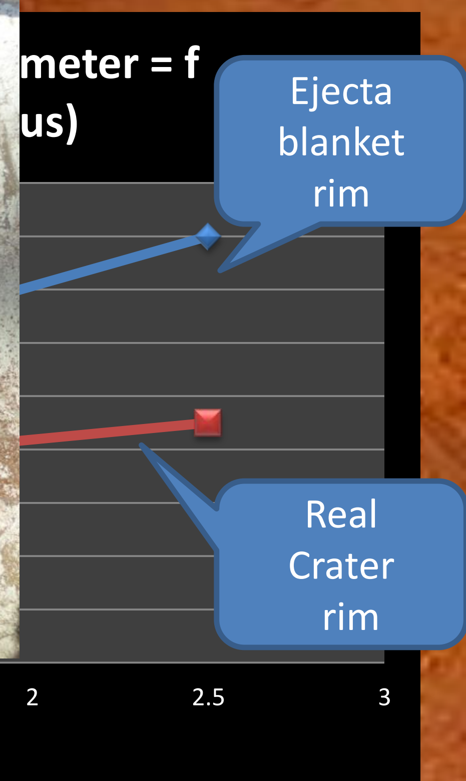
Volume of the impactor

Modelling material : you will have to pick Different sized marbles

Investigation 1 :

Basic treatment:

Diameter		Radius (cm)	Volume (cm^3)
Real Crater	Ejecta Blanket		
1,8	3,5	0,5	
2,5	4	0,8	
3,5	6	1,3	
4	6,5	1,7	
4,5	8	2,5	



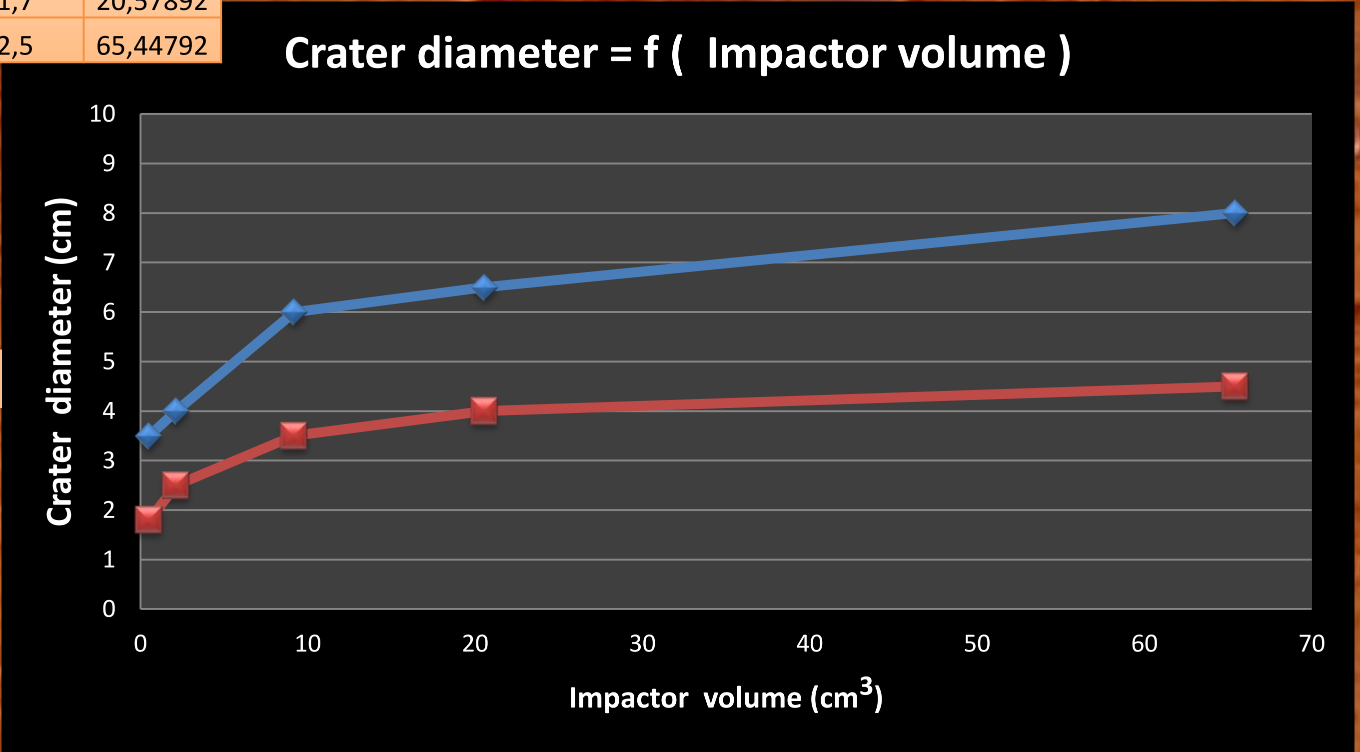
Investigation 1 :

Advanced treatment : from R you get the Volume

Diameter		Radius (cm)	Volume (cm^3)
Real Crater	Ejecta Blanket		
1,8	3,5	0,5	0,523583
2,5	4	0,8	2,144597
3,5	6	1,3	9,202501
4	6,5	1,7	20,57892
4,5	8	2,5	65,44792

V= 4/3* Π *R^3

=(4/3)*3,1415*(D3*D3*D3)



Investigation 2 :

Variable :

Height of Drop

Modelling material : you will have to pick

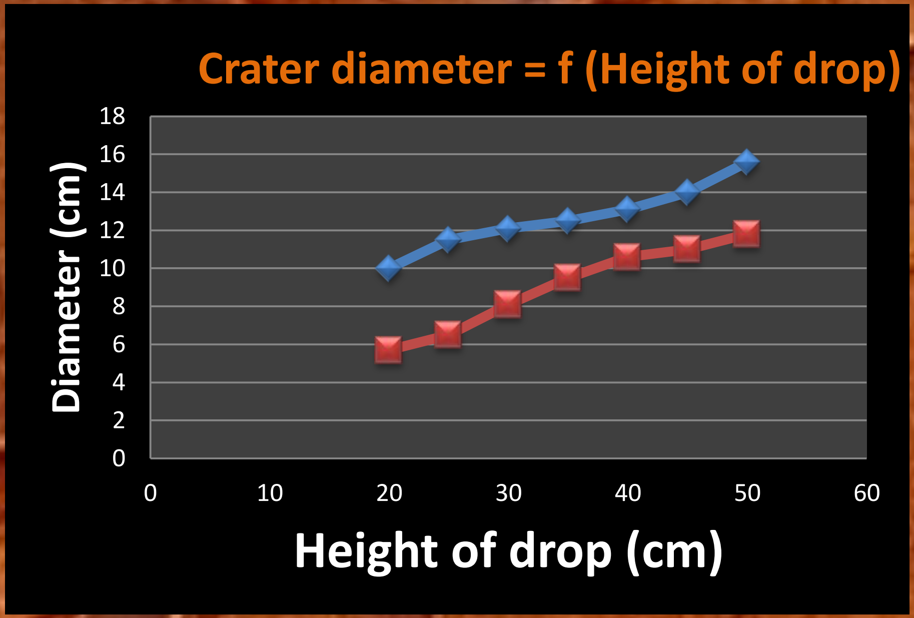
Same marbles but

to choose different heights of drop

Investigation 2 : Height of Drop

Basic treatment:

Diameter		Drop Height (cm)
Red marble	Blue marble	
5,7	10	20
6,5	11,5	25
8,1	12,1	30
9,5	12,5	35
10,6	13,1	40
11	14	45
11,8	15,6	50



Investigation 2 : Height of Drop

<u>Advanced treatment:</u>

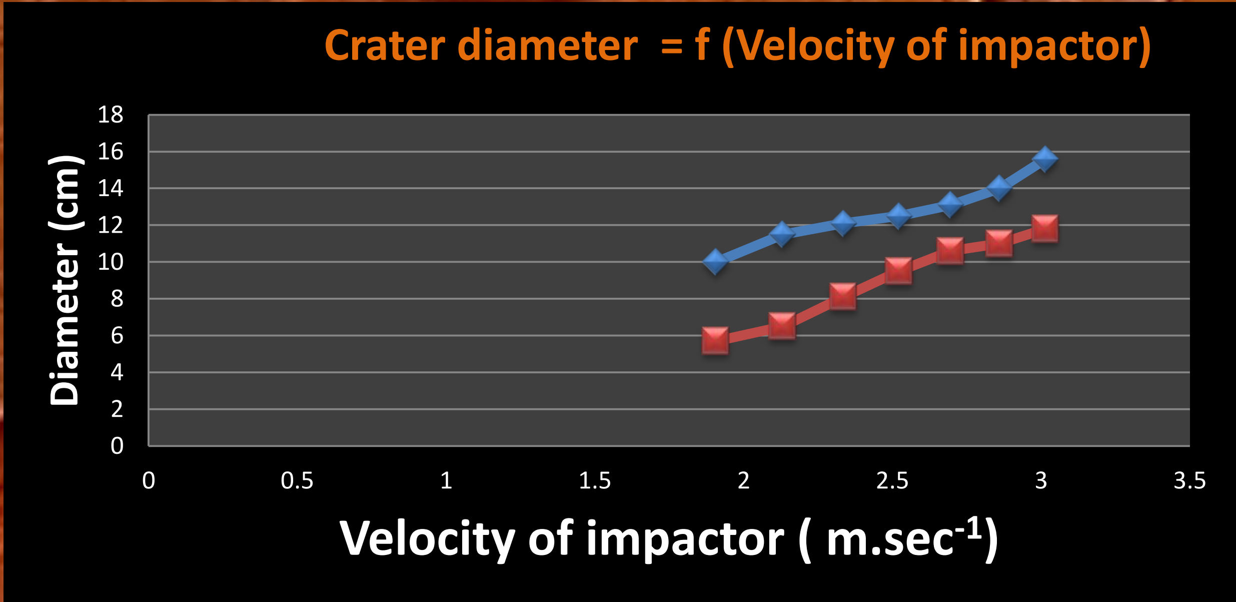
Crater diam. Against Velocity

Diameter		Drop Height (cm)	Velocity (m/s)
Red marble	Blue marble		
5,7	10	20	1,907878403
6,5	11,5	25	2,133072901
8,1	12,1	30	2,336664289
9,5	12,5	35	2,523885893
10,6	13,1	40	2,698147513
11	14	45	2,861817604
11,8	15,6	50	3,016620626

Ke = Pe

$$\frac{1}{2} m v^2 = mgh$$

$$V = \sqrt{(2gh)}$$



Investigation 3 :

Variable :

Density of the impactor

Modelling material : you will have to pick 4 balls of Same volume (use clipper !) **but different density balls !**

Investigation 3 :

Variable :

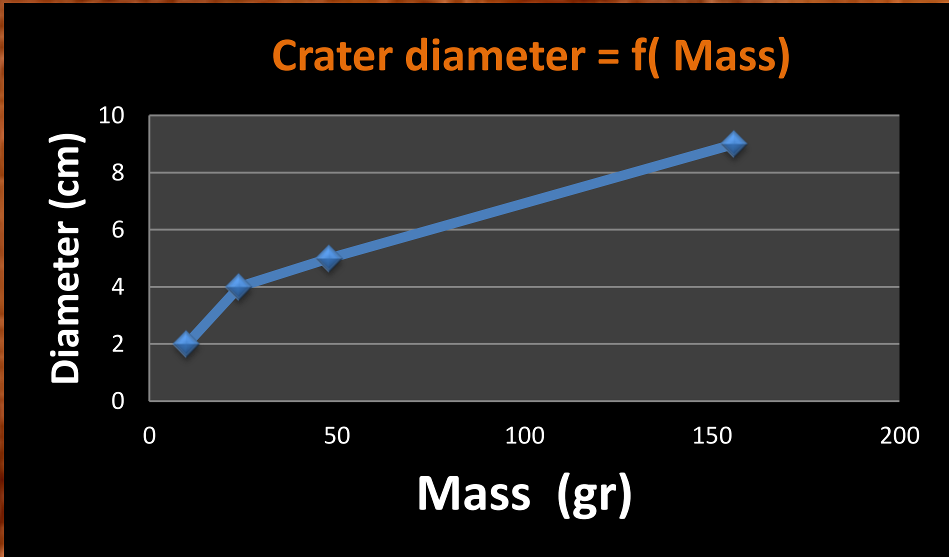
Density of the impactor

Basic treatment:

Crater diam. Against Mass of impactor

(for a same volume)

impactor (5 cm)	Diameter ejecta rim	Mass (g)
impactor 1	2	10
impactor 2	4	24
impactor 3	5	48
impactor 4	9	156



Investigation 3 :

<u>Variable :</u>

Density of the impactor

<u>Advanced treatment:</u>

Crater diam. Against density of impactor :

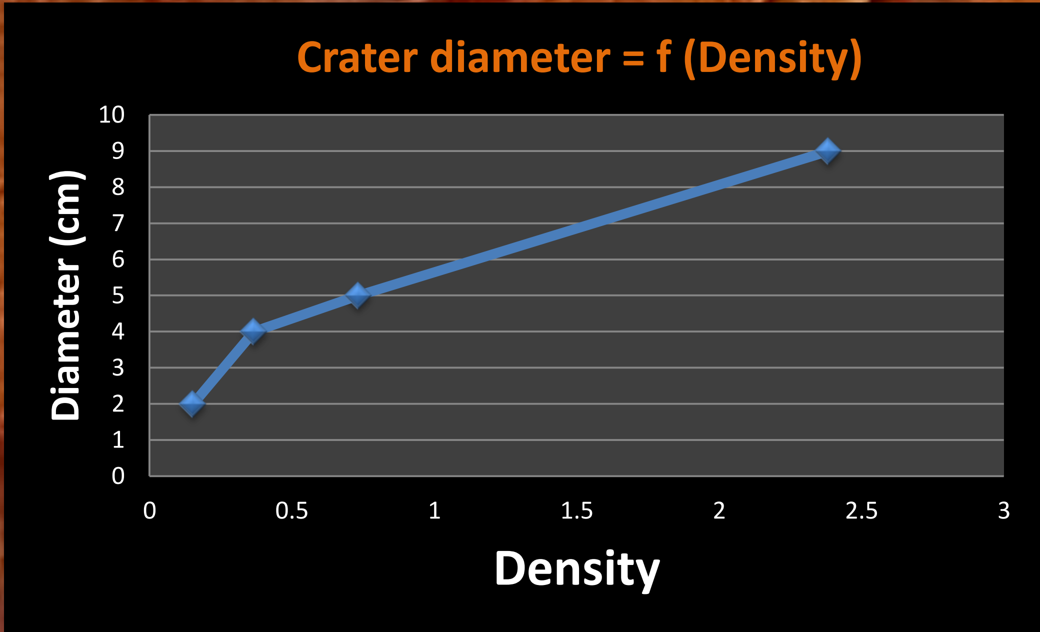
impactor (5 cm)	Diameter ejecta rim	Mass (g)	volume (cm3)	density
impactor 1	2	10	65,44792	0,152793
impactor 2	4	24	65,44792	0,366704
impactor 3	5	48	65,44792	0,733408
impactor 4	9	156	65,44792	2,383575

Data you'll need :

Volumetric mass of water :

ρ (water) = 1 000 kg/m^3

ρ (water) = 1g/cm^3



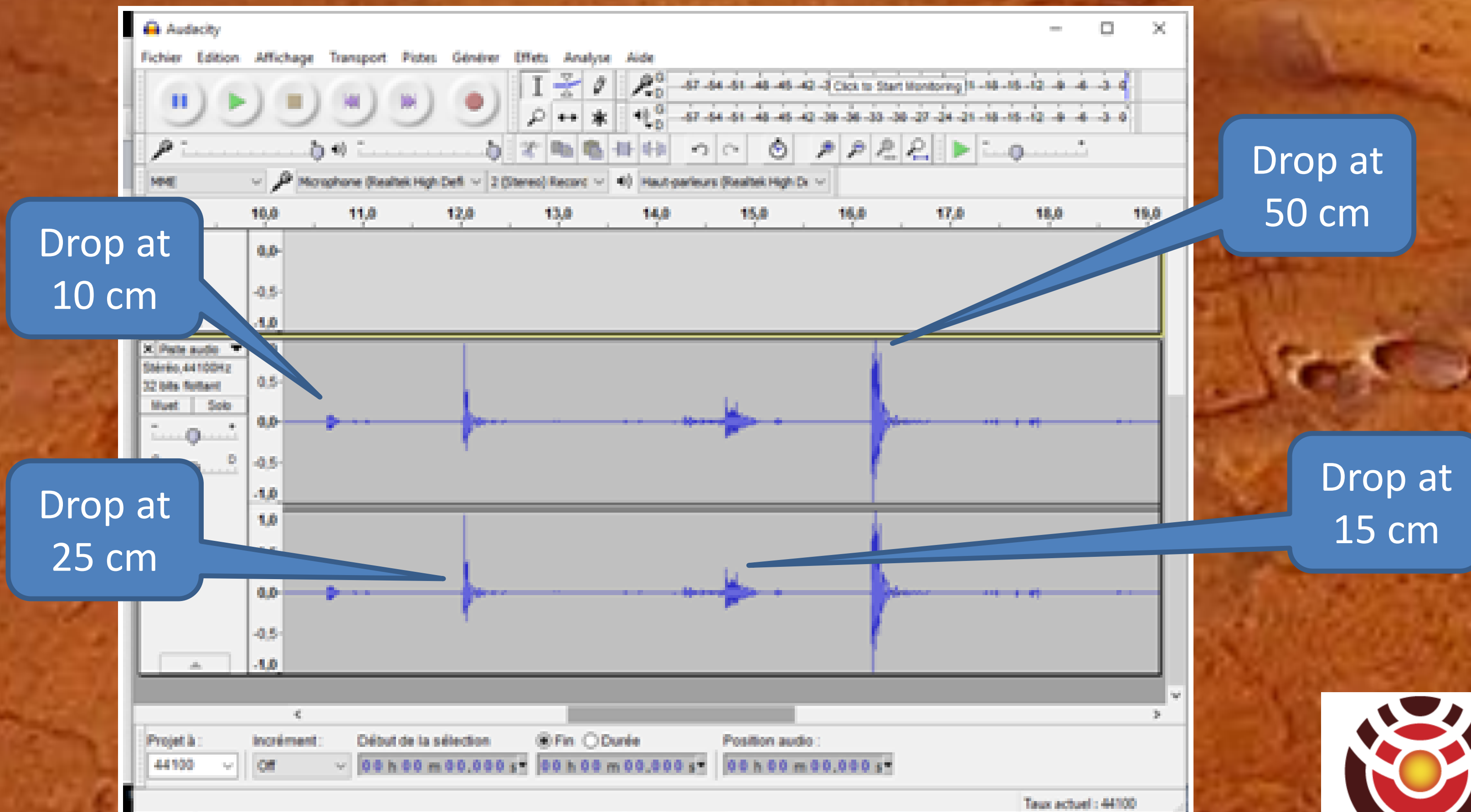
Investigation 4 :

How to plot a calibration curve ?

Modelling material : **you will have to use Audacity software , pick some marbles, and ruler .**

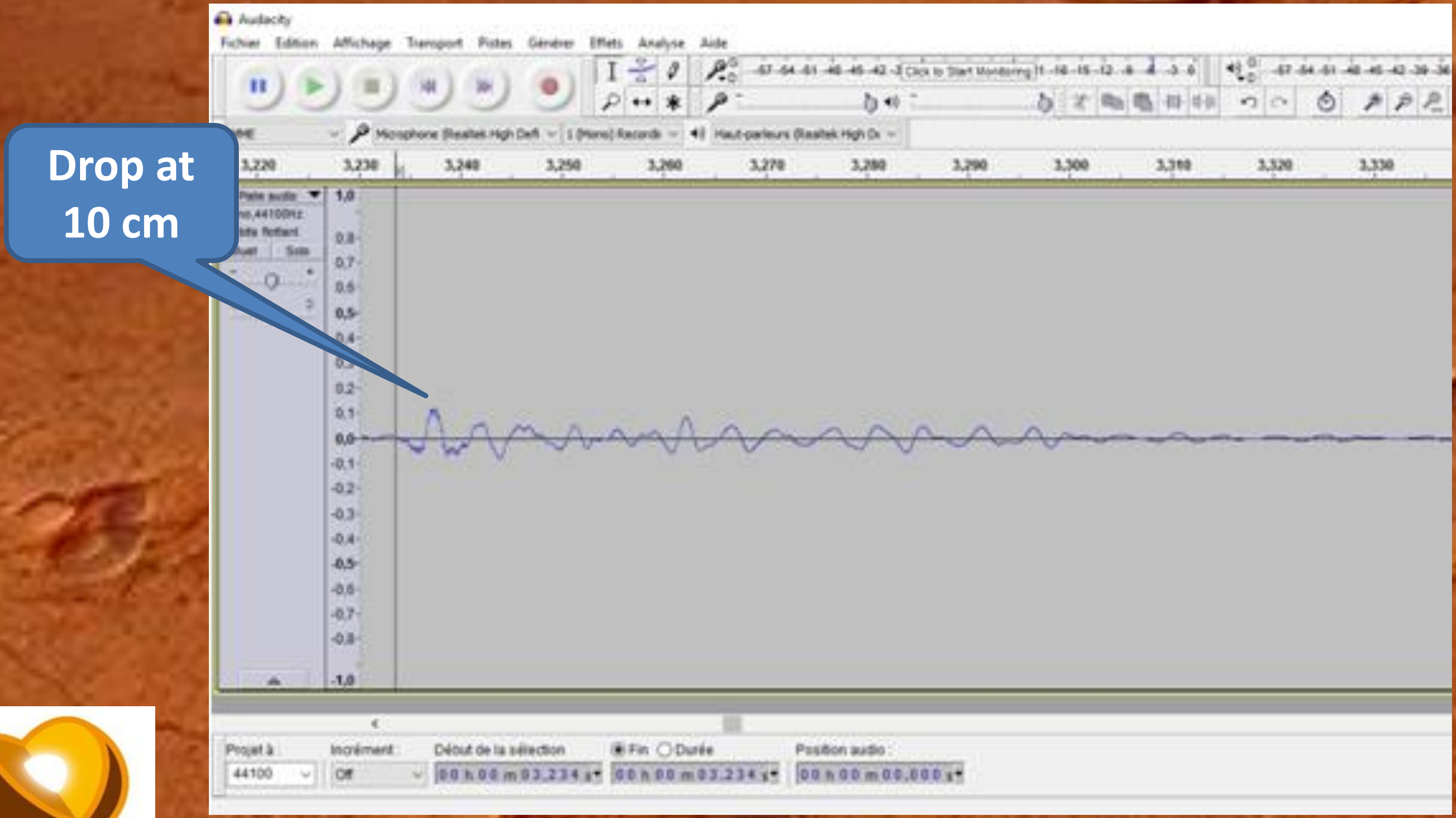
Investigation 4 :

How to plot a calibration curve ?



Investigation 4 :

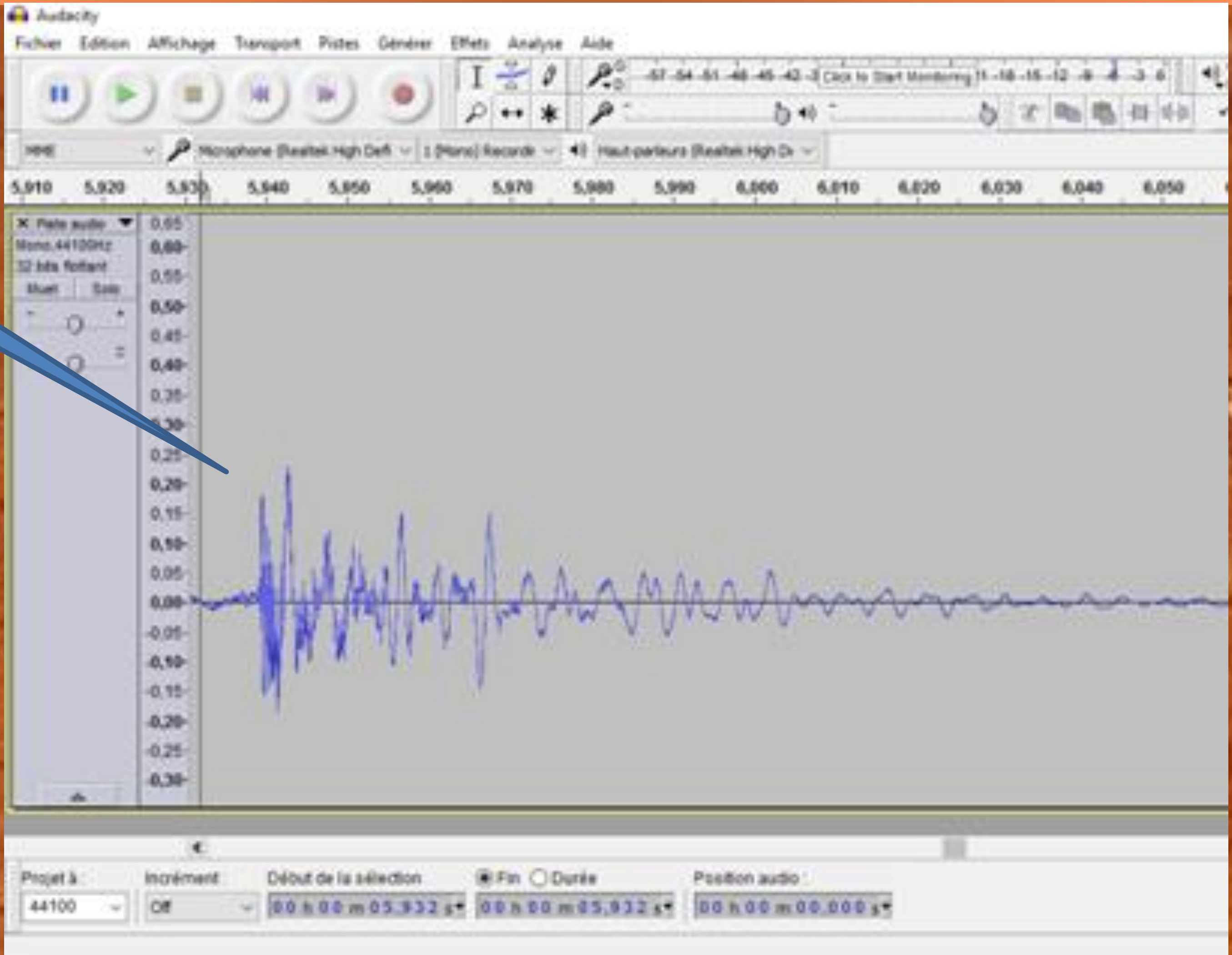
How to plot a calibration curve ?



Investigation 4 :

How to plot a calibration curve ?

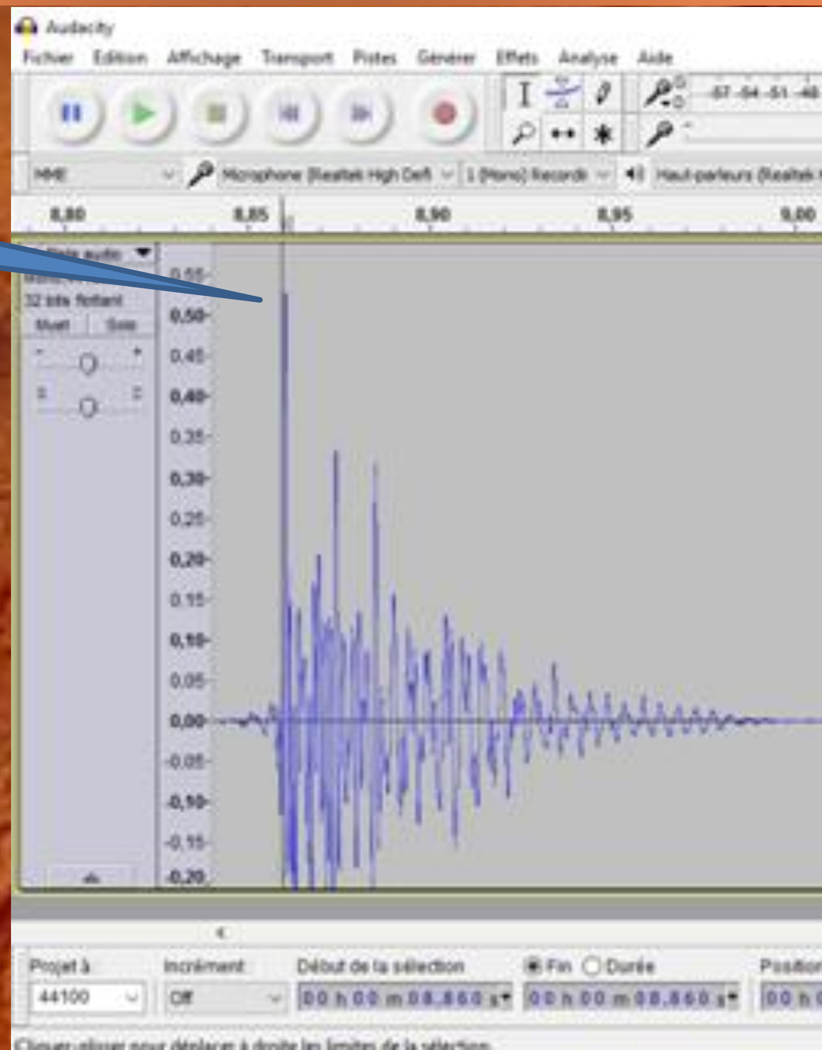
Drop at 25 cm



Investigation 4 :

How to plot a calibration curve ?

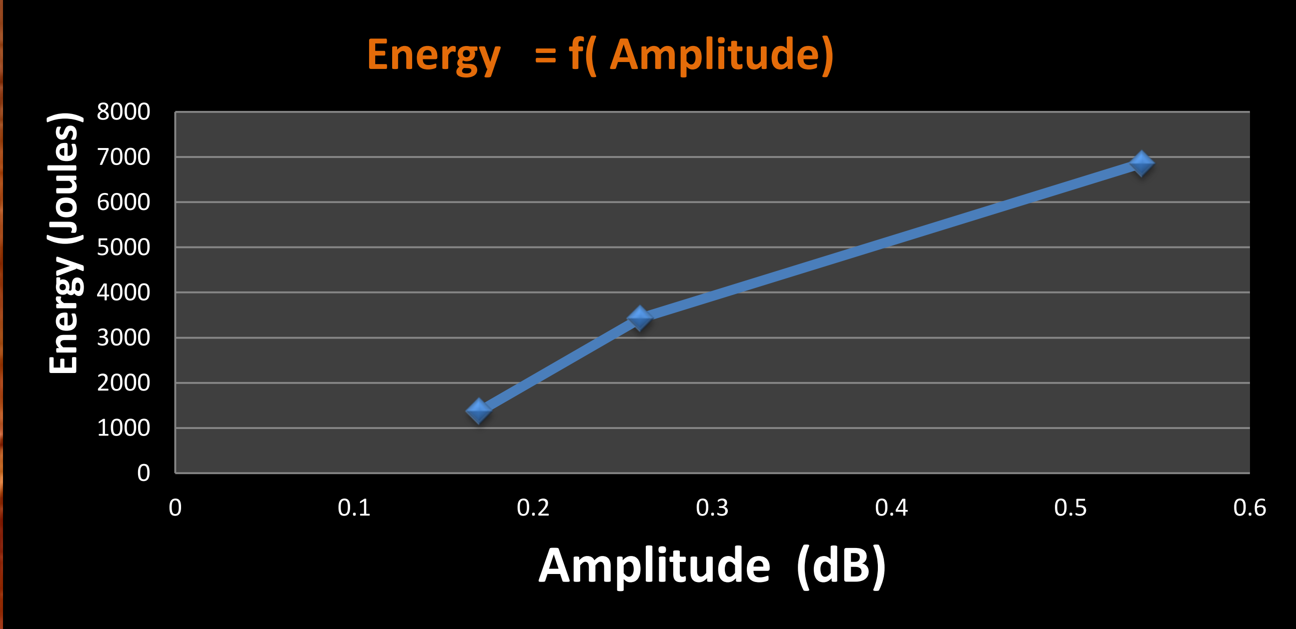
Drop at
50 cm



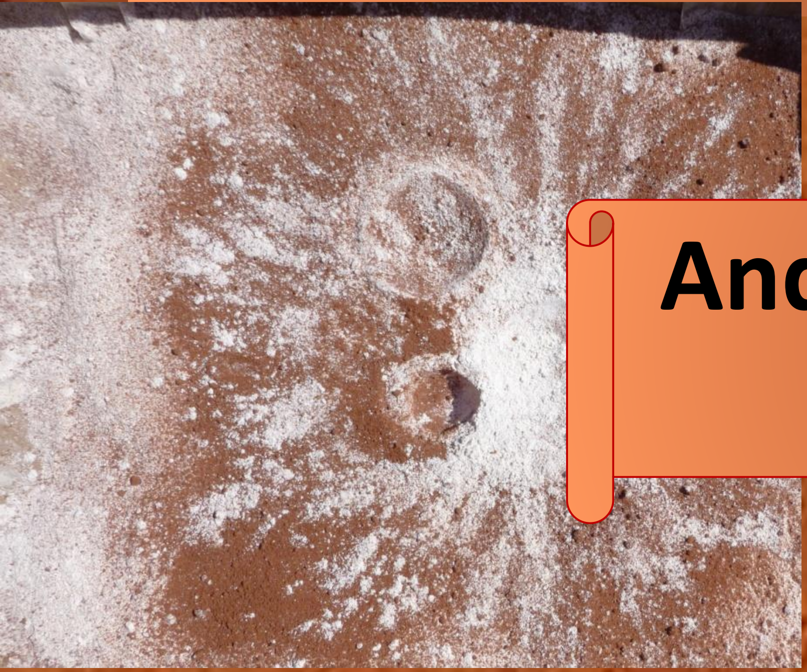
Investigation 4 :

How to plot a calibration curve ?

Impact	Mass of impactor (g)	standard acceleration due to gravity ($m.s^{-2}$)	Energy (Joules) Ke = 1/2 mv^2		Amplitude (dB)	
10	14	9,8	1372		0,17	
25	14	9,8	3430		0,26	
50	14	9,8	6860		0,54	



Thank you for your attention !



Andy will go further with craters !