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# Searching for life in impact structures: stable isotope geochemistry and mineralogy of post-impact hydrothermal deposits of the Rochechouart structure

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# Life in extreme environments

"**Extremophile:** an organism that is tolerant to environmental extremes and that has evolved to grow optimally under one or more of these extreme conditions*"

...ie. "unusual" conditions - no sunlight, highly acidic/alkaline, very cold/hot, etc...

**Hydrothermal systems:** thermophiles/thermoacidophiles, sulphur reducers, halophilic, chemosynthesizers or endoliths (few ex.)

- **Provides heat + volatiles + chemical nutrients** = suitable environment for life (not always!)
- Hot springs/vents, MOR "black smokers", volcanoes.

http://cdn.zmescience.com/wp-content/uploads/2010/08

http://artsandsciences.colorado.ed

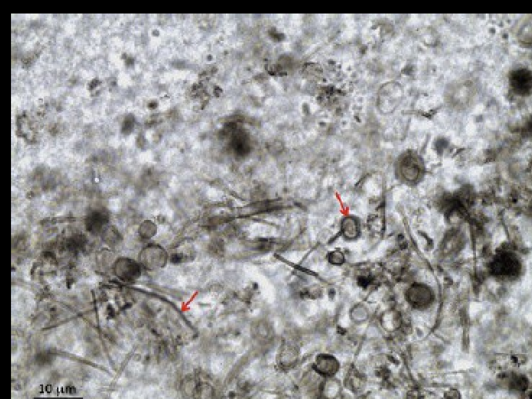


*Encyclopaedia Brittanica

# Finding (microbial) life in rocks

http://www.geomicro.ethz.ch/research


http://www.mindat.org/photo-115782.html




Wacey *et al.* (2014)

**Geochemistry and mineralogy**: stable isotopes and crystal habit.

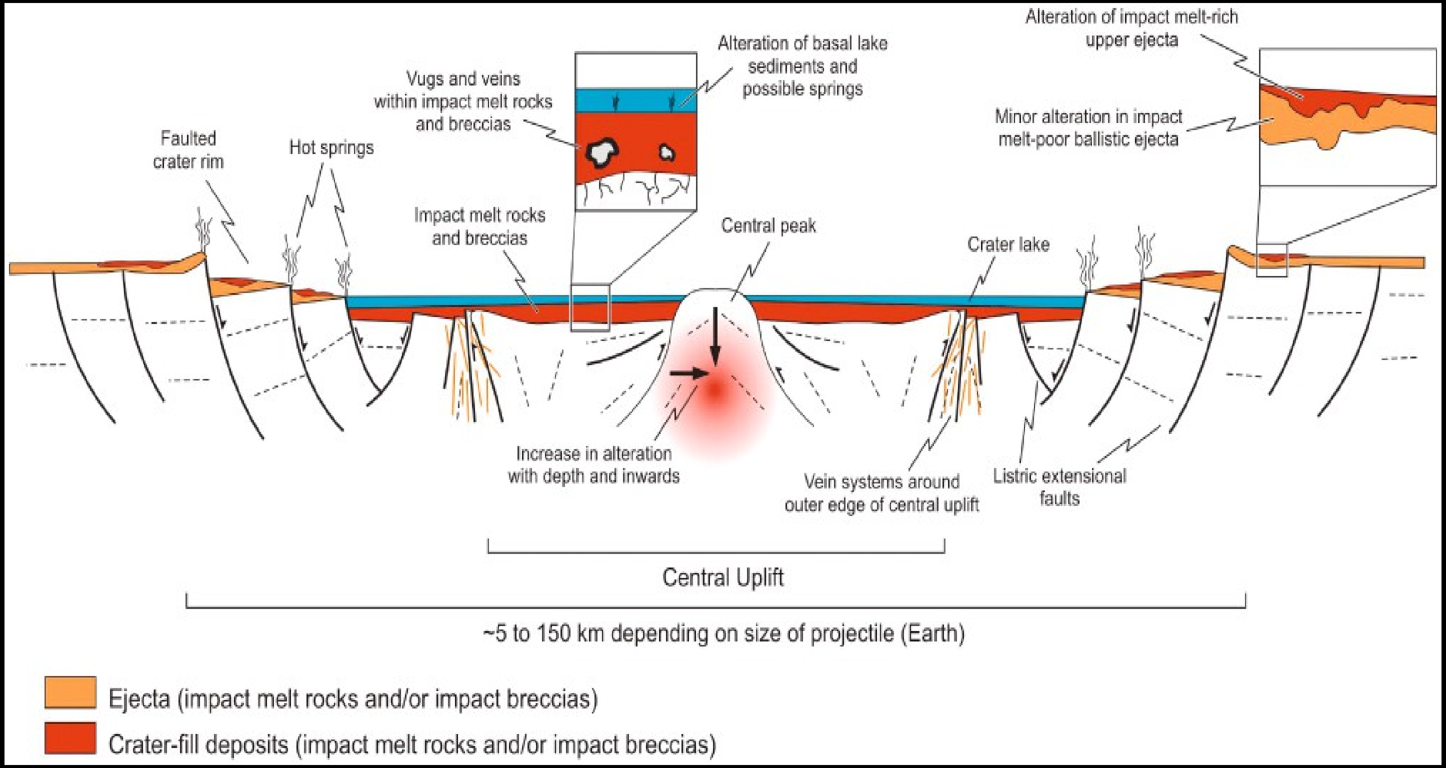
- Can find biosignatures in minerals, especially carbonates and sulphides, metals.

**Microfossils**: endoliths, stromatolites.

**Petrology:** know your minerals, know your environment!

# Impact-generated hydrothermal systems

**Heat source** melt, uplifted geothermal gradient.
**Shocked minerals** highly unstable and reactive. Complex chemistry.
**Shocked rocks** porosity, fractures.
**Water source** depends on target. Surface liquids and ices, hydrated mineral phases.

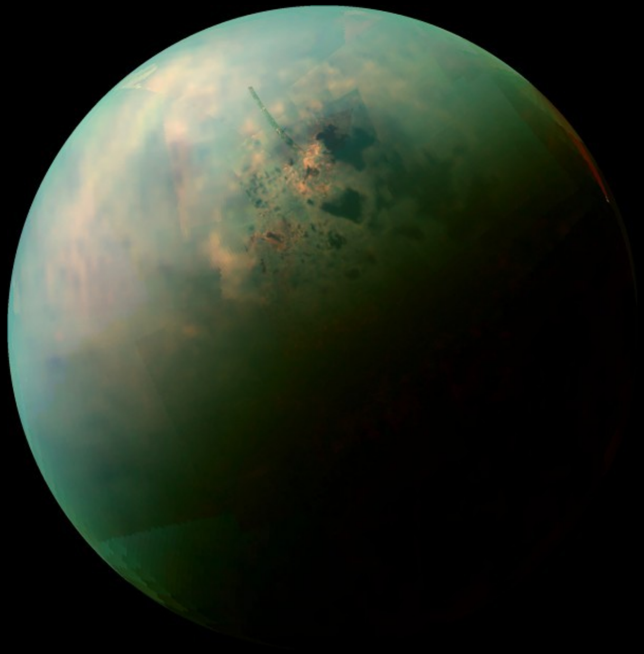



Oainaki, 2012

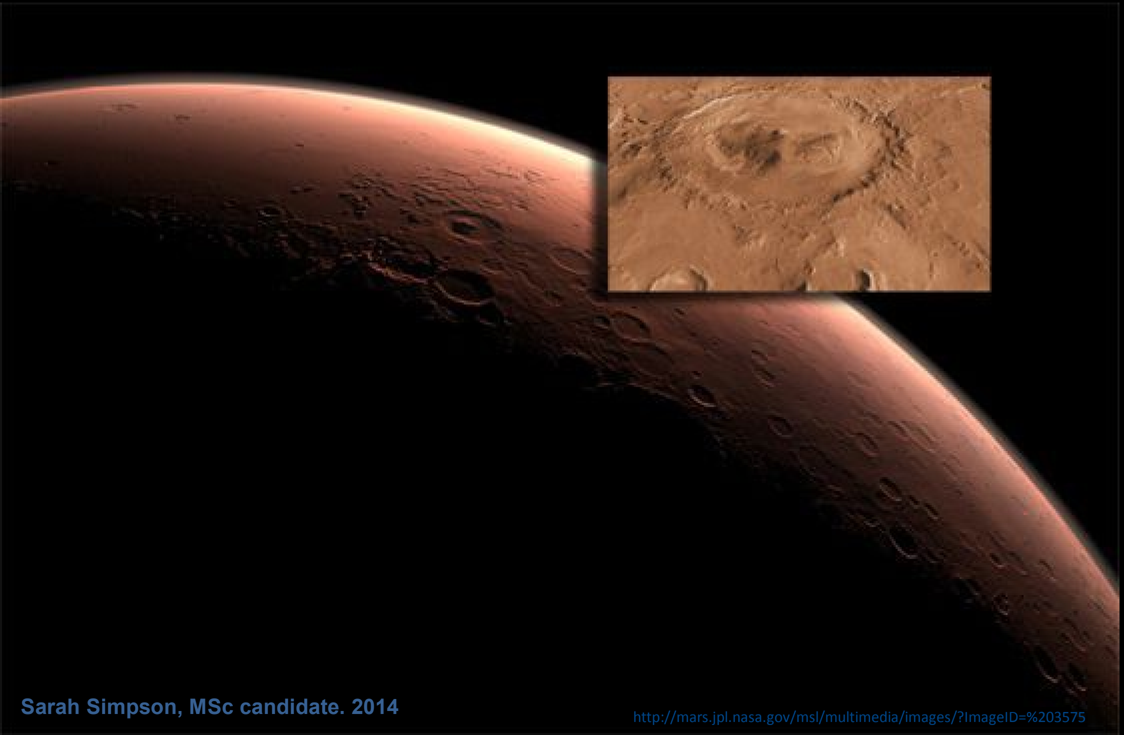
- **Longevity** **varies, few hundred to million years. Retrograde.**
- **Brings heat/energy to tectonically "dead" bodies**
- **Evidence on Mars**

# Ideal candidates

**Rocky/terrestrial planets and satellites**
Need solid surface, rocks hold heat (ie don't look to Jupiter or Neptune).



NASA/JPL/University of Arizona



http://mars.jpl.nasa.gov/msl/multimedia/images/?ImageID=%203575

**Evidence for volatiles and/or volcanism**
Ice, liquids, hydrated mineral phases (water, SO2, CO2, phyllosilicates). Complex chemistry, ie. Mars.

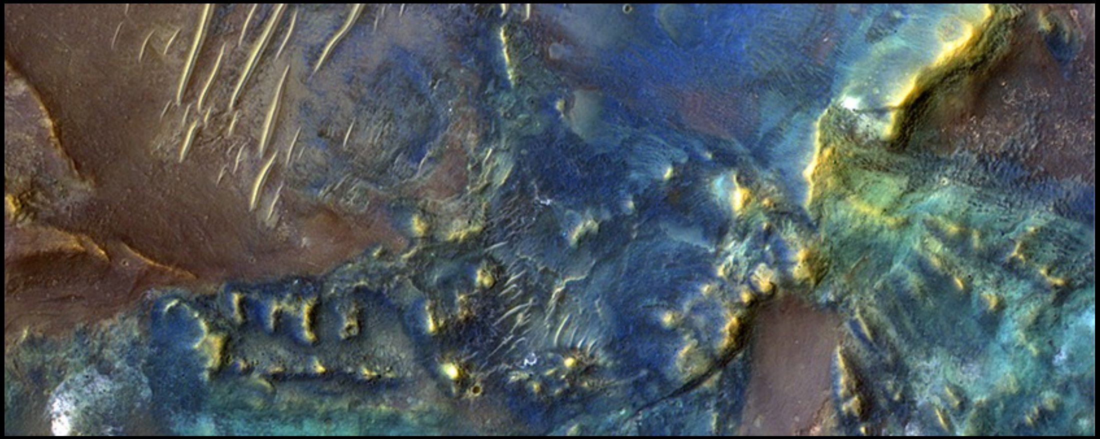
# How do we study them?

**Mars exploration** – Rovers, CRISM (spectroscopy) hydrated mineral phases. Very "young" science.

**Terrestrial analogues** – use ground truths on Earth to better understand how these systems work on other bodies.

**Problems with studying impacts on Earth** – Earth is active and crust is recycled. Older, larger impacts preserved only in cratons.

http://www.trekmatesindia.com/2014/07/tour-to-lonar-crater-with-trek-mates.html



*NASA* CRISM

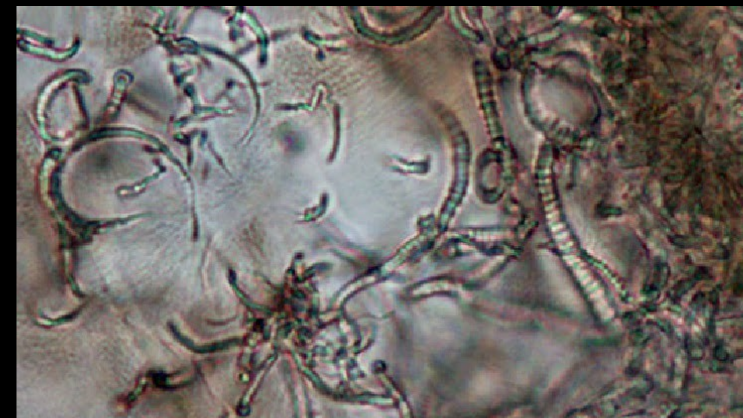
*NASA*

# Water and life in Earth impact structures

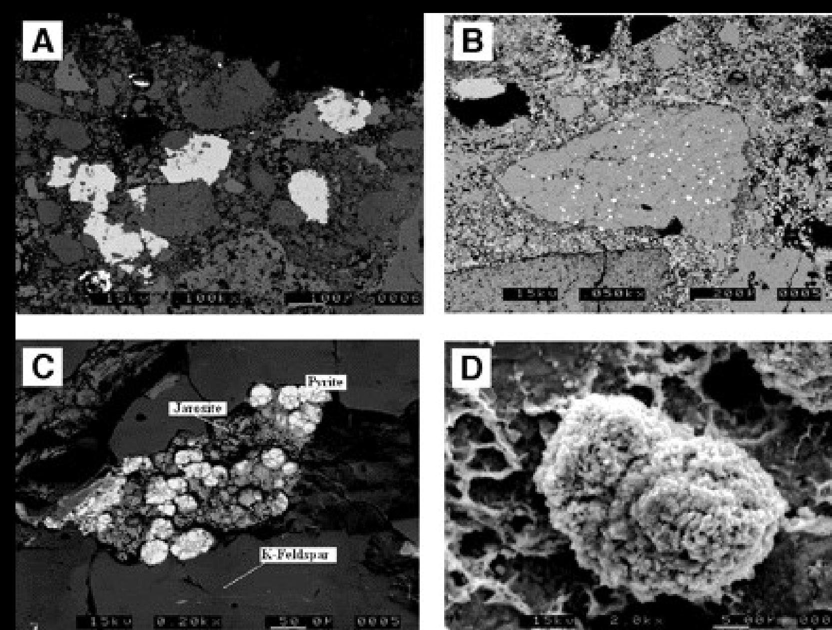
**Ries, carbonate target –** colonization in impact glasses.

**Haughton, mixed sed-xline –** S stable isotopes in hydrothermal breccias, reduction of target sulphate by thermophilic microbes.

**Areas of fluid flow and heat –** can be pervasive, can be localized**,** porous lithic breccias, fractured basement, central uplift, melt



Sapers et al 2014



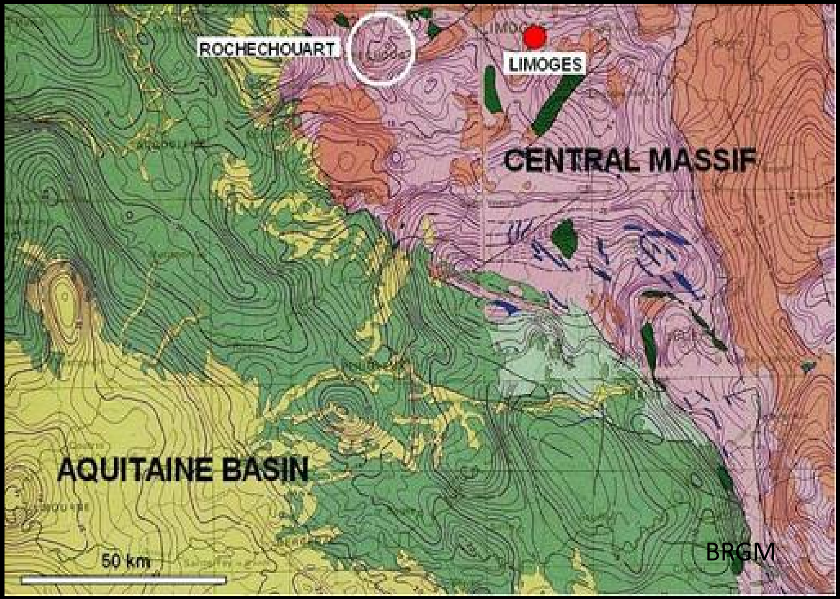

Parnell et al. 2009

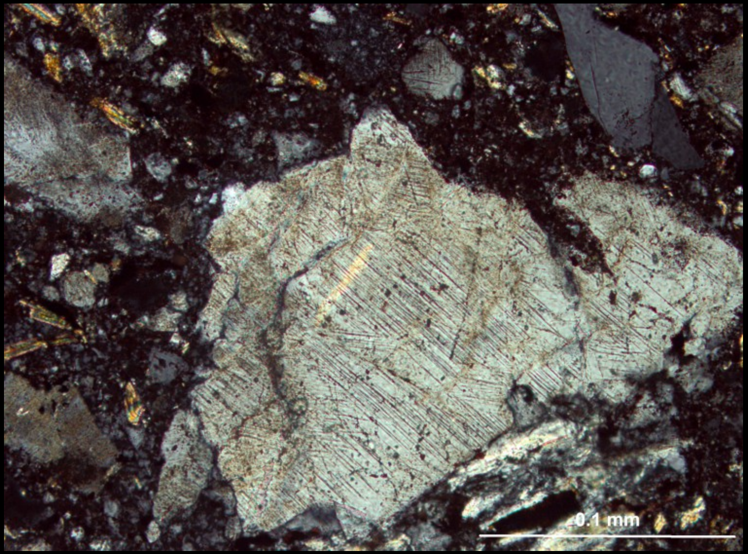
# Case Study: The Rochechouart impact structure

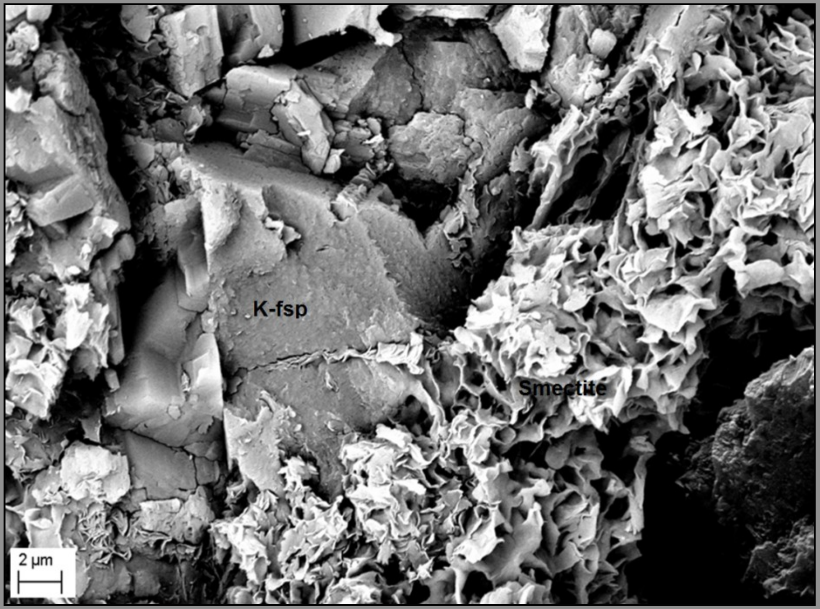
**201 +/- 2 Ma 23km diameter impact structure in France** (Schmeider 2010).

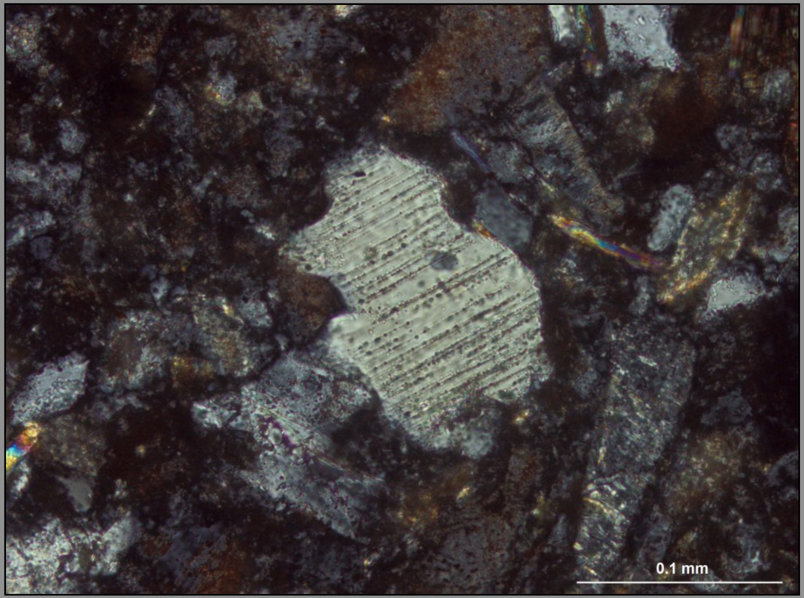
**Target crystalline, shoreline of Aquitaine basin and Central Massif** (Lambert, 1977 and 2010)

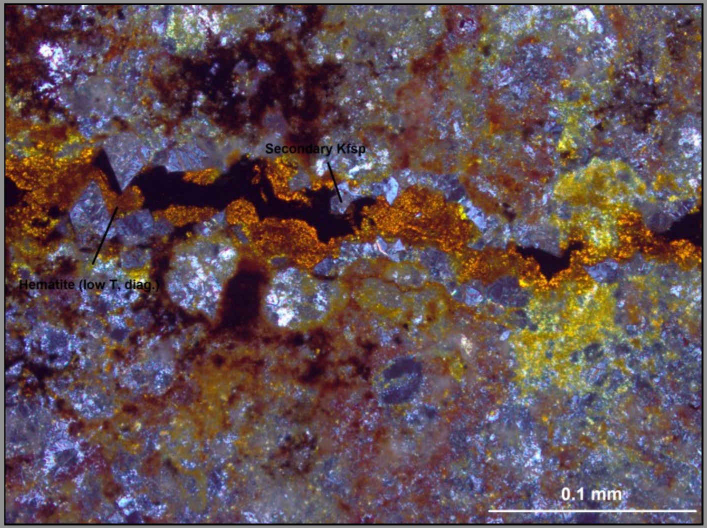
- **Previous authors noted hydrothermal overprint**
- **None to little crater morphology preserved**

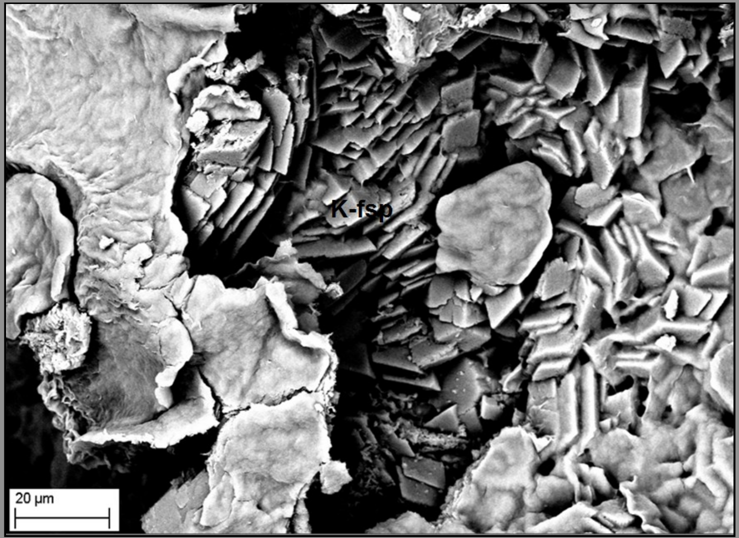




K-fsp
Smectite
2 µm

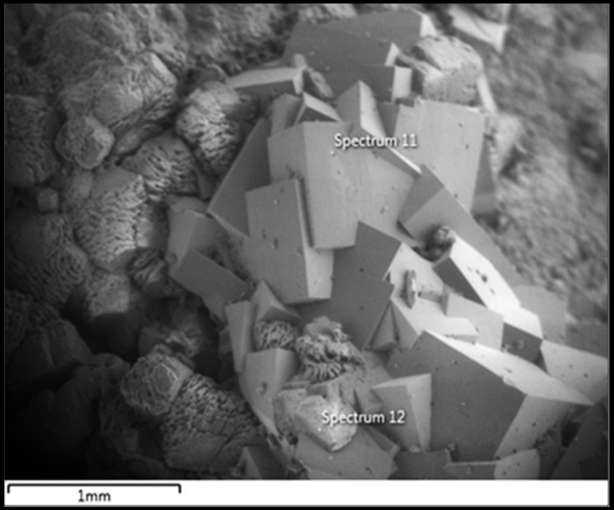

0.1 mm

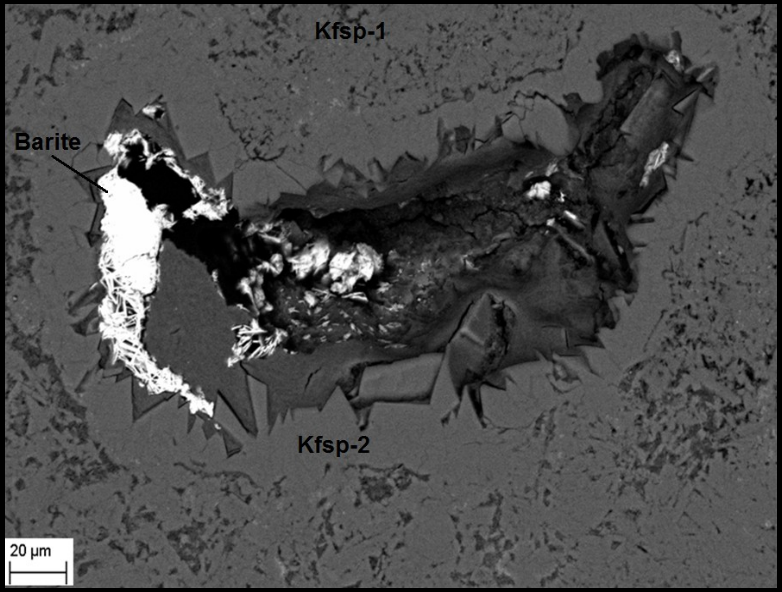

Secondary Kfsp
Hematite (low T, diag.)
0.1 mm

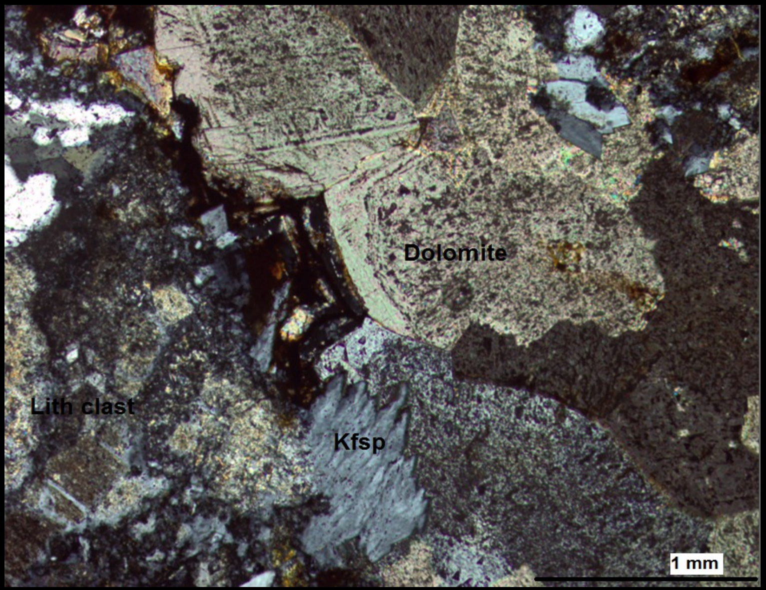

K-fsp
20 µm

## Sulphates, carbonates and sulphides

- Lithic breccias and vesicular melt, barite, dolomite, calcite, pyrite, chalcopyrite, siderite.

## Questions

**1) Primary water source for hydrothermal activity?**

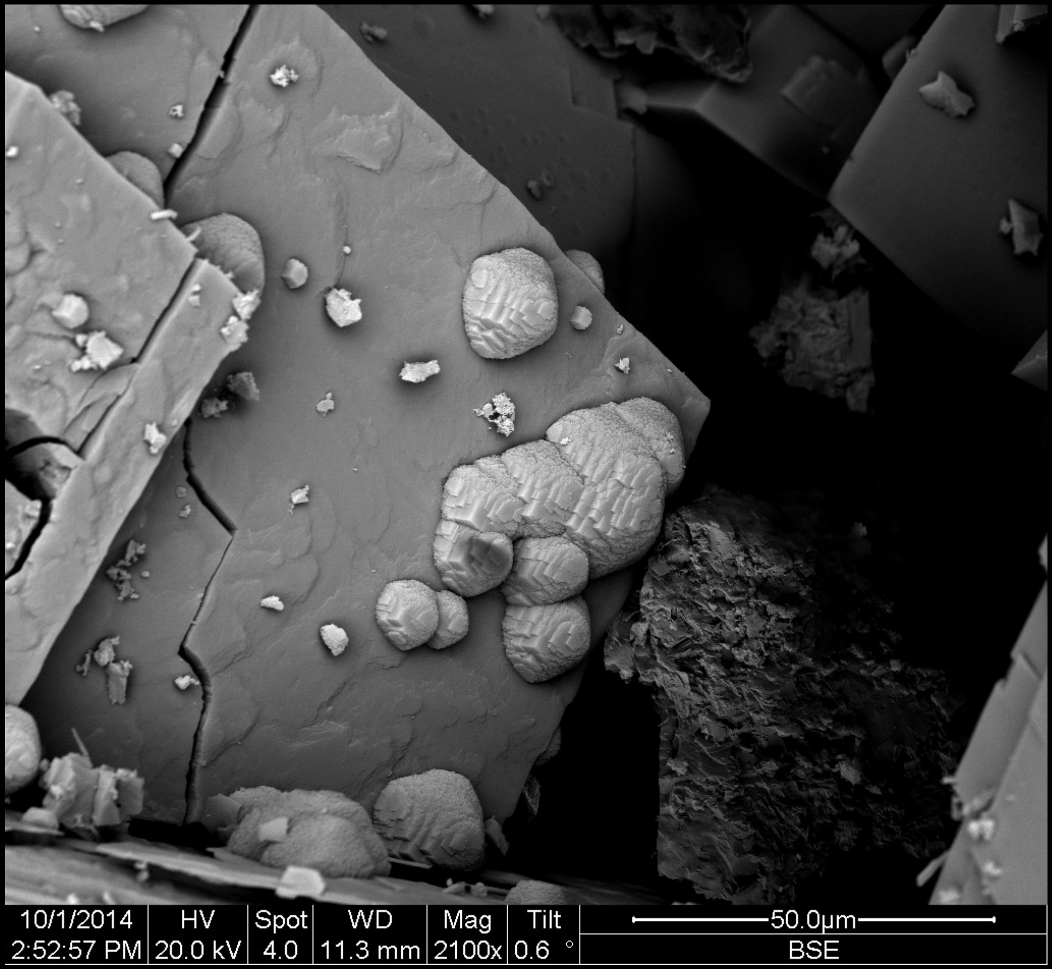
**2) Which areas of structure/lithologies are ideal to support life?**

**3) Sulphides and carbonates source?** Inherited from target material or contain biosignatures?

## ...and how to answer them

**Secondary mineral assemblages** observe, classify and interpret. Geochemistry.

**Stable isotopes** secondary minerals in impactites and target analysis, δ34S δ13C and δ18O, sulphides and carbonates.



# Stable isotopes

Those isotopes of elements which are not radioactive.

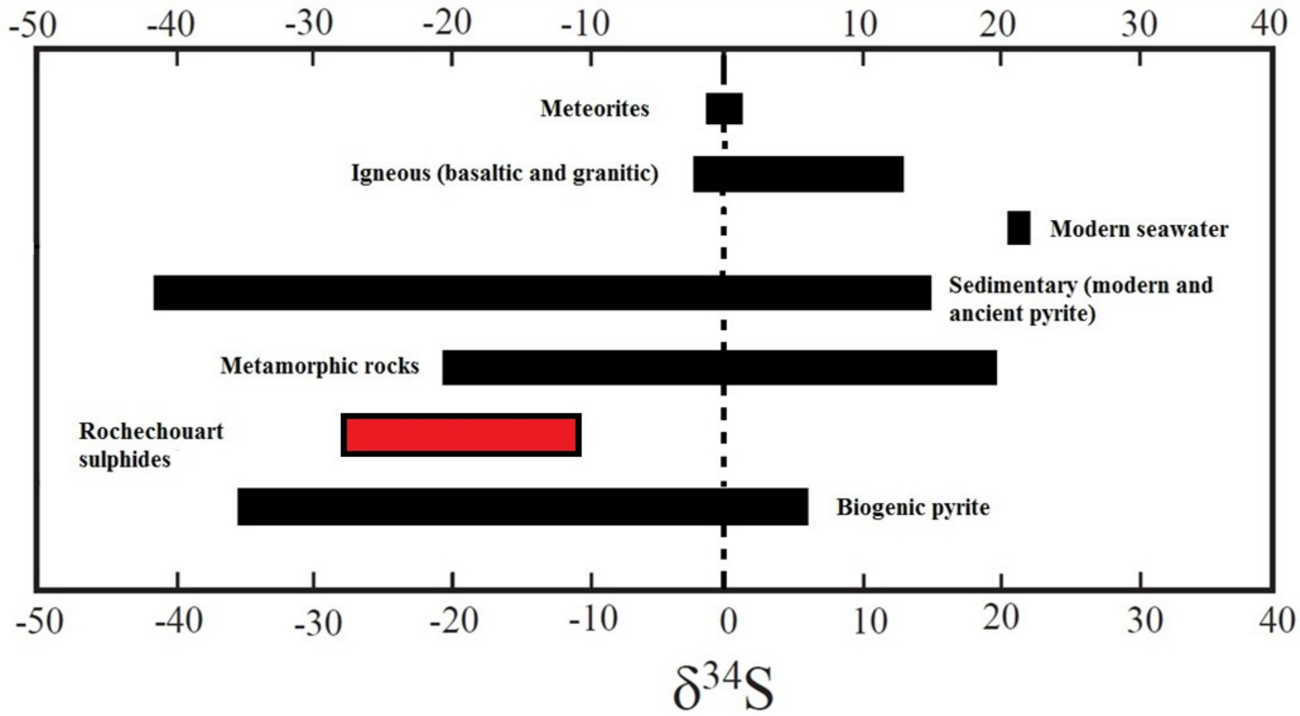
**Differences in mass affect behavior** partition into different phases – gas, liquid, high pressure, high temperature, etc...based on mass.

**Kinetic fractionation** Biological processes (ie - metabolic pathways)

**Most common** Oxygen, carbon, sulphur, hydrogen.

## February 2014

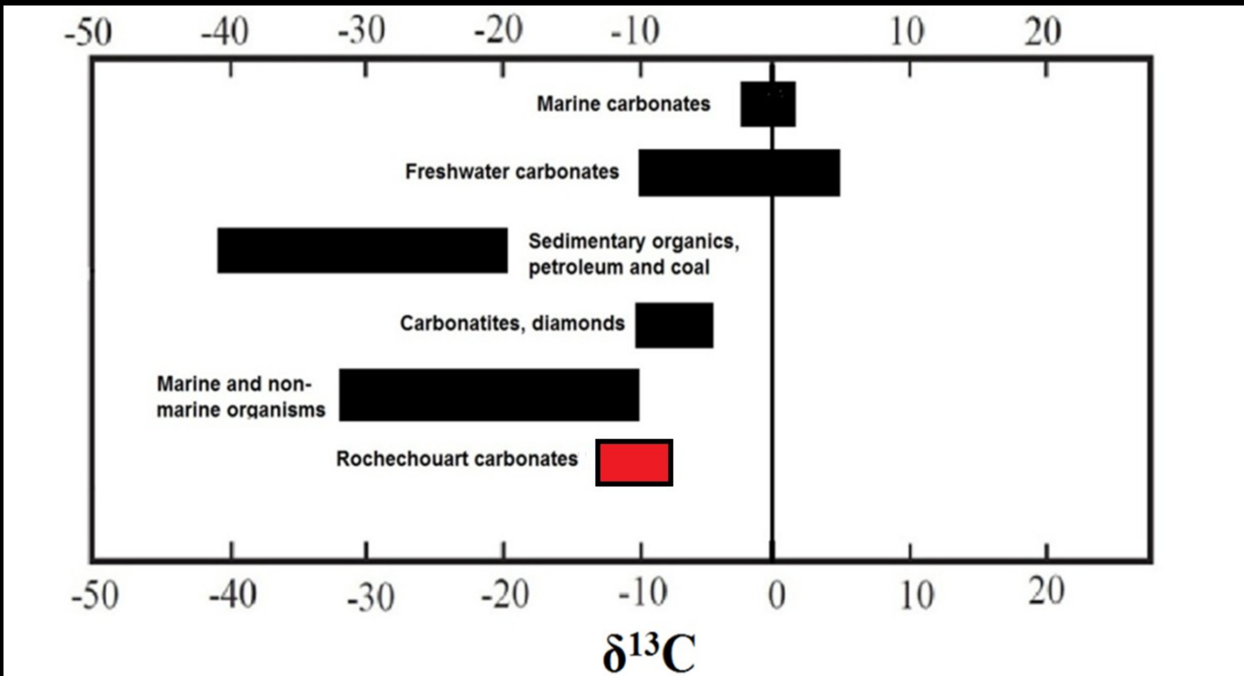
**δ34S stable isotope analysis of sulphides – monomict lithic breccia**




$\delta^{34}S$ of major geologic reservoirs, modified from Seal et al (2000a) and Hoefs (2009), including values of Rochechouart sulphides. All values in permil (VCDT).

## February 2014

δ13C and δ18O stable isotope analysis of sulphides and carbonates



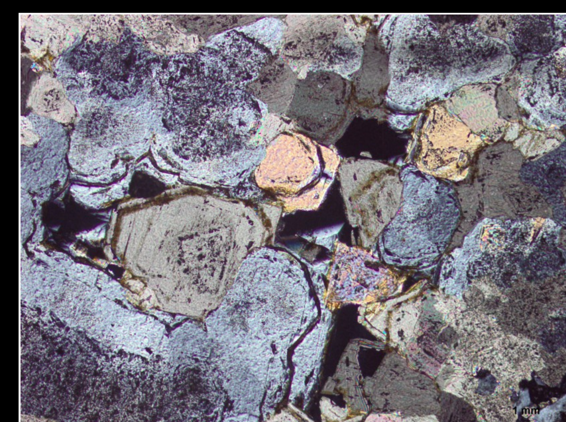

$\delta^{13}C$ of important geologic and environmental reservoirs, including range of Rochechouart carbonates extracted from lithic breccias, dolomite and calcite, for comparison. All values in permil (VPDB). Modified from Hoefs (2009).

### δ18O Averages (VSMOW)

Calcite: 25 ‰
Dolomite: 24.4 ‰

### δ13C Averages (VPDB)

Calcite: -11.2 ‰
Dolomite: -10.8 ‰



# Impact structures are open systems!

**In Rochechouart...**

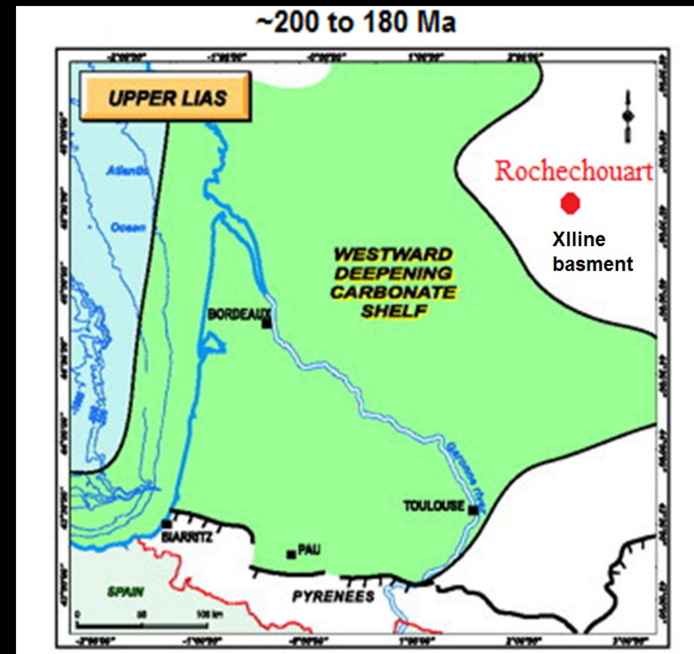
**Isotopes inherited from target?**

- Variety of geologic events recorded. Compare to target material.

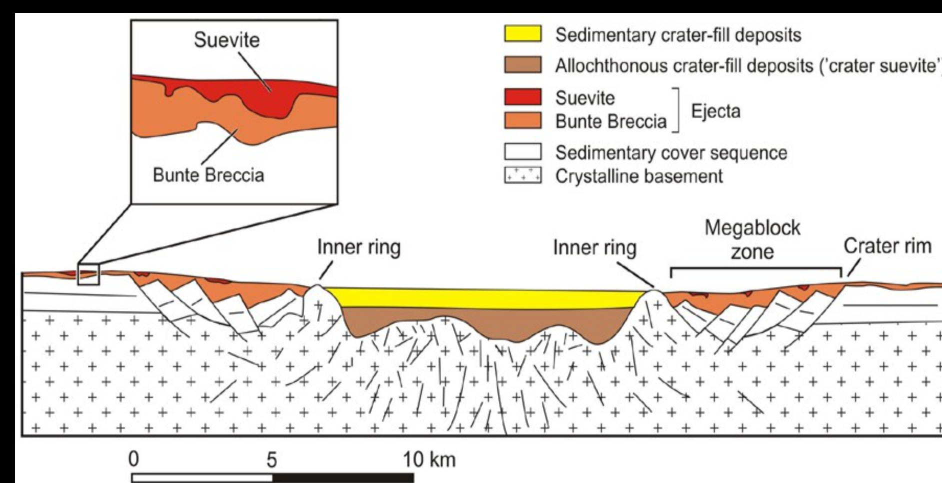
**Paleogeographic influences:**
**Proximity to sea**

Target was on a shoreline - shock fractured basement extend to nearby sea? Mechanics of impacts.

Did seawater infiltrate and sulphate metabolized by organisms in hydrothermal systems?




Petroleum Geoscience, August 2006, v. 12, p. 247-273,




Osinski, modified from Huttner, 1999

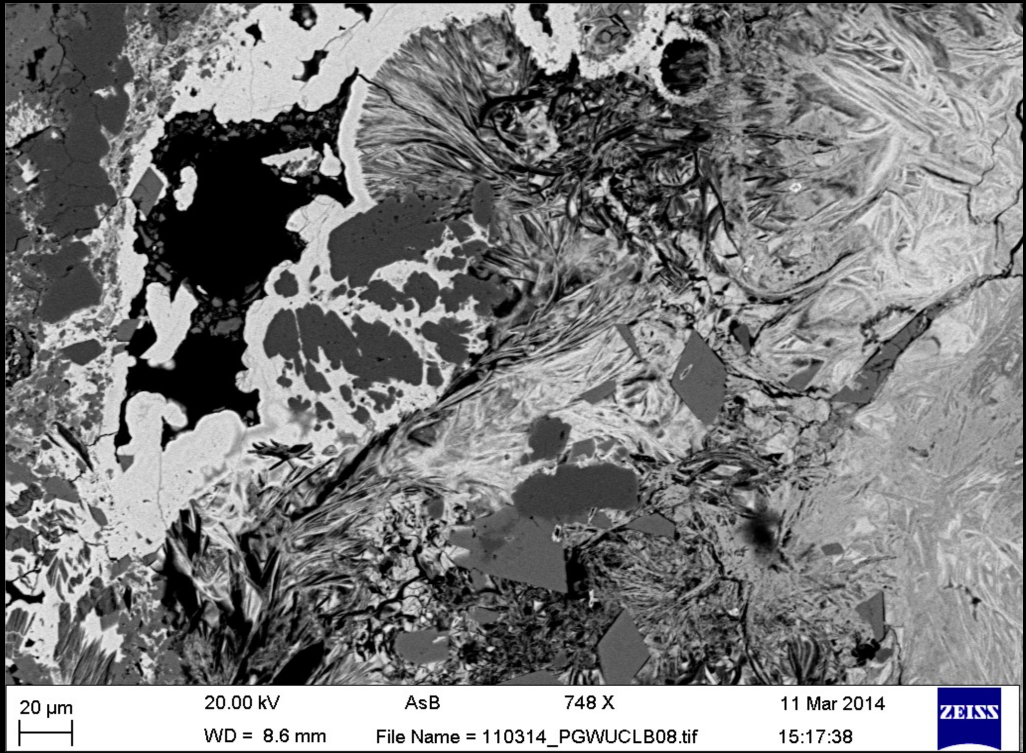
# Impact structures proven to be suitable habitats for life on Earth...

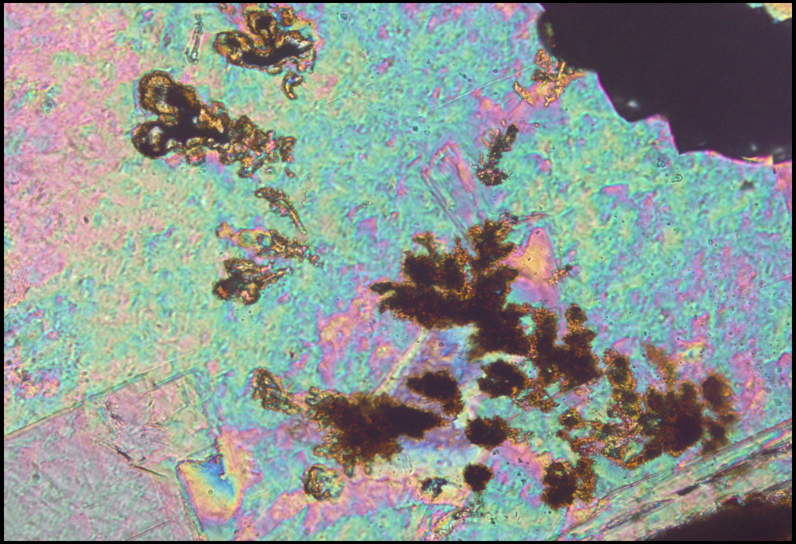
## Next steps:

**Lots of comparative isotope work…**

**What was source of fluid? T constraints? Was there life?**

**Ongoing work on structures suitable as Mars analogues**



## Thanks to

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