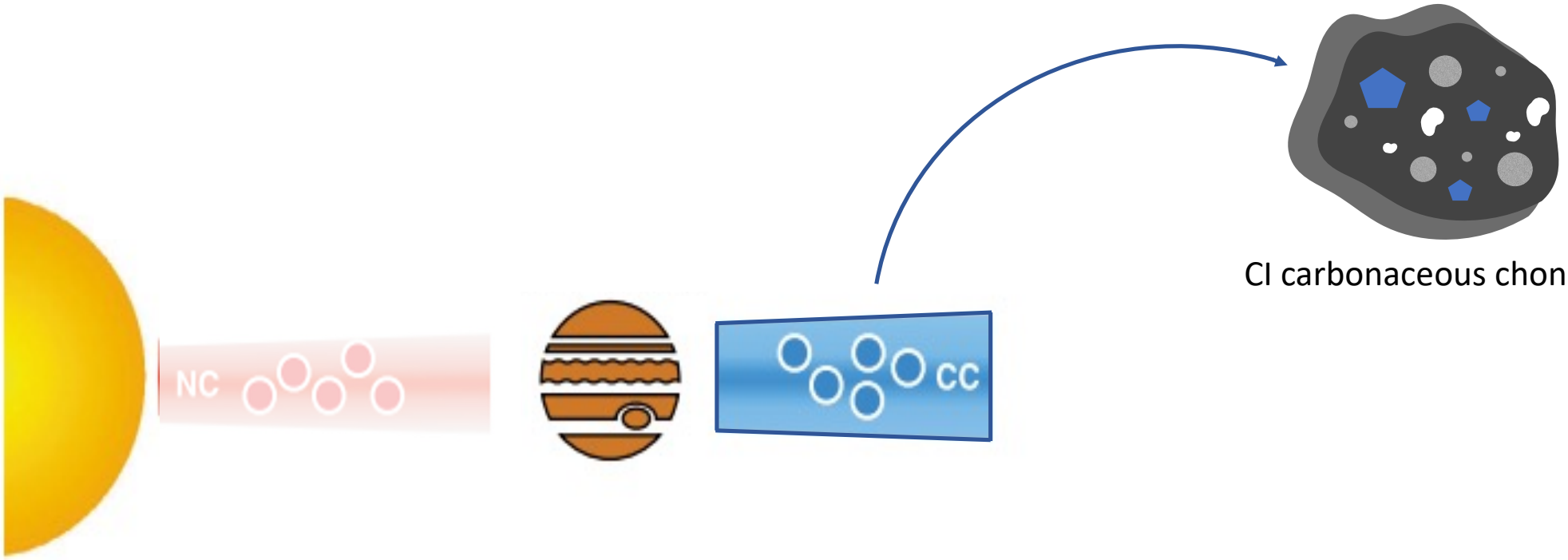
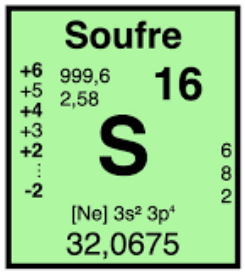
Sulfur isotope anomaly in the Ryugu asteroïd

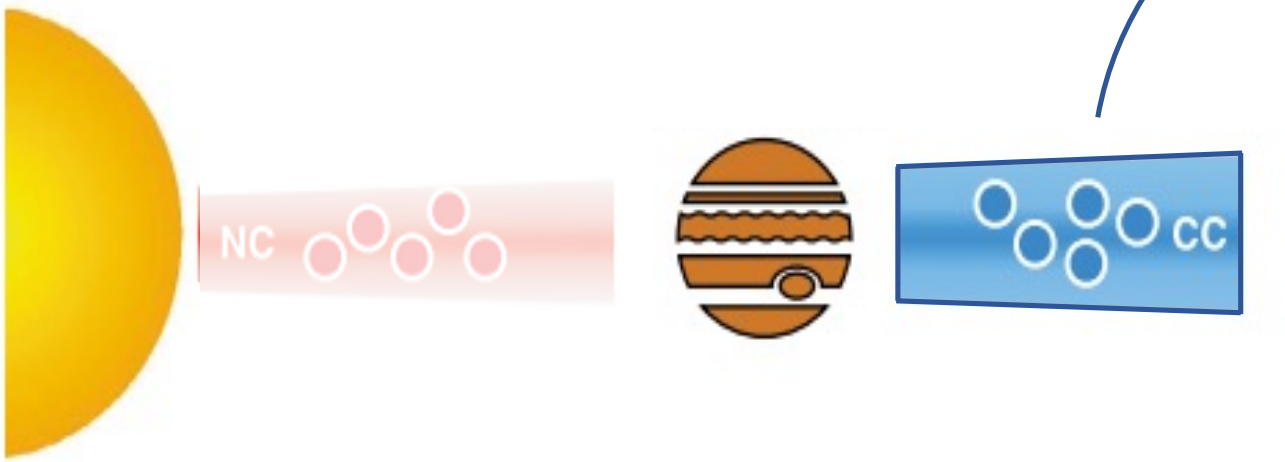
Debruycker Margot, Labidi Jabrane, Moynier Frederic, Cartier Camille, Bizzarro Martin

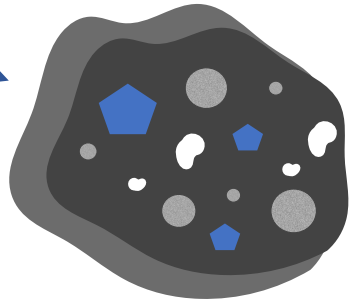


CI carbonaceous chondrites



Chondrites = primary meteorites

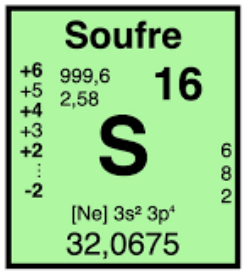




CI carbonaceous chondrites

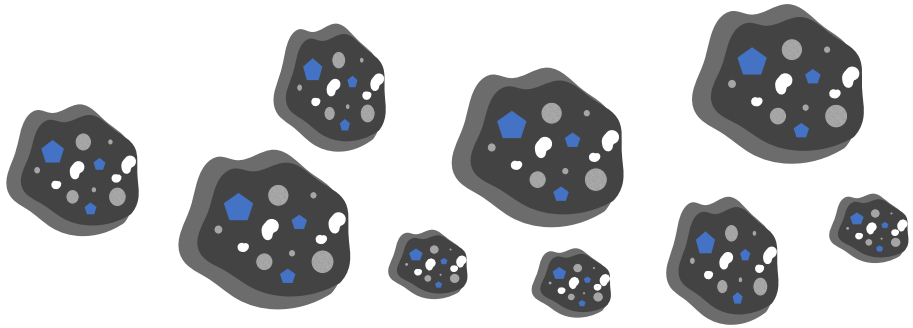
+

Ryugu

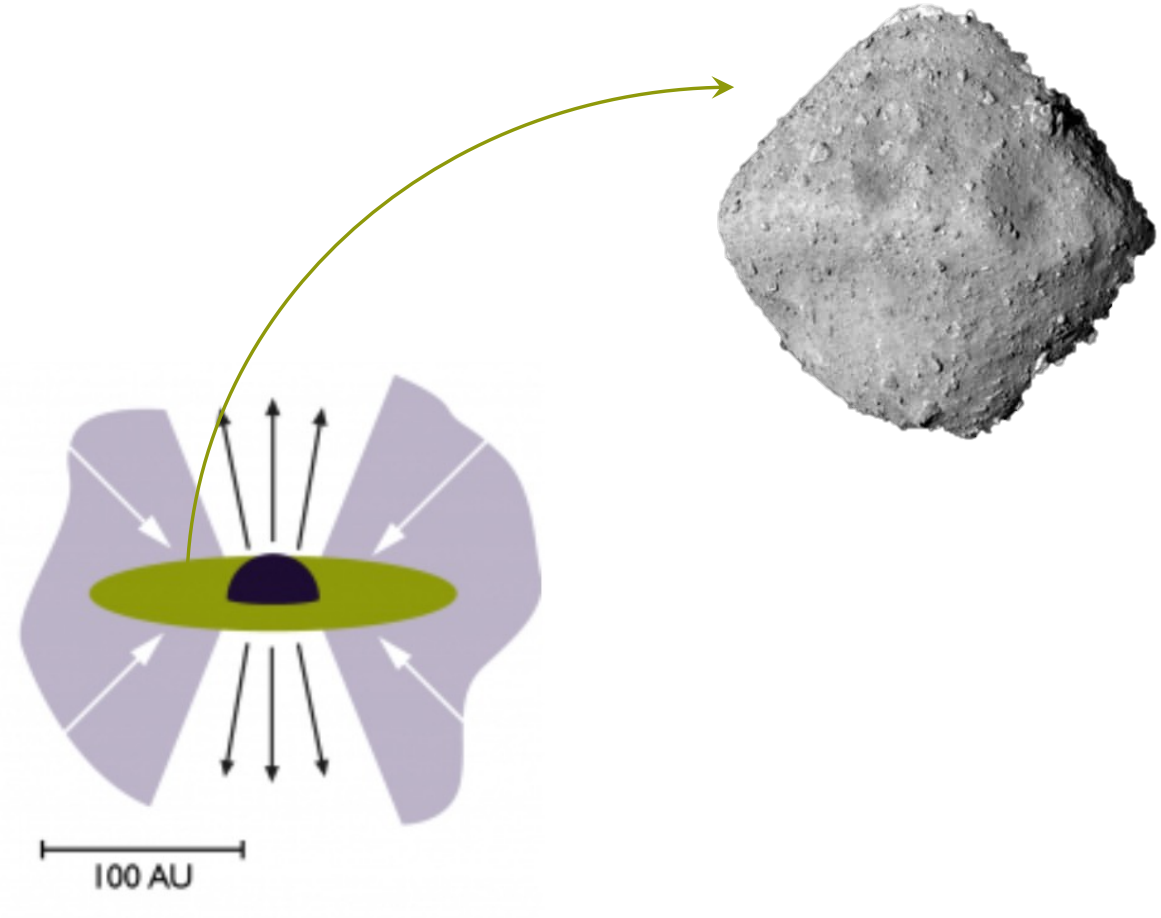


Chondrites = primary meteorites

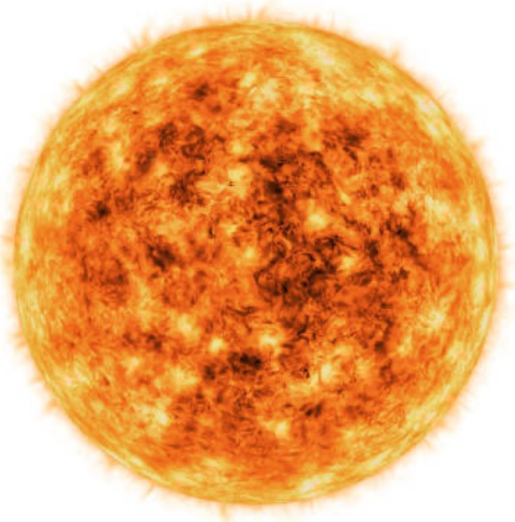
Ryugu = parent body

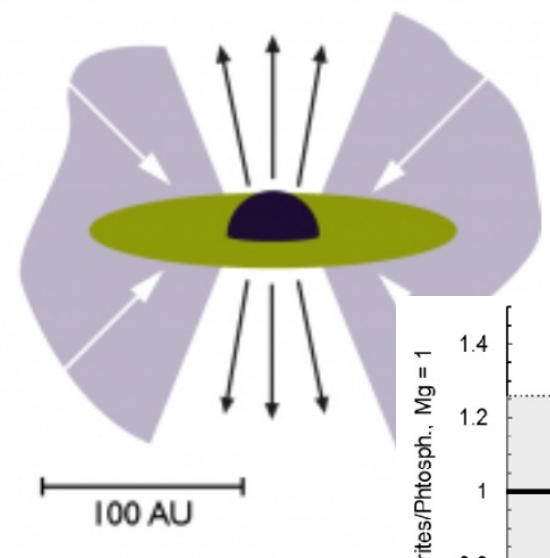


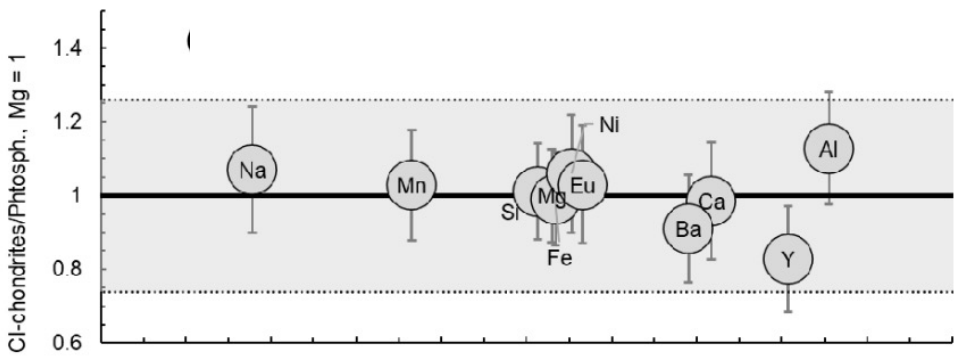
CI carbonaceous chondrites


100 AU

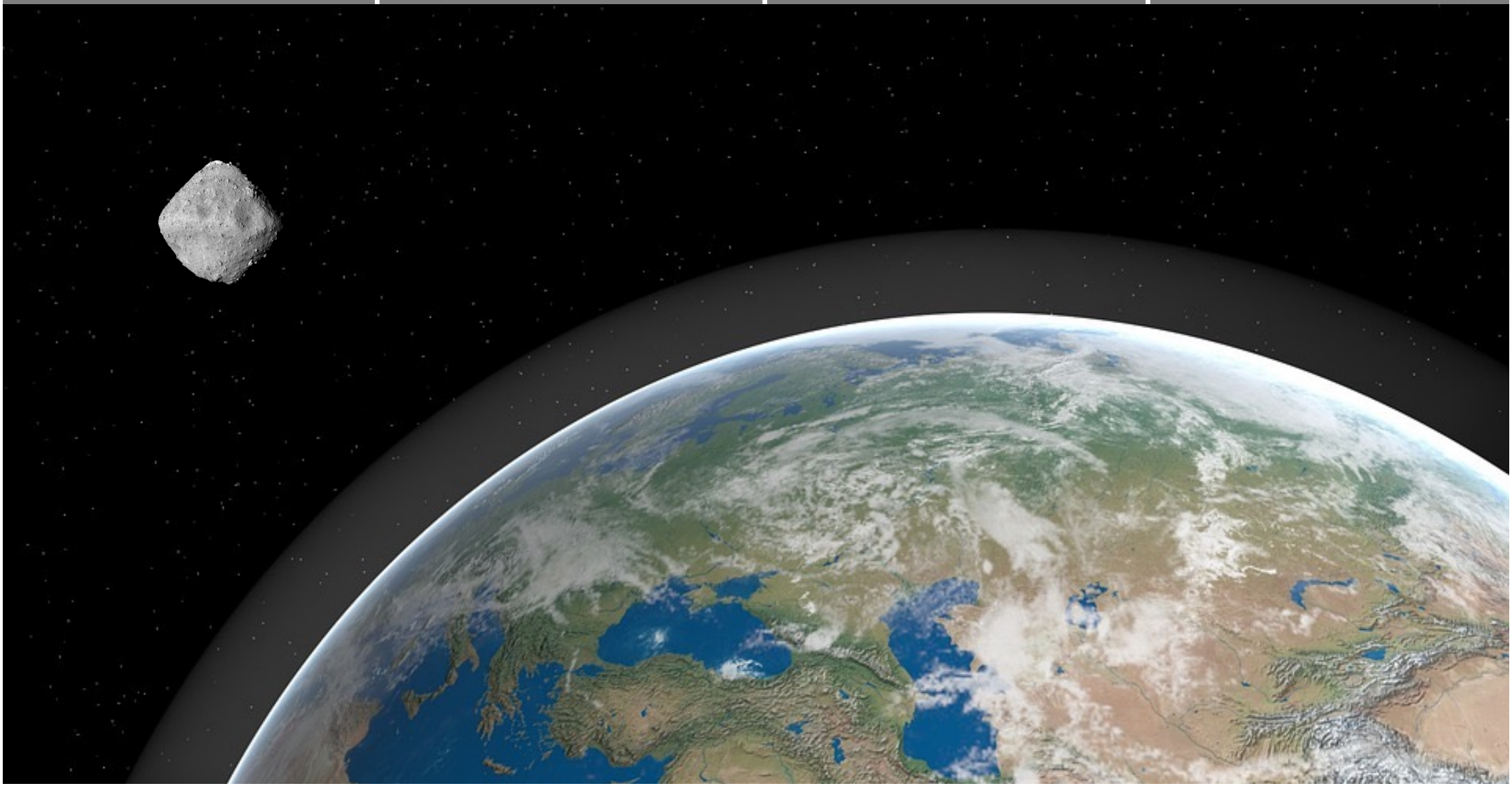
=99wt.% of the solar system

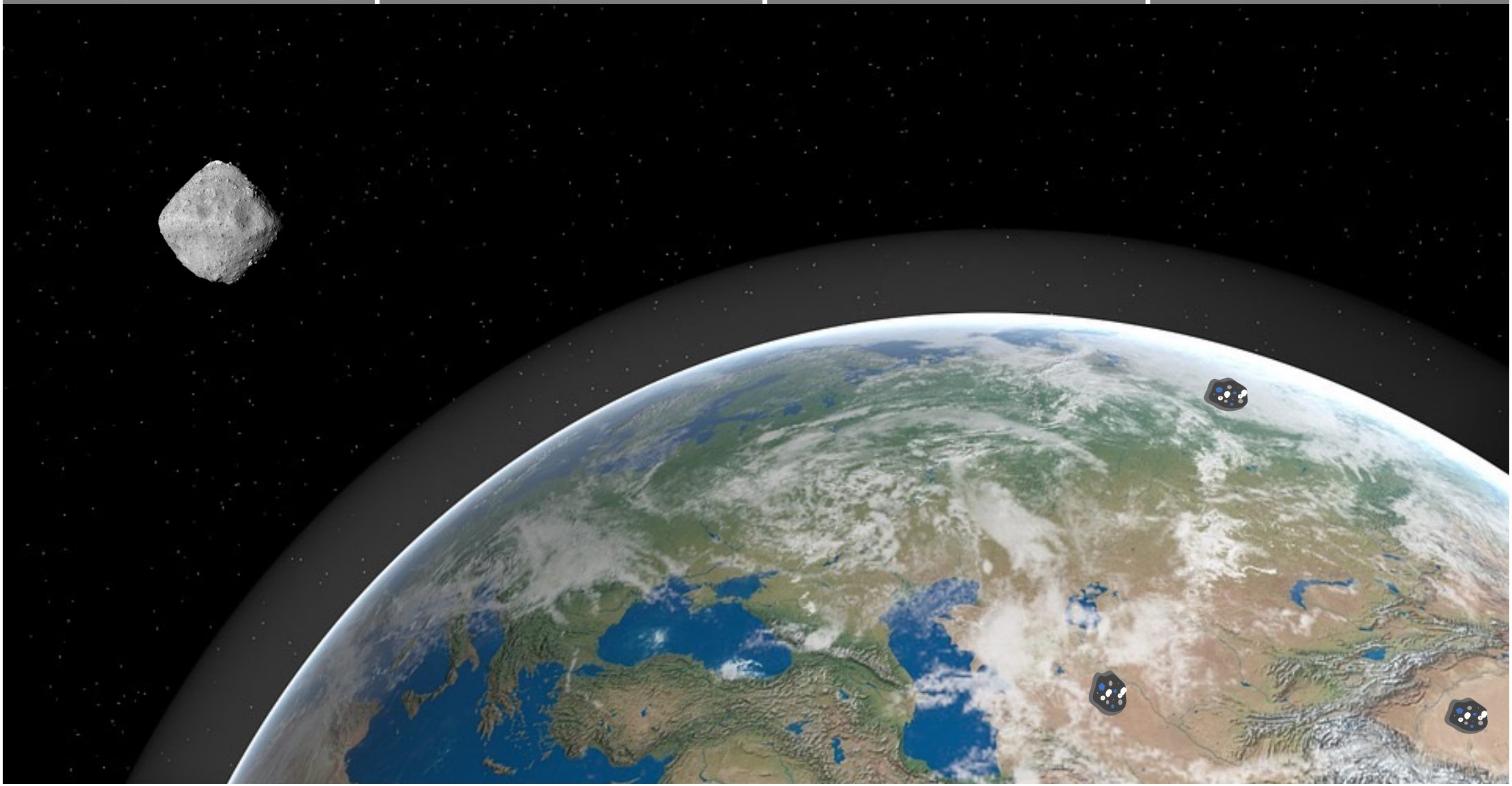


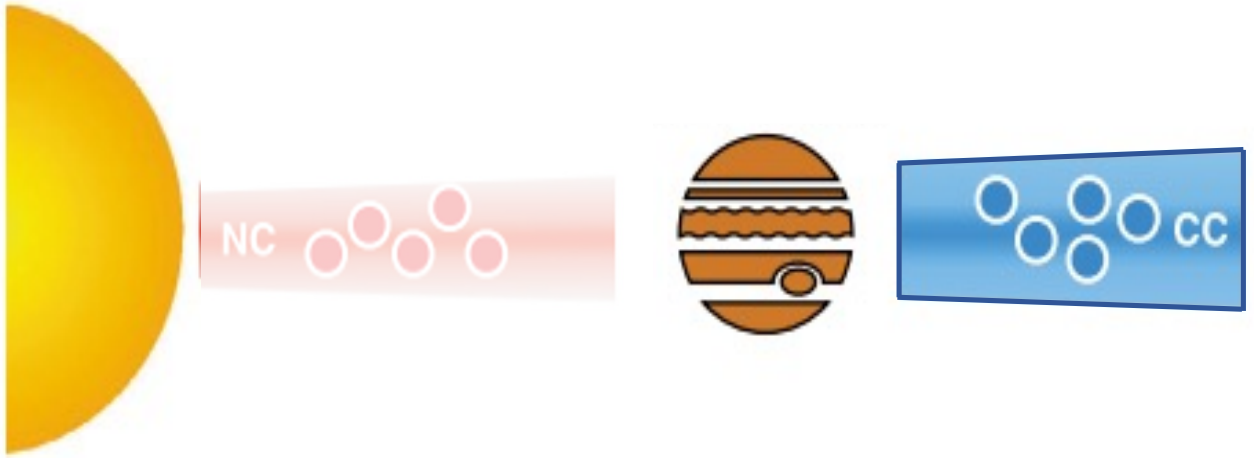




Lodders+ 2025








Orgueil


Ivuna

FALLs


Y-980115

Antarctica

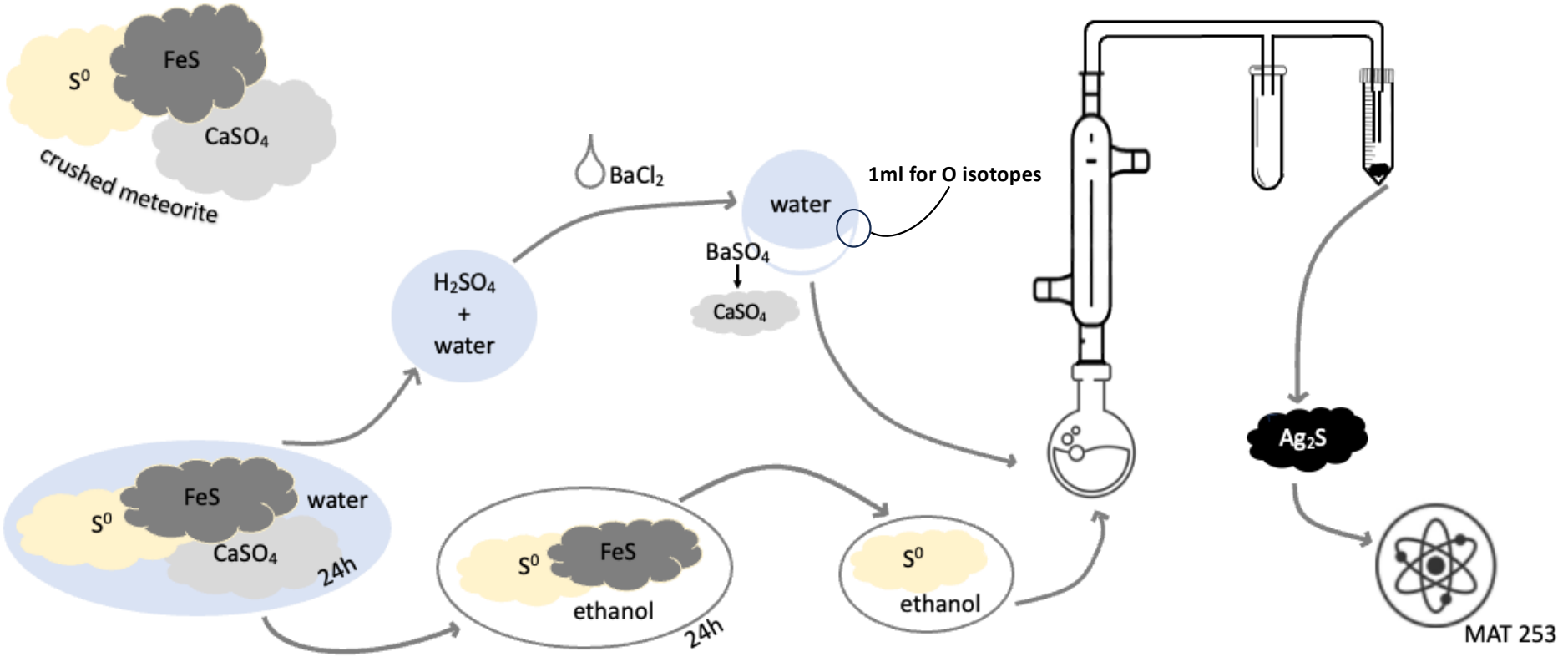

Oued Chebeika 002

No terrestrial alteration (Gattacceca+ 2025)


Ryugu

Asteroïd

What is the origin of sulfur in CI bodies ?



Validation of the protocol (**sequential extraction**) with selected terrestrial components :

- No fractionation
- Losses minimized at each step

Orgueil

Ivuna

Y-980115

Oued Chebeika 002

Ryugu

Historical CI

Newly discovered CI

2 chemical patterns

Orgueil

Ivuna

Y-980115

Oued Chebeika 002

Ryugu

Historical CI

Newly discovered CI

2 chemical patterns

Orgueil

Ivuna

Historical CI

Y-980115

Oued Chebeika 002

Ryugu

Newly discovered CI

2 different parent bodies ?

- Sulfates and S^0 produced via sulfide oxidation?

2 chemical patterns

Orgueil

Ivuna

Historical CI

Y-980115

Oued Chebeika 002

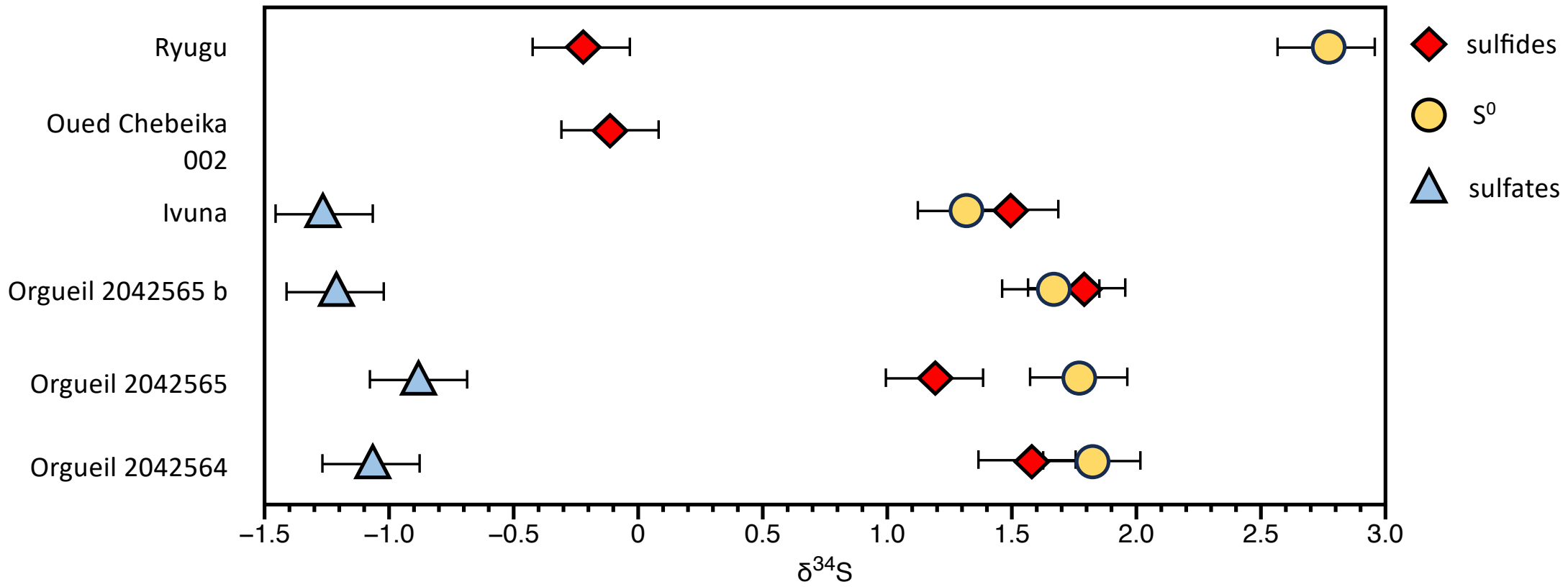
Ryugu

Newly discovered CI

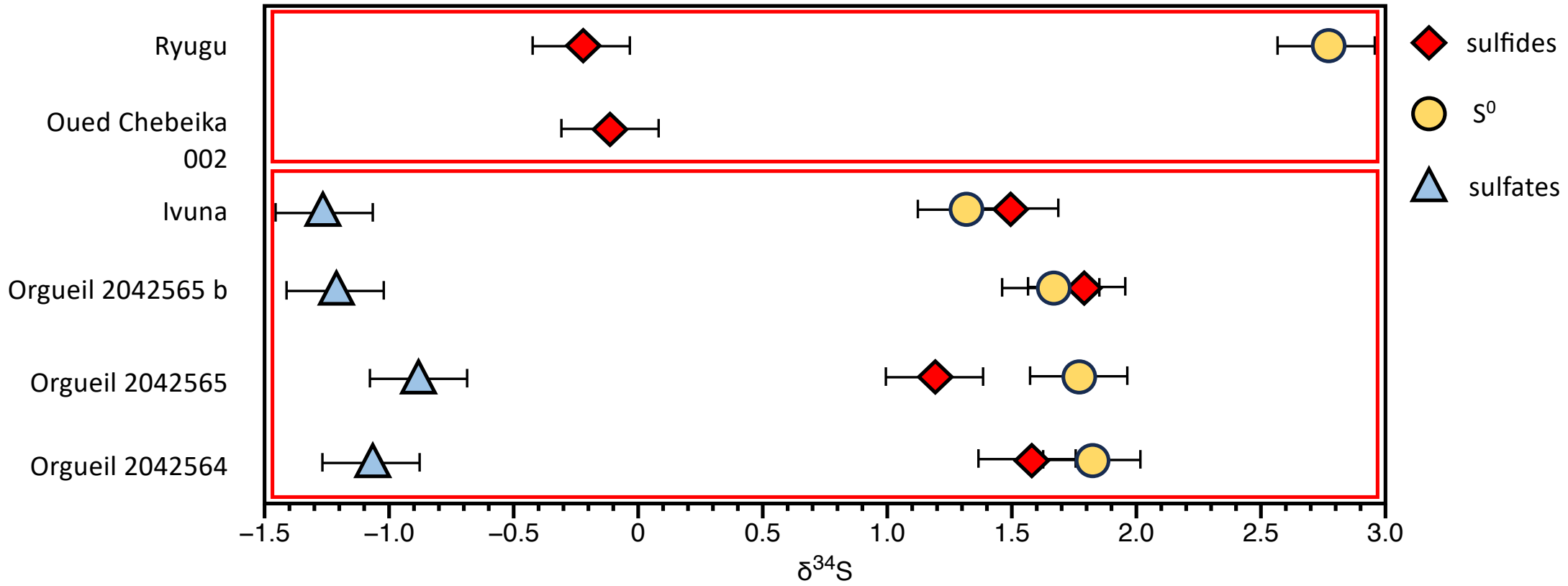
2 different parent bodies ?

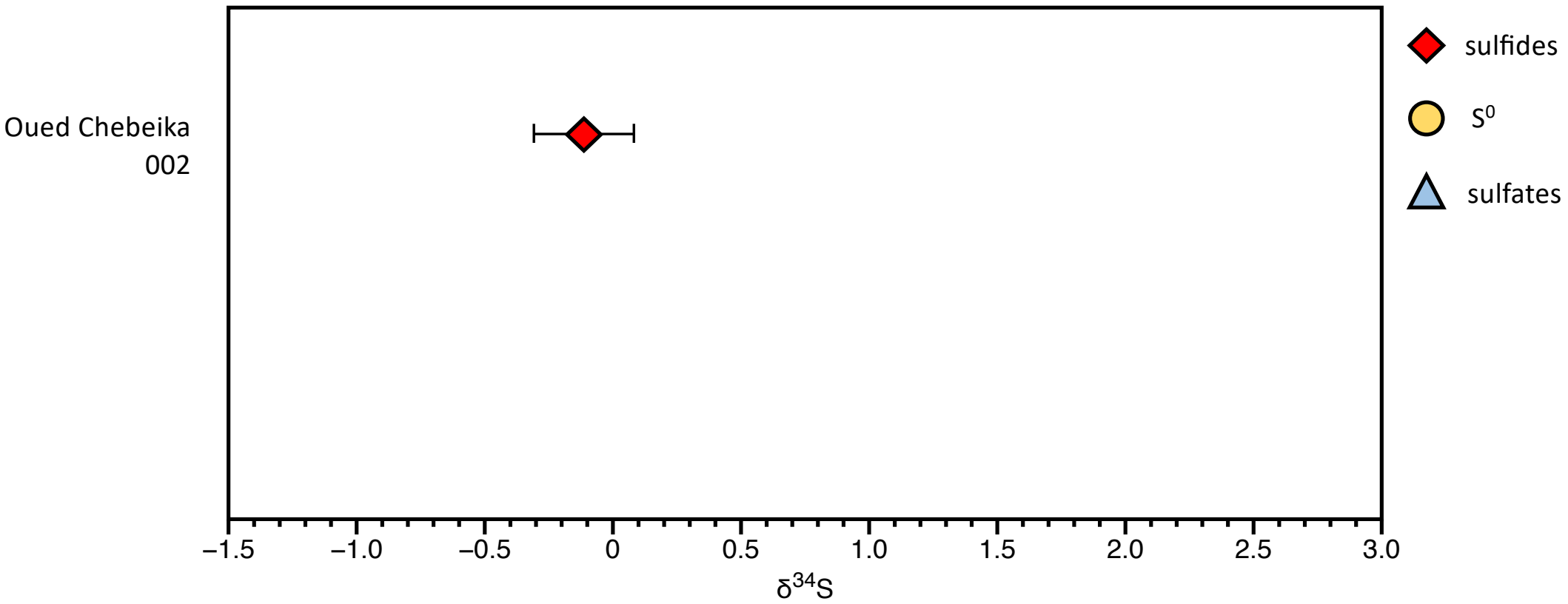
- Sulfates and S^0 produced via sulfide oxidation?
- needs an aqueous system

2 chemical patterns


Ryugu
Oued Chebeika 002
Ivuna
Orgueil 2042565 b
Orgueil 2042565
Orgueil 2042564
sulfides
S0
sulfates
−1.5
−1.0
−0.5
0
0.5
1.0
1.5
2.0
2.5
3.0
δ34S

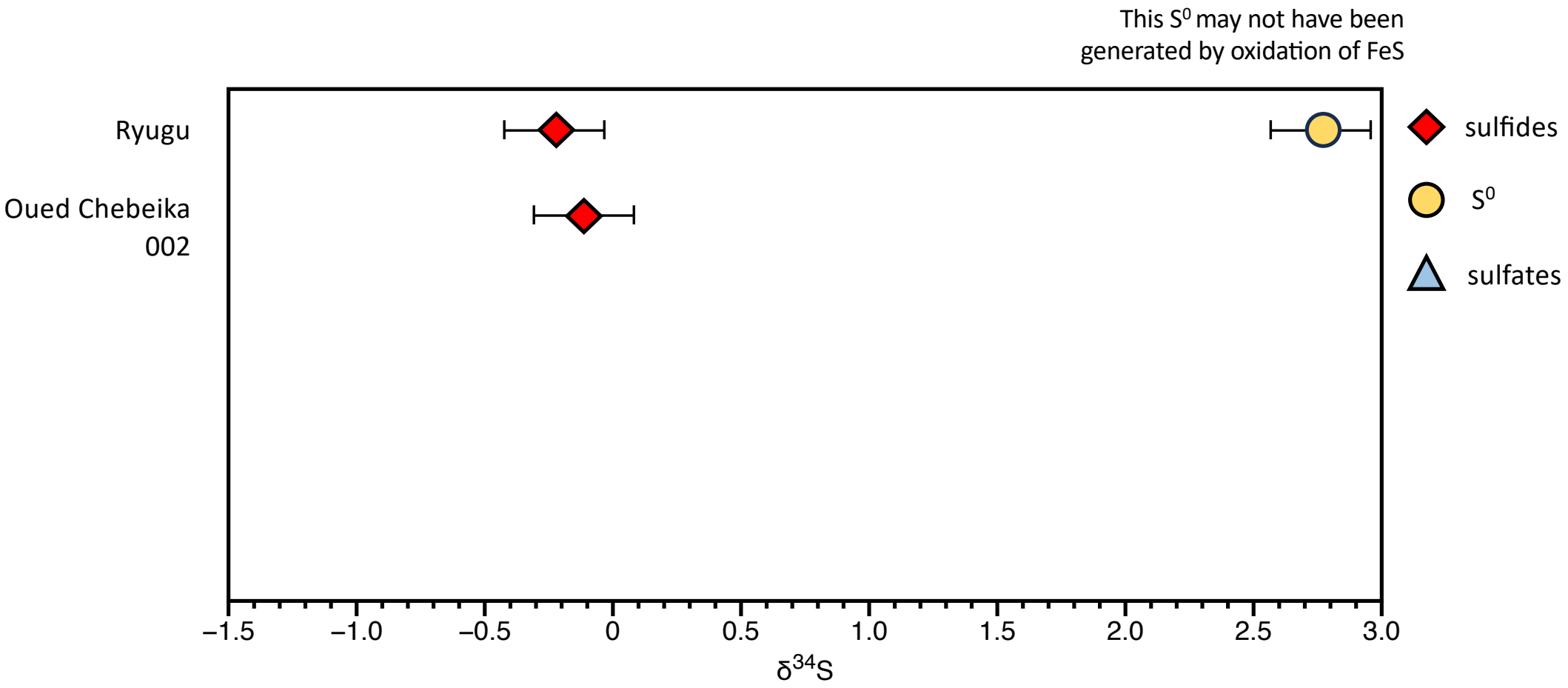
2 isotopic patterns



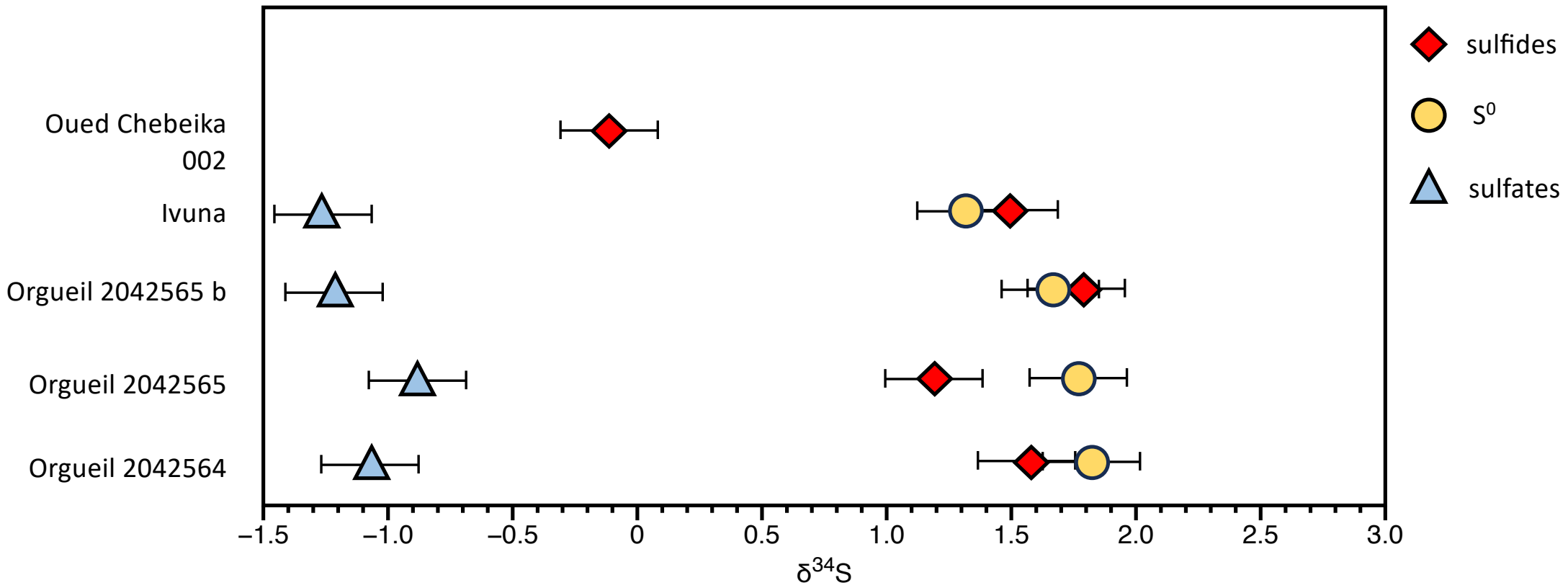


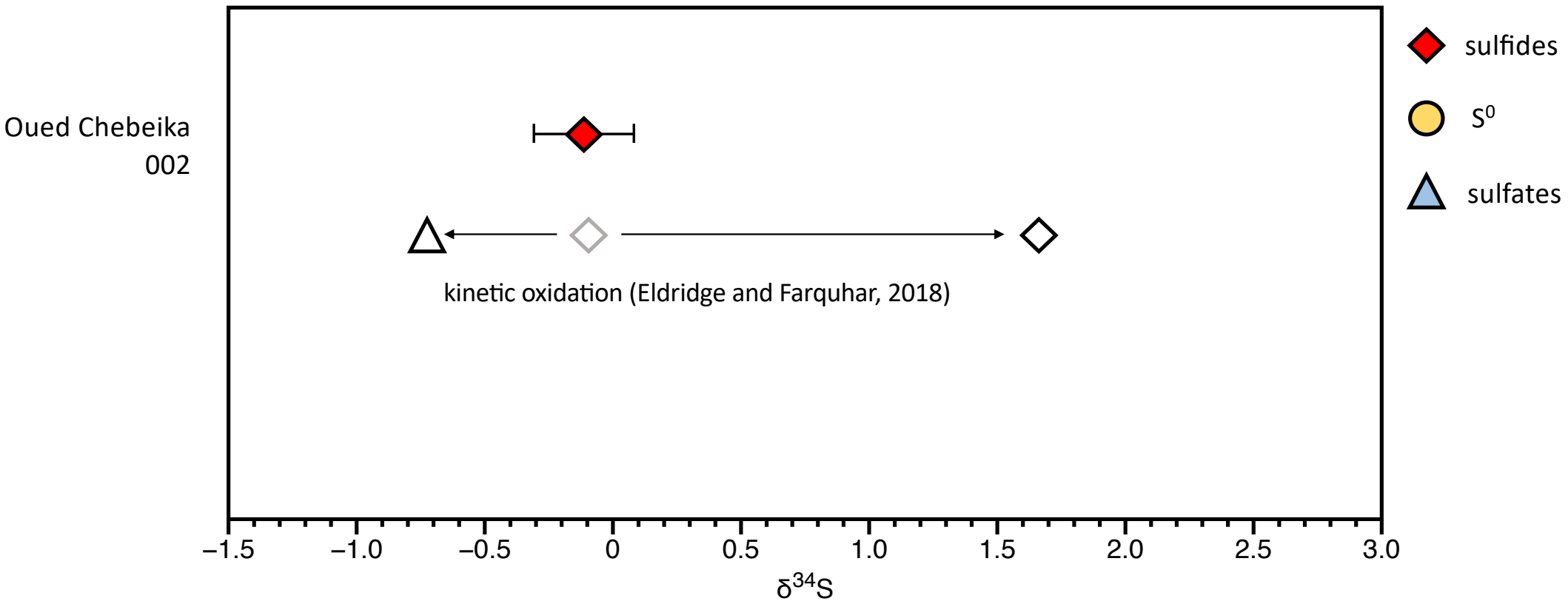
No oxidation products observed

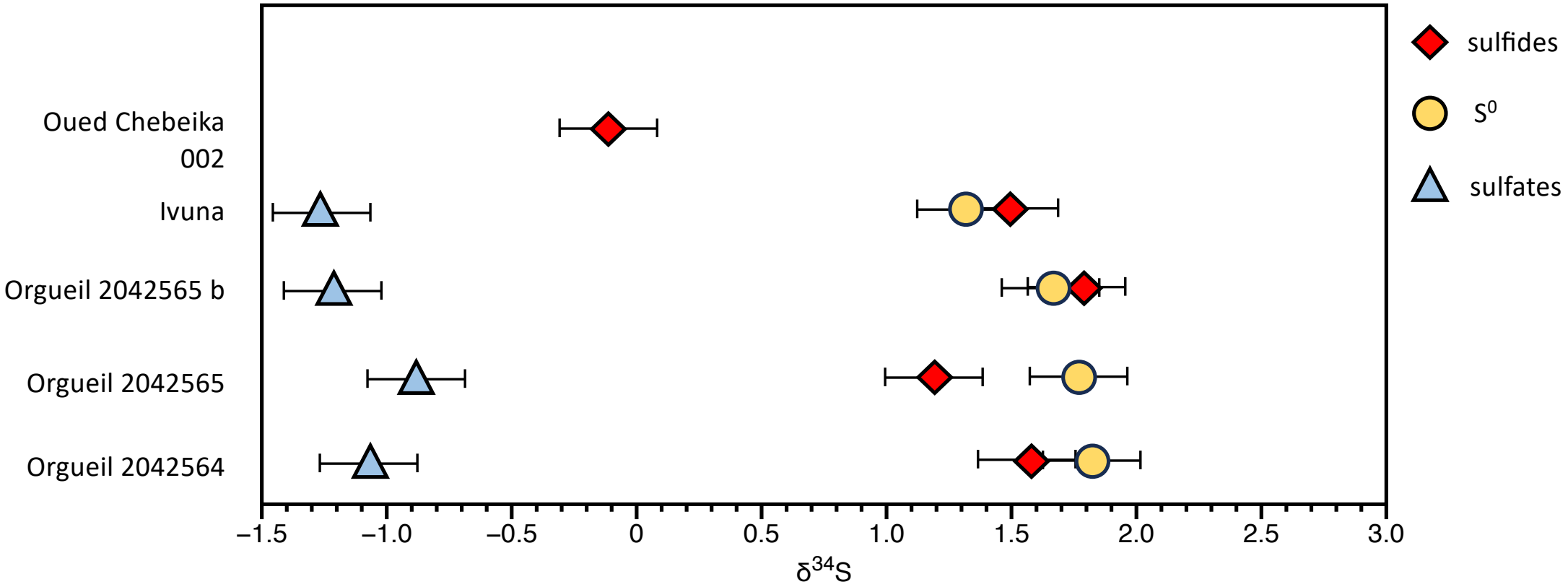
→ The pristine value of $\delta^{34}S$ of FeS



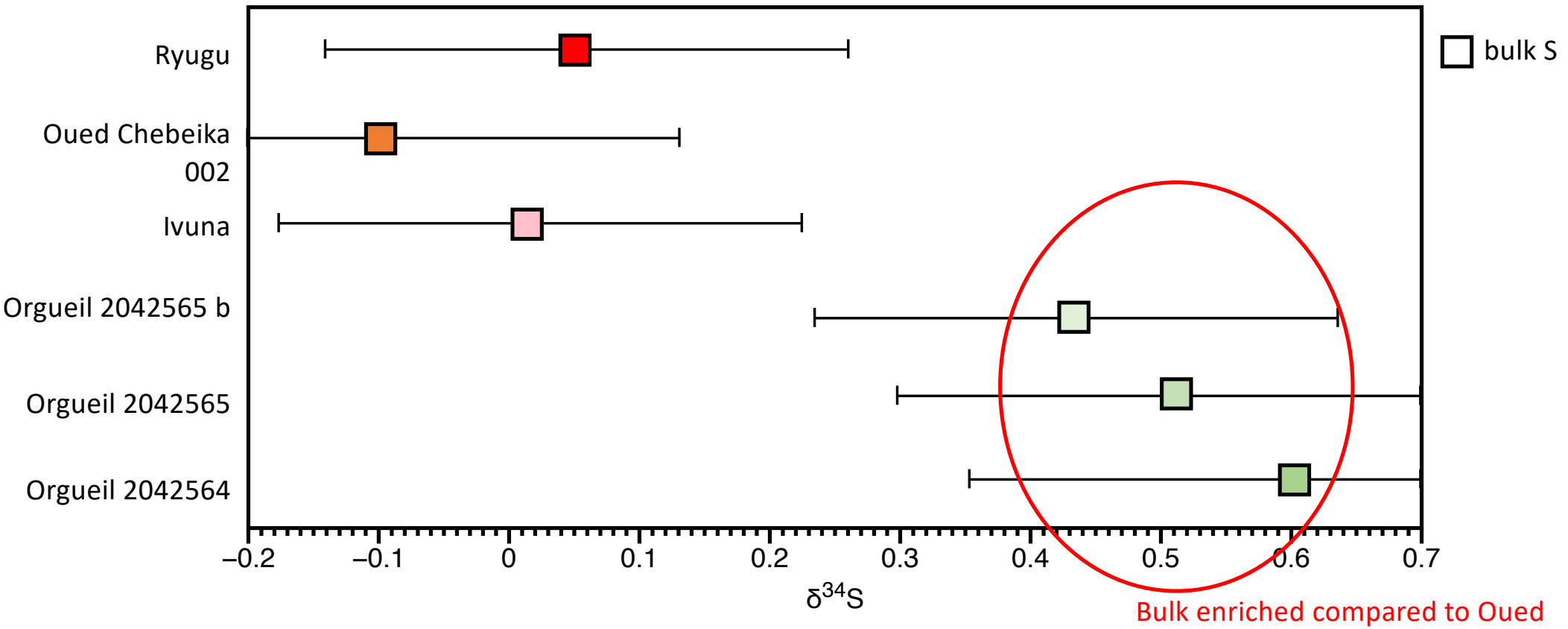
What's its origin ?


Oued Chebeika 002
Ivuna
Orgueil 2042565 b
Orgueil 2042565
Orgueil 2042564
−1.5
−1.0
−0.5
0
0.5
1.0
1.5
2.0
2.5
3.0
δ34S
sulfides
S0
sulfates

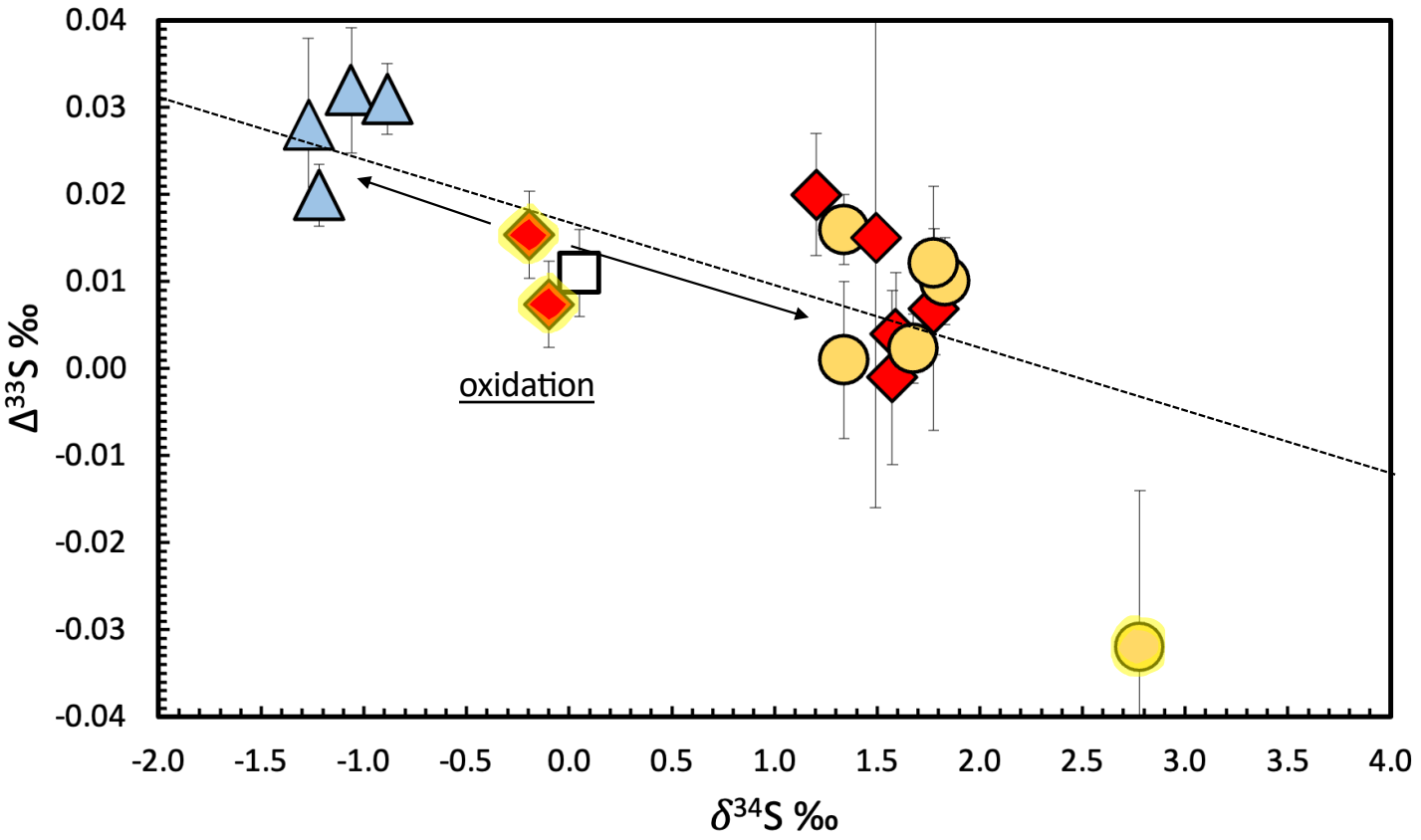

Oued Chebeika
002
kinetic oxidation (Eldridge and Farquhar, 2018)
sulfides
S0
sulfates
−1.5
−1.0
−0.5
0
0.5
1.0
1.5
2.0
2.5
3.0
δ34S



What's the origin of the S^0 of the historical CI ?



Bulk enriched compared to Oued
→ Loss of depleted sulfates ?
→ Input of an enriched component ?



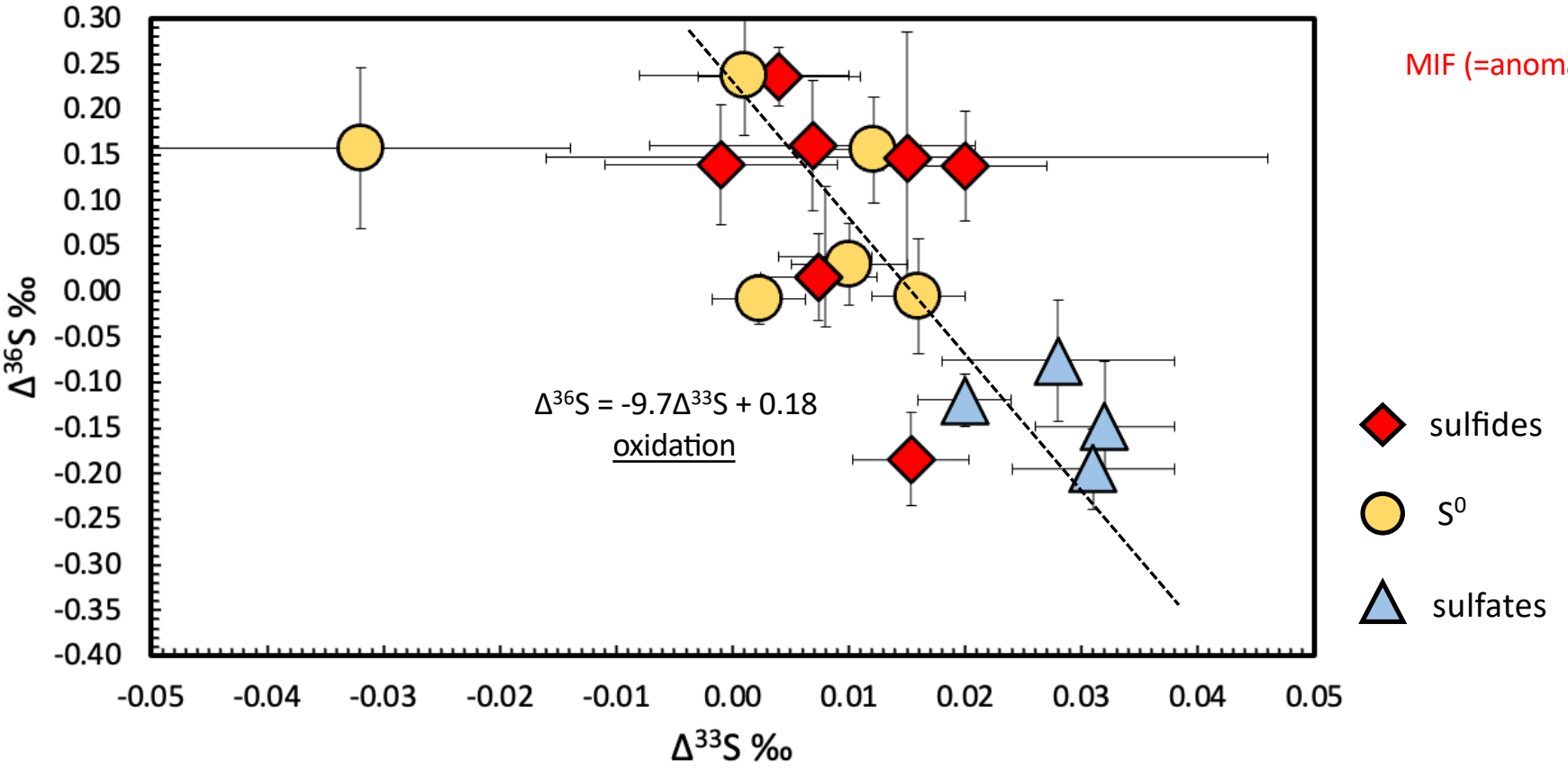
MIF (=anomaly) on the S^0 of Ryugu ?

Oued Chebeika 002 and Ryugu

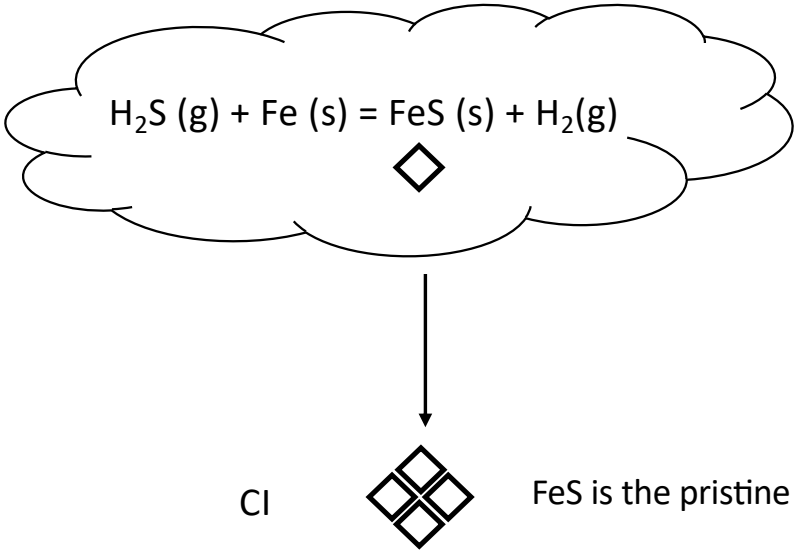
sulfides

S^0

sulfates

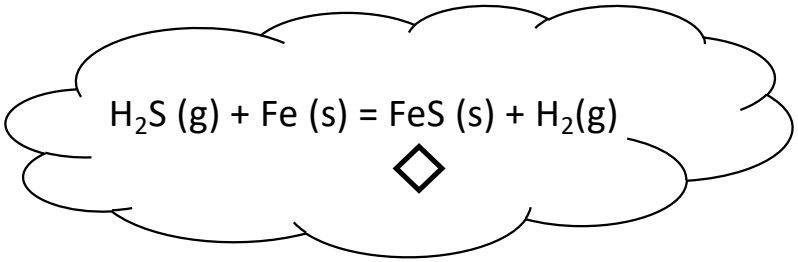


MIF (=anomaly) on the S^0 of Ryugu !



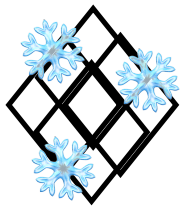
CI

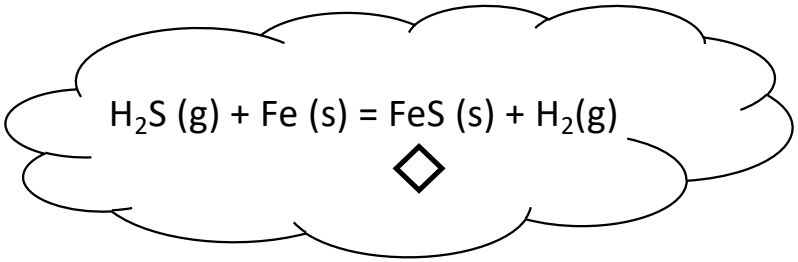
FeS is the pristine material = FeS of the protosolar nebula

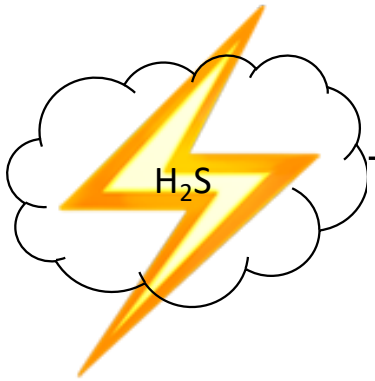


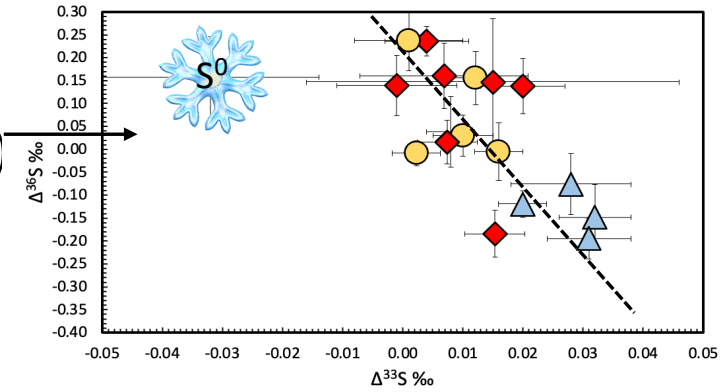
CI

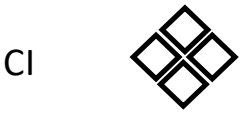
FeS is the pristine material = FeS of the protosolar nebula

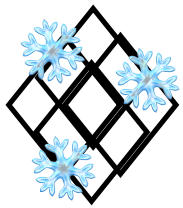


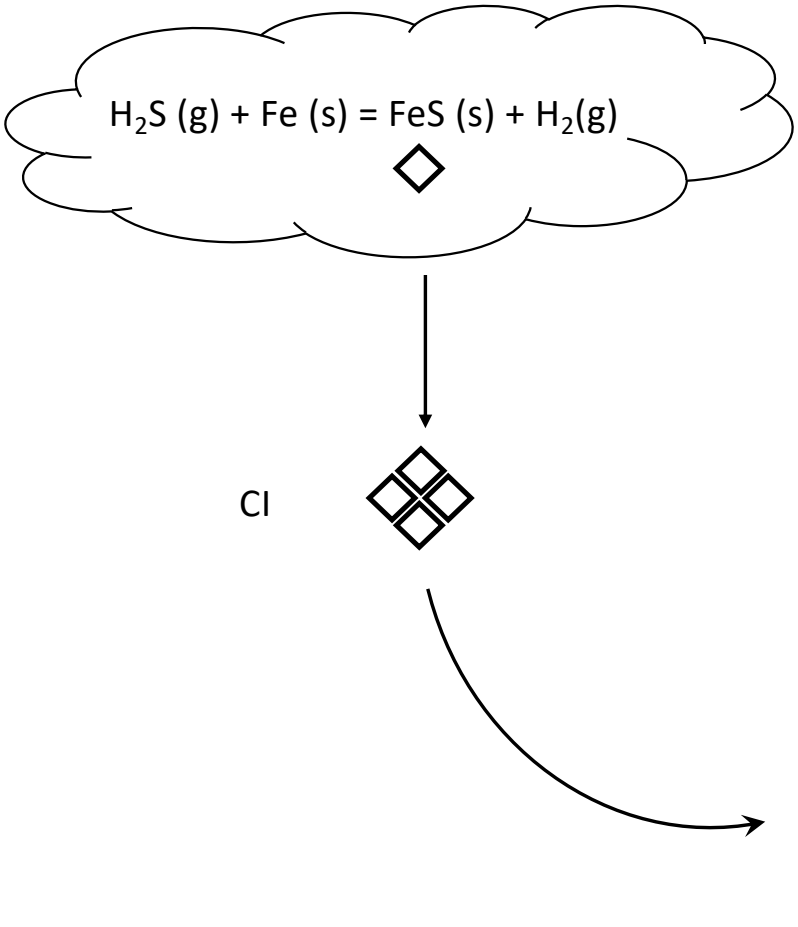

H_2S (g) + Fe (s) = FeS (s) + H_2(g)

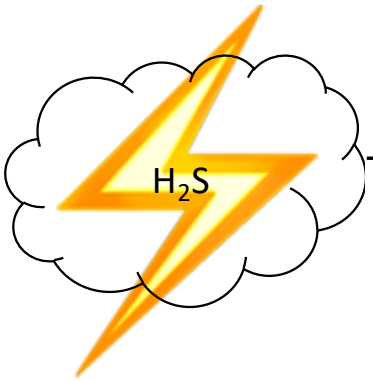

H_2S

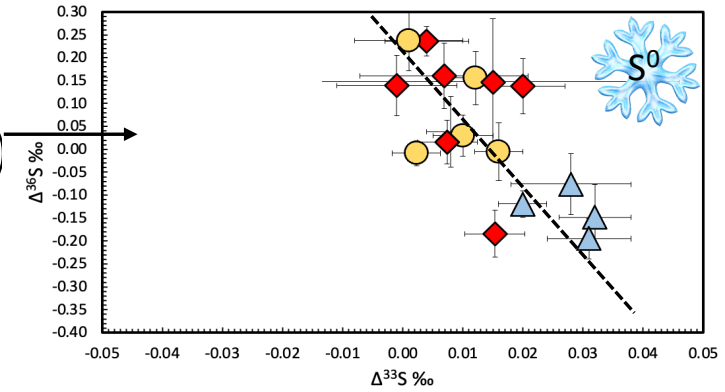

S^0
$\Delta^{36}S$ ‰
$\Delta^{33}S$ ‰
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
-0.35
-0.40
-0.05
-0.04
-0.03
-0.02
-0.01
0.00
0.01
0.02
0.03
0.04
0.05


Cl

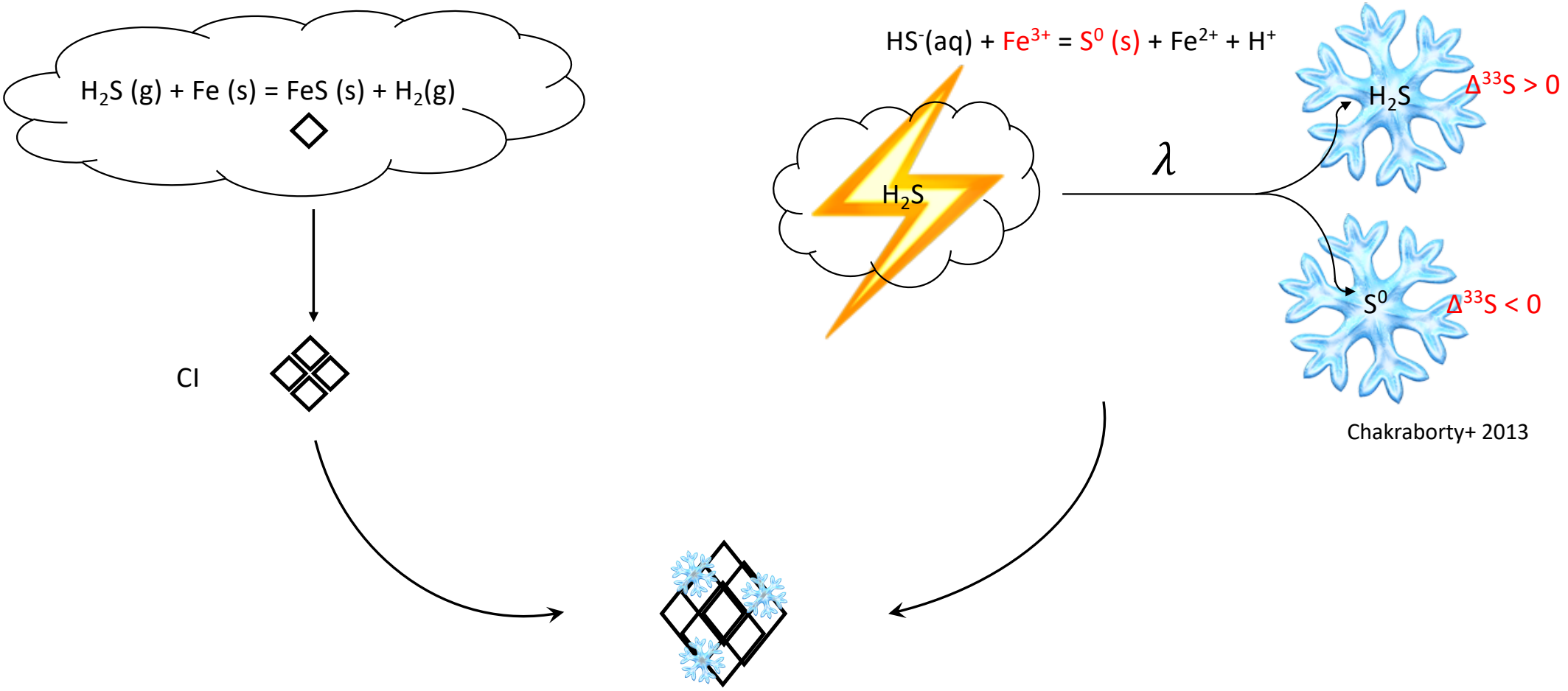


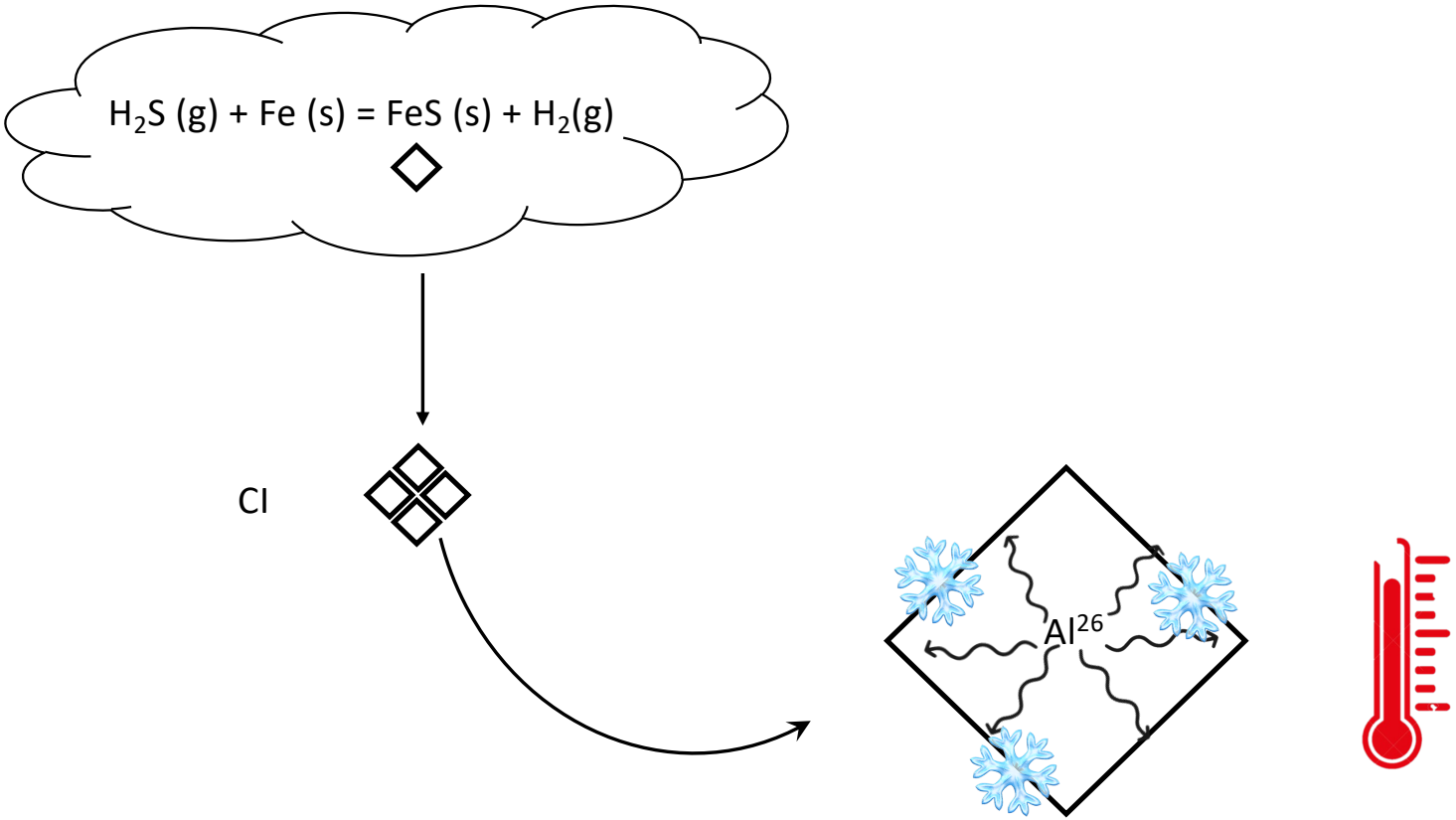


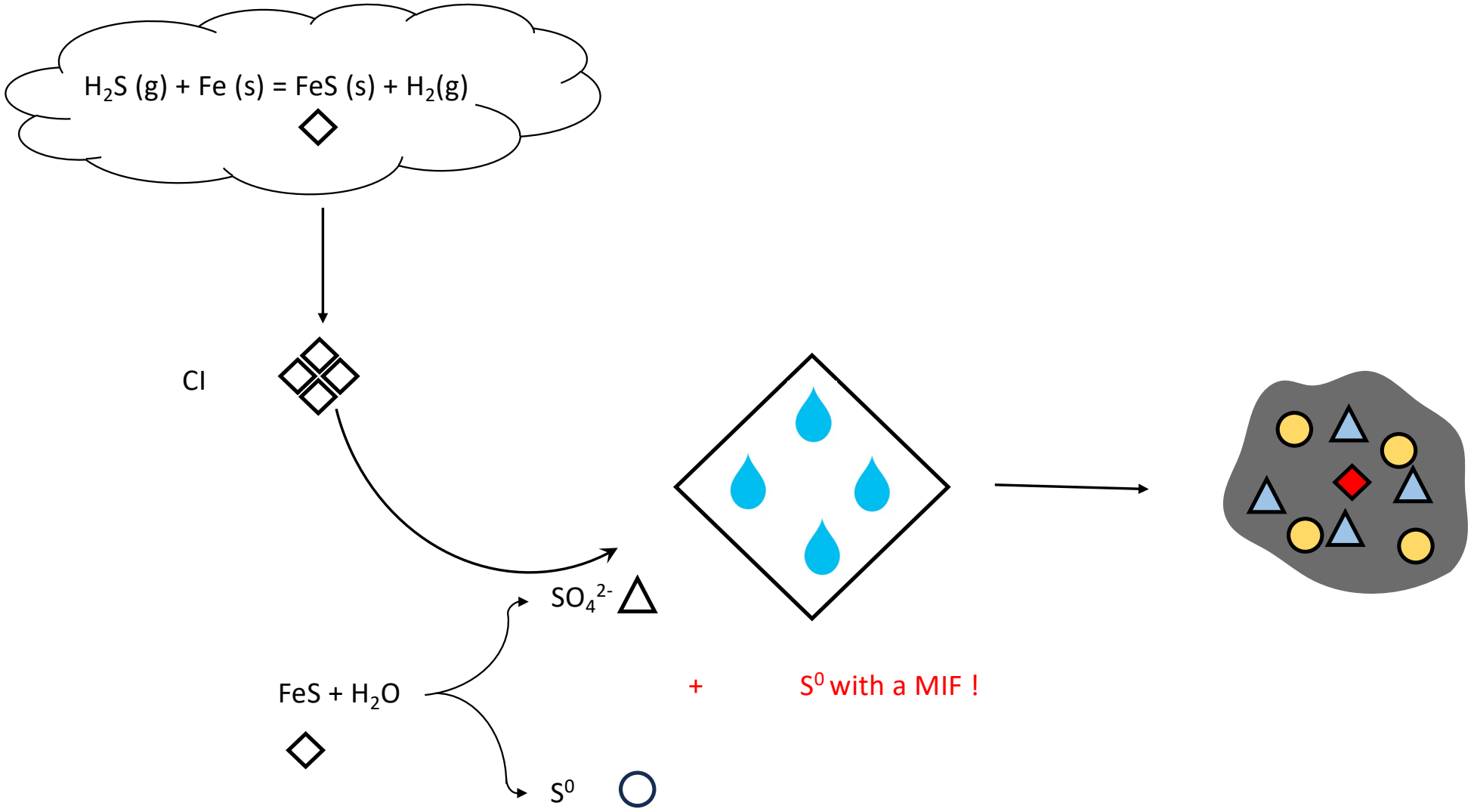


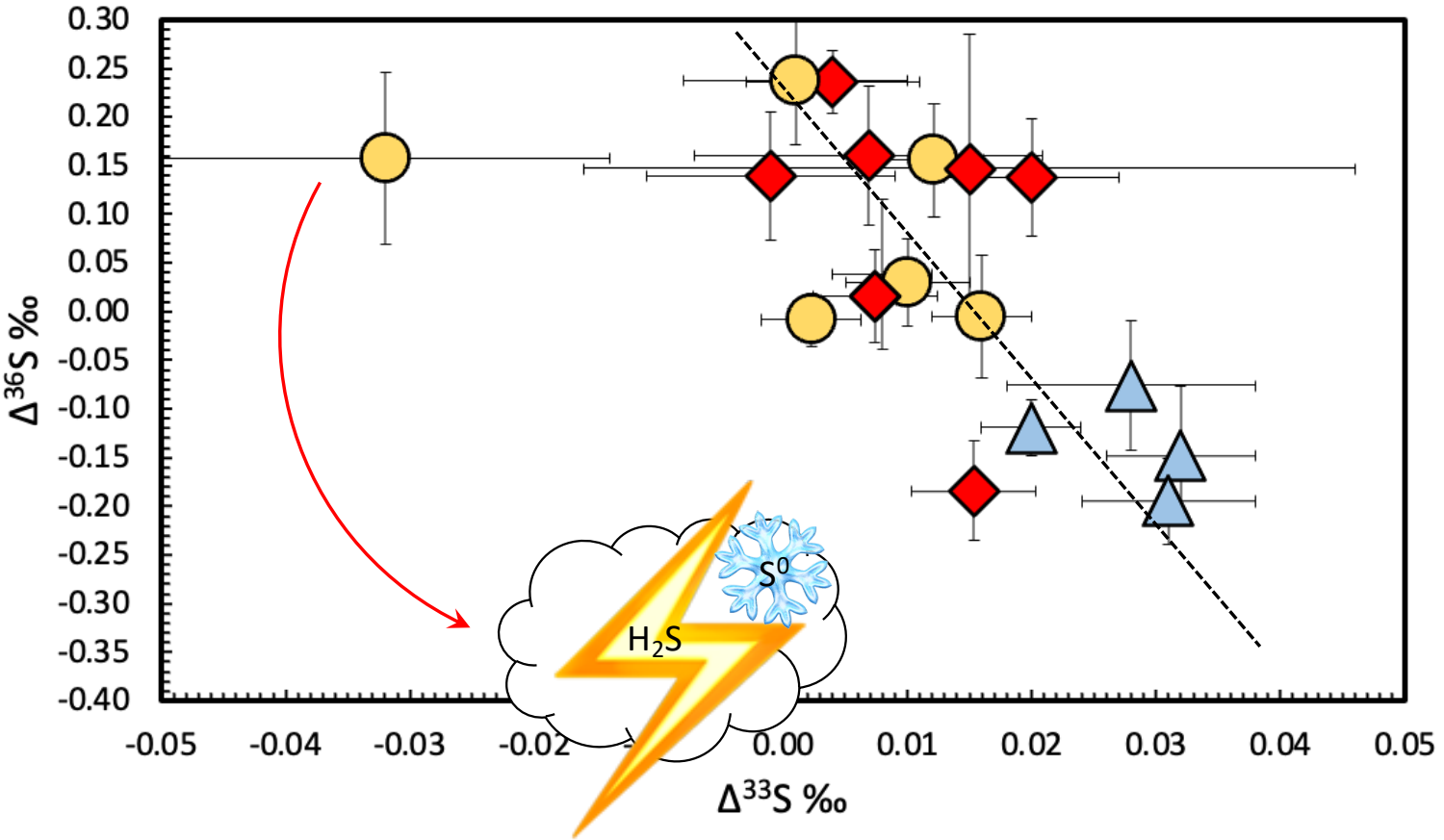


Chakraborty+ 2013


H_2S (g) + Fe (s) = FeS (s) + H_2(g)
CI
HS^-(aq) + Fe^{3+} = S^0 (s) + Fe^{2+} + H^+
H_2S
λ
H_2S
$\Delta^{33}S > 0$
S^0
$\Delta^{33}S < 0$
Chakraborty+ 2013


H_2S (g) + Fe (s) = FeS (s) + H_2(g)
Cl
Al^{26}


H_2S (g) + Fe (s) = FeS (s) + H_2(g)
CI
SO_4^{2-}
FeS + H_2O
S^0
+
S^0 with a MIF !



MIF (=anomaly) on the S^0 of Ryugu !
Produced by photodissociation and delivered by ice ?

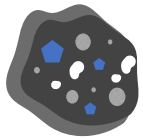
sulfides

S^0

sulfates

Take home messages :

- **Two different isotopic and chemical patterns between historical and newly discovered CI**
  - **→ different parent bodies or terrestrial alteration ?**
- **MIF in the S^0 of Ryugu delivered by ice ? → CI not always representative of the sun composition for S isotopes**
- **But Oued Chebeika 002 is**
- **Ices contribute volatiles to CI bodies (e.g., carbonates in Ryugu (Fujiya+ 2023))**



CI and Ryugu

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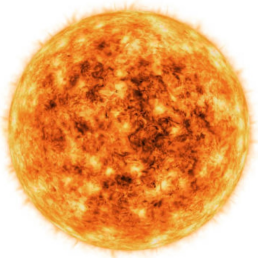

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Oued Chebeika 002