HYDRATED MINERALS IN METEORITES

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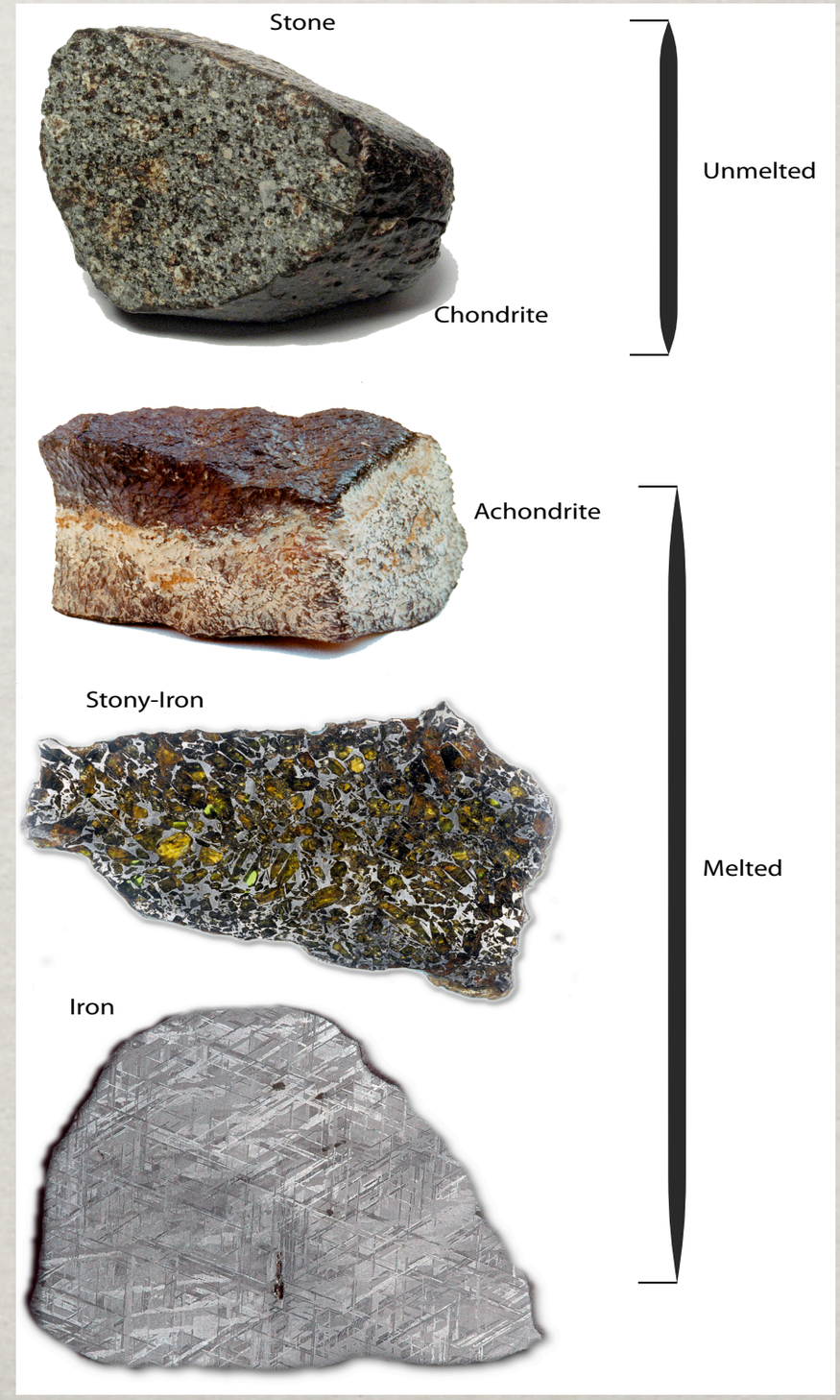
Overview

- Meteorite Basics
- Evidence for aqueous alteration
  - Diagnostic minerals
  - Distribution in meteorites
  - Abundances (i.e. modal mineralogy)
- Implications for spectra

Meteorite classes

- **Three broad categories**
  - **Range from primitive to differentiated**
- Can be grouped according to chemistry
  - into ~40 classes



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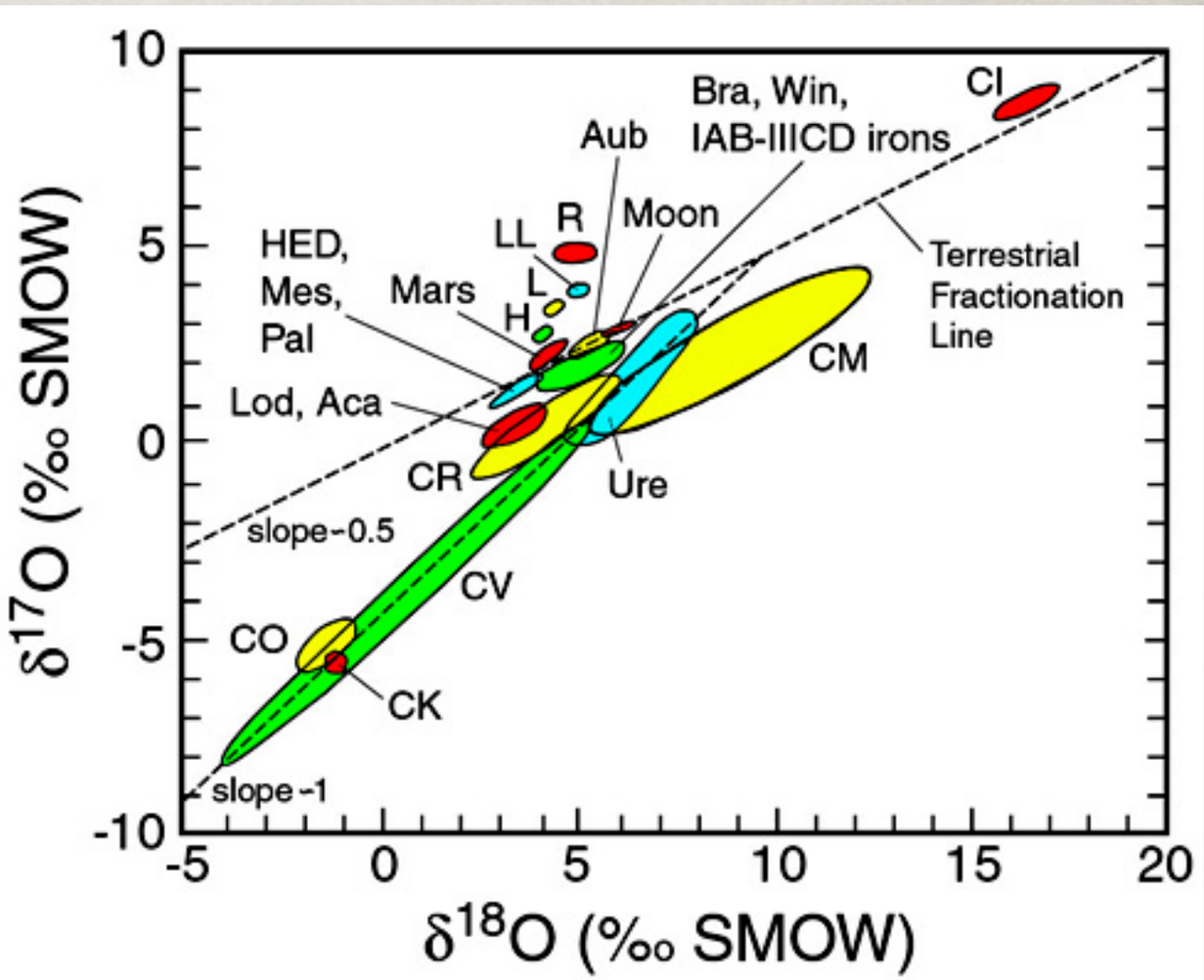
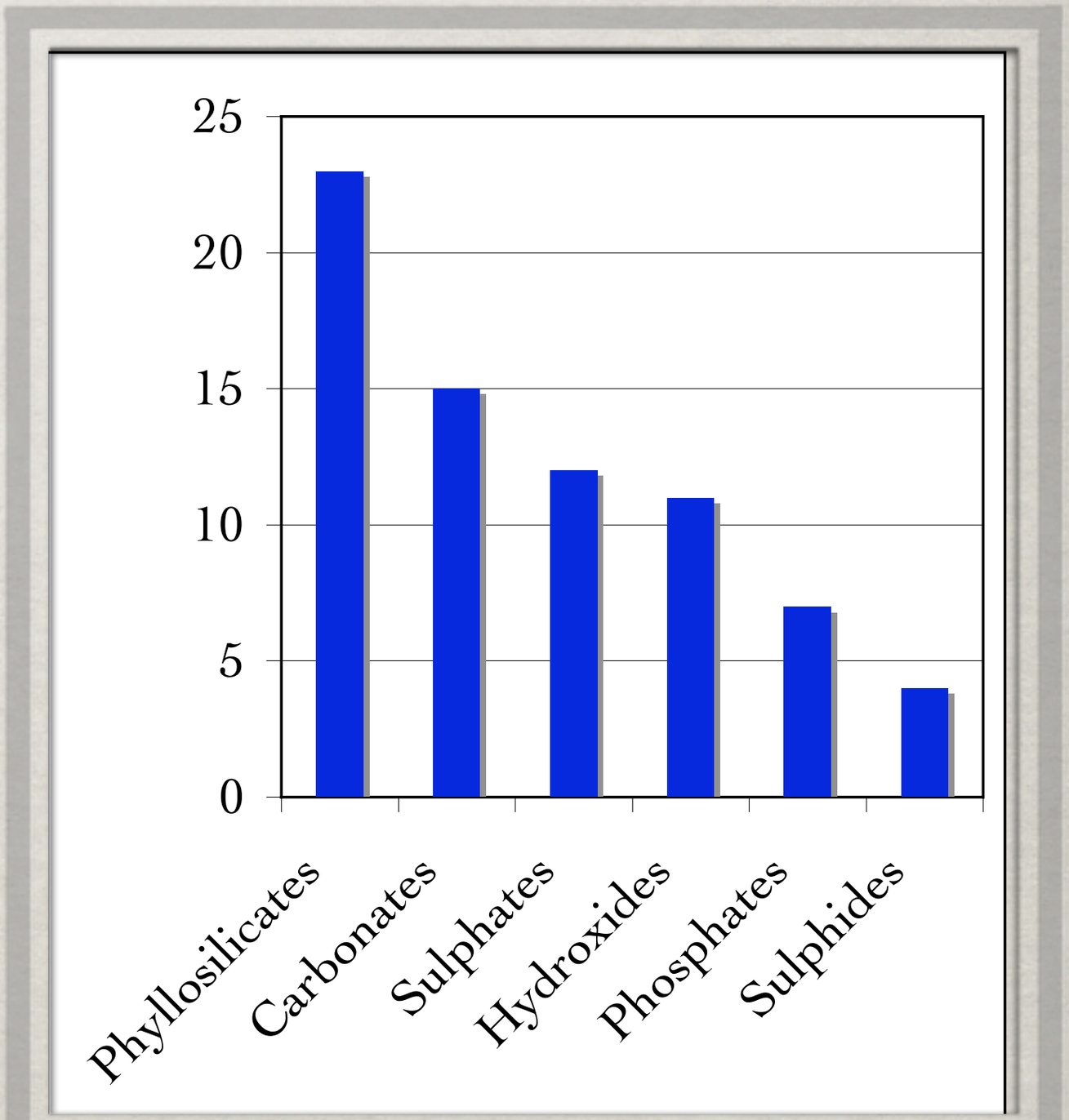


Hydrated minerals

- 275 different mineral species reported in meteorites (Rubin, 1997)

- ~78 different hydrated minerals in meteorites



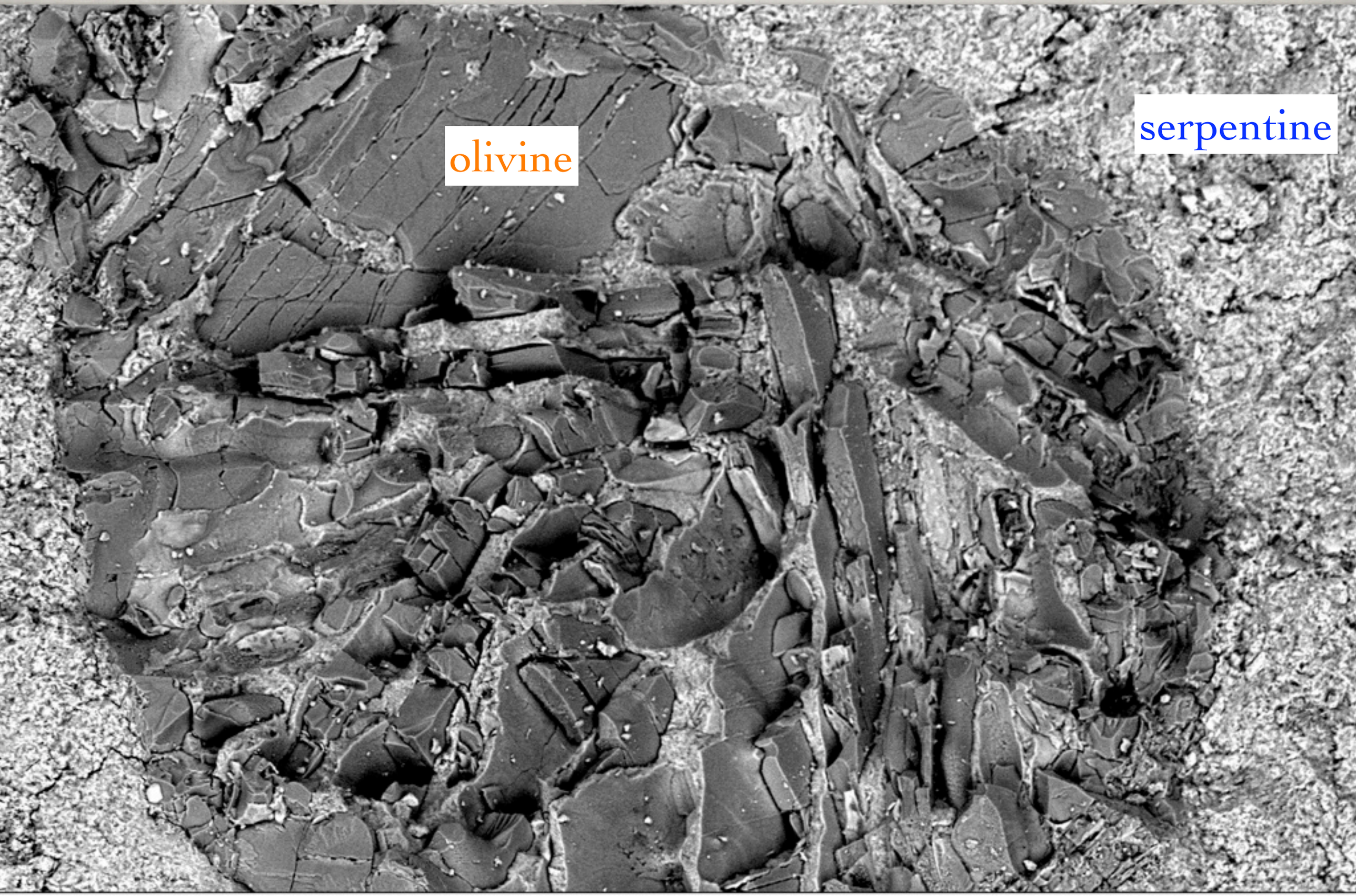
Aqueous alteration

- Most obvious effect of interaction with water is the presence of Fe,Mg phyllosilicates

- Typical phyllosilicates (ideal formula)
  - Cronstedtite - $Fe_2^{+2}Fe^{+3}(SiFe^{+3})O_5(OH)_4$
  - Chrysotile/Lizardite/Antigorite - $Mg_3Si_2O_5(OH)_4$
  - Saponite - $(Ca,Na)_{0.3}(Mg,Fe^{+2})_3(Si,Al)_4O_{10}(OH)_2 \bullet 4H_2O$

General reaction sequence

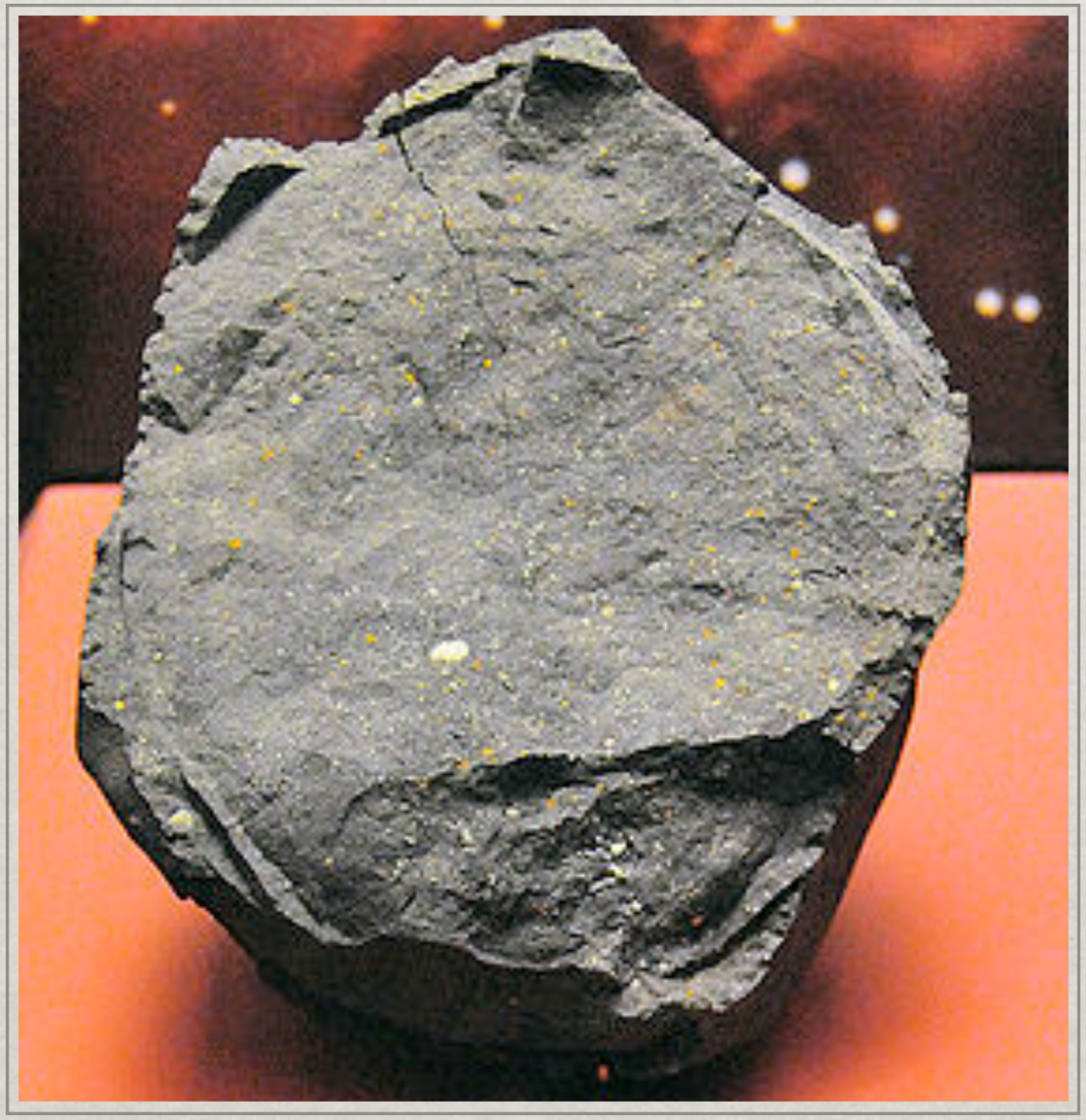
- H_2O reacts with Fe metal and sulphide to form Tochilinite (2[(Fe,Mg,Cr,Ni[])S•1.57-1.85[(Mg,Fe,Ni,Al,Ca)$(OH)_2$])
- Solution reacts with silicates to form Fe-rich phyllosilicates
- Mg-phyllosilicates are last to form as solution evolves further


olivine
serpentine
100µm*
Mag = 398 X
EHT = 20.00 kV
Signal A = QBSD
Chamber = 14 Pa
WD = 15 mm
Spot Size = 500
File Name = KH0006.tif

Distribution of minerals - CV

A slice through the CV3 meteorite Vigarano - Photo courtesy of NHM

Distribution of Minerals - CM

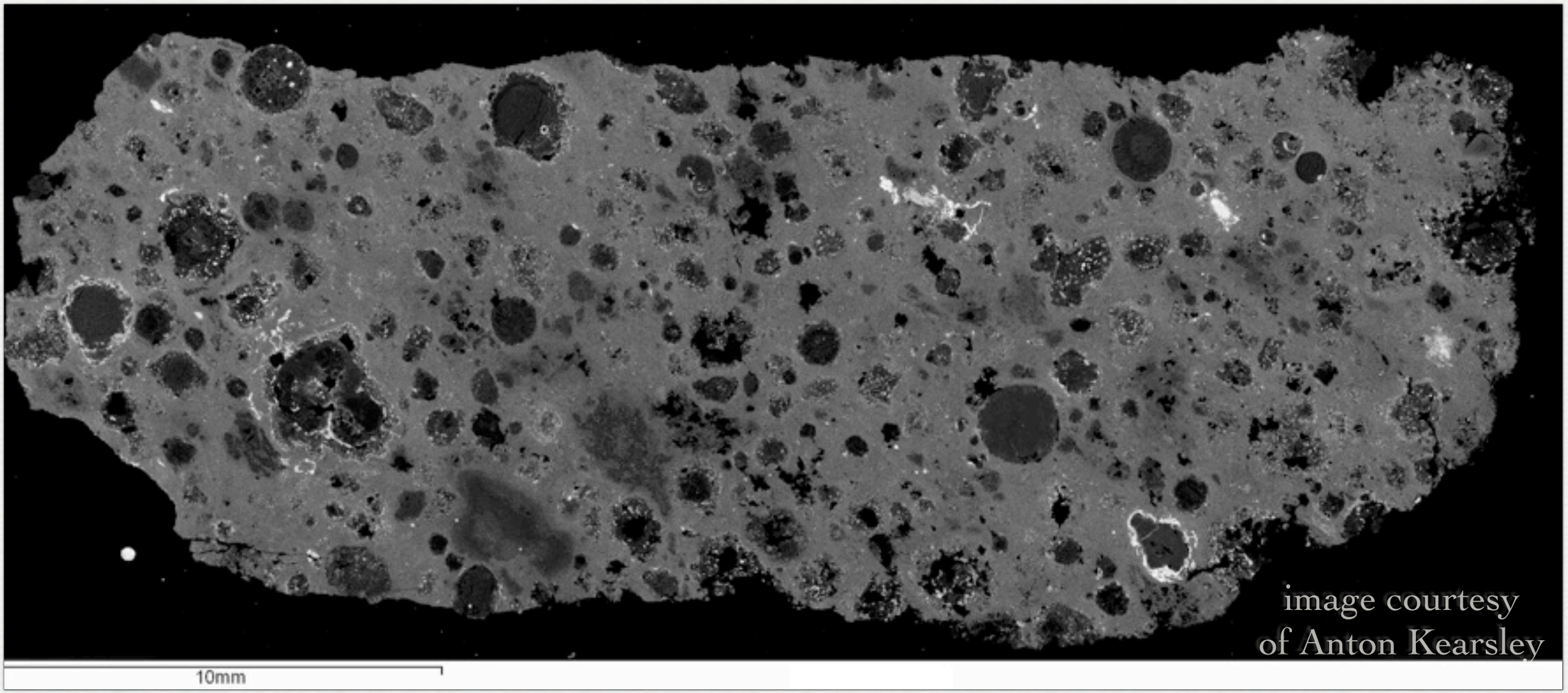


A Murchison meteorite specimen at the National Museum of Natural History (Washington)

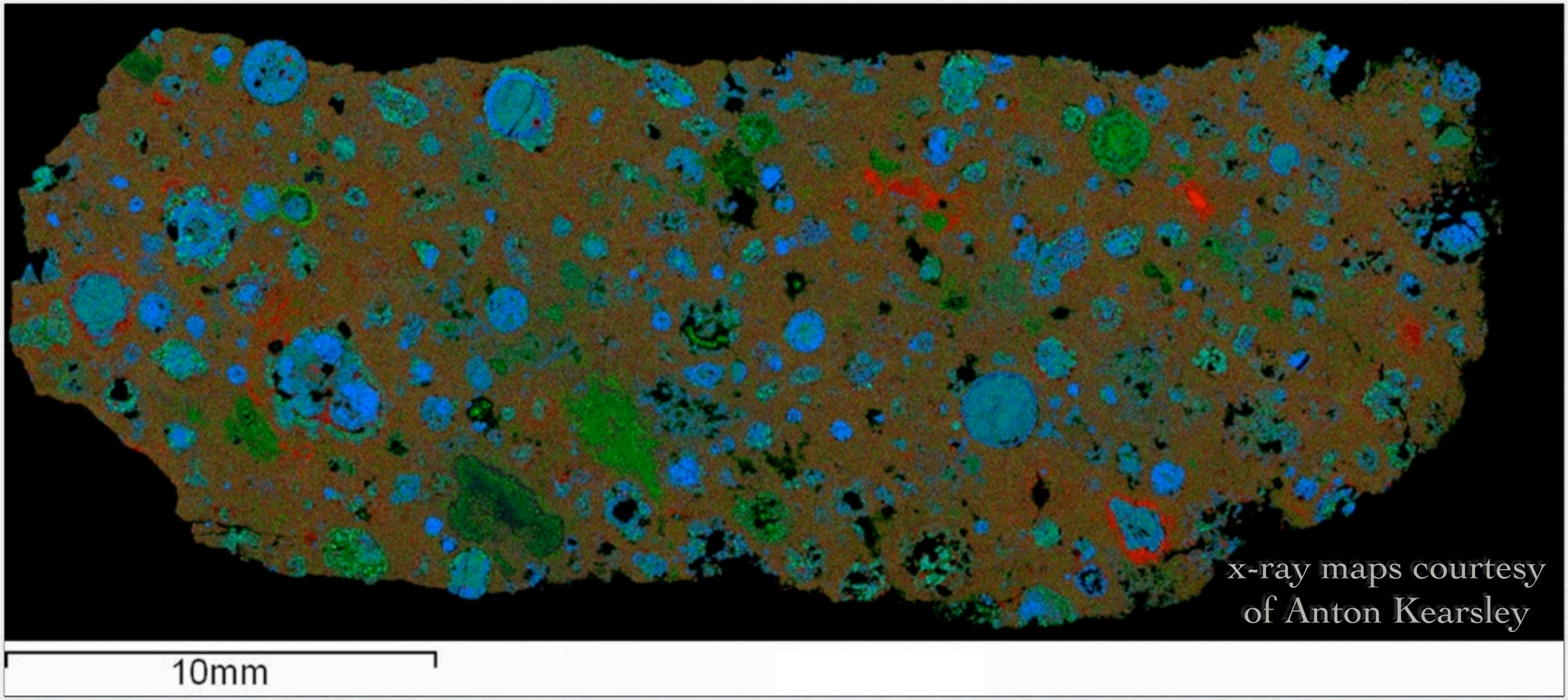
Distribution of Minerals - CI

Ivuna, CI Carbonaceous Chondrite

(Image courtesy of the Natural History Museum, London.)

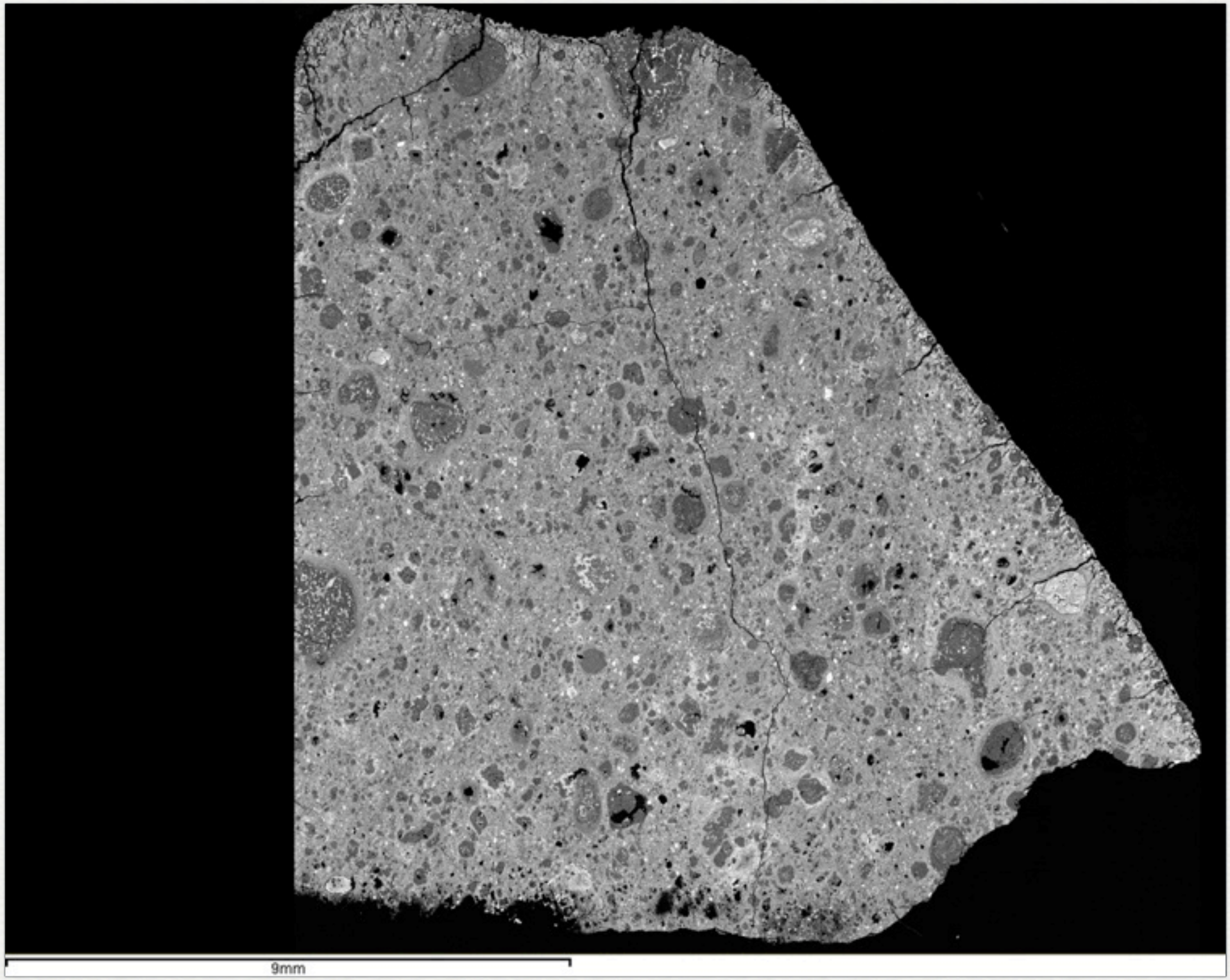


Allende - CV chondrite

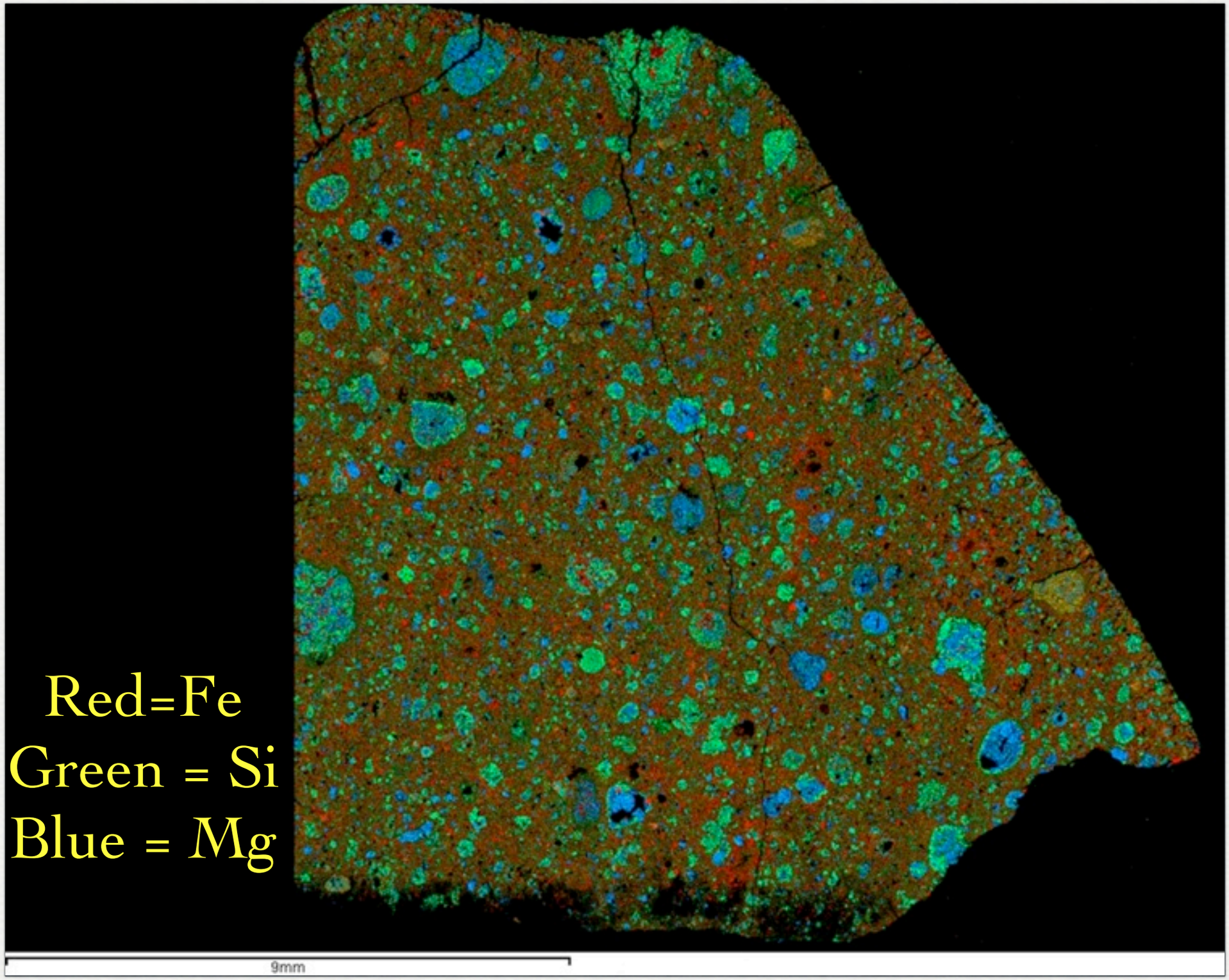


Red=Fe; Green = Si; Blue = Mg

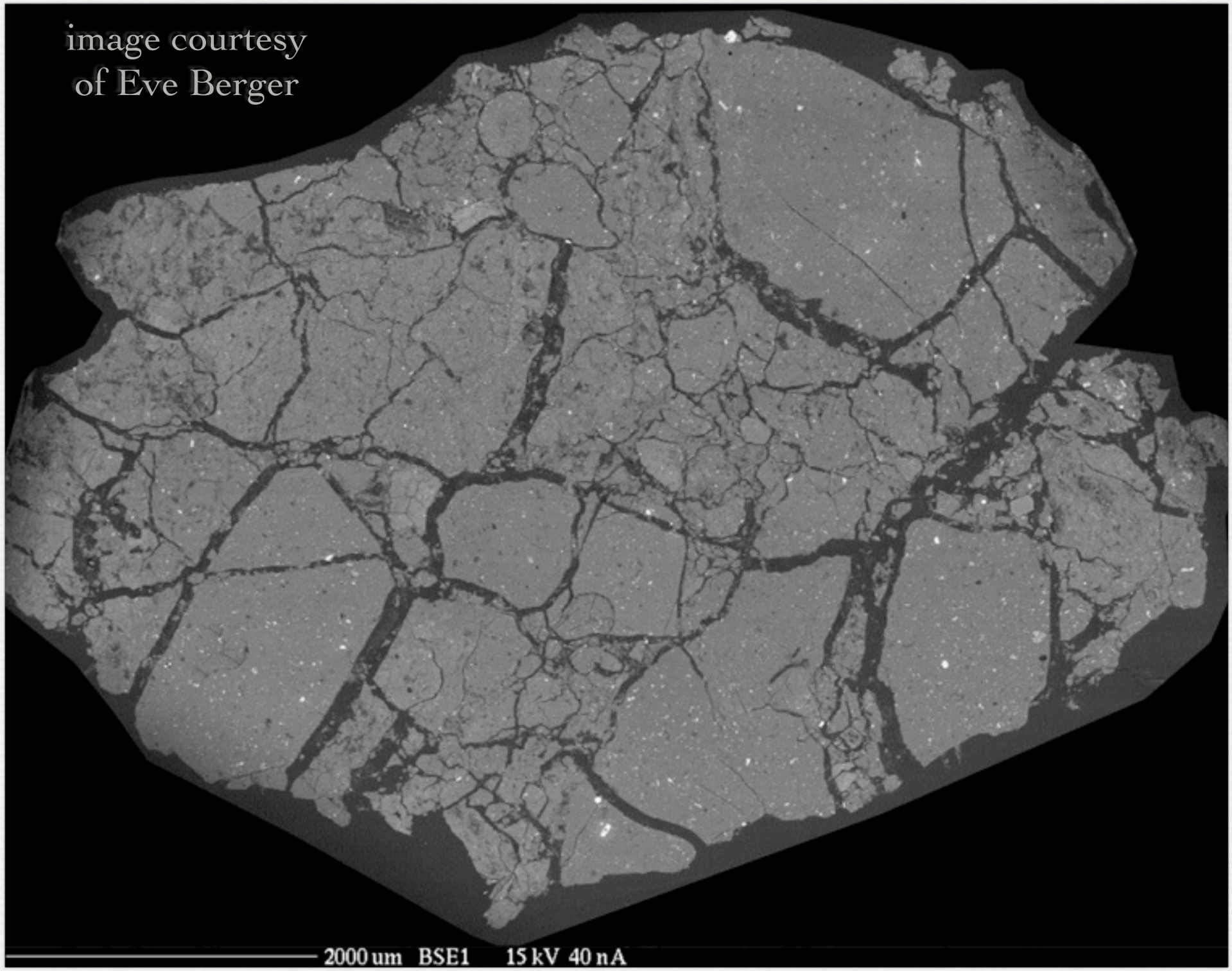
Allende - CV chondrite



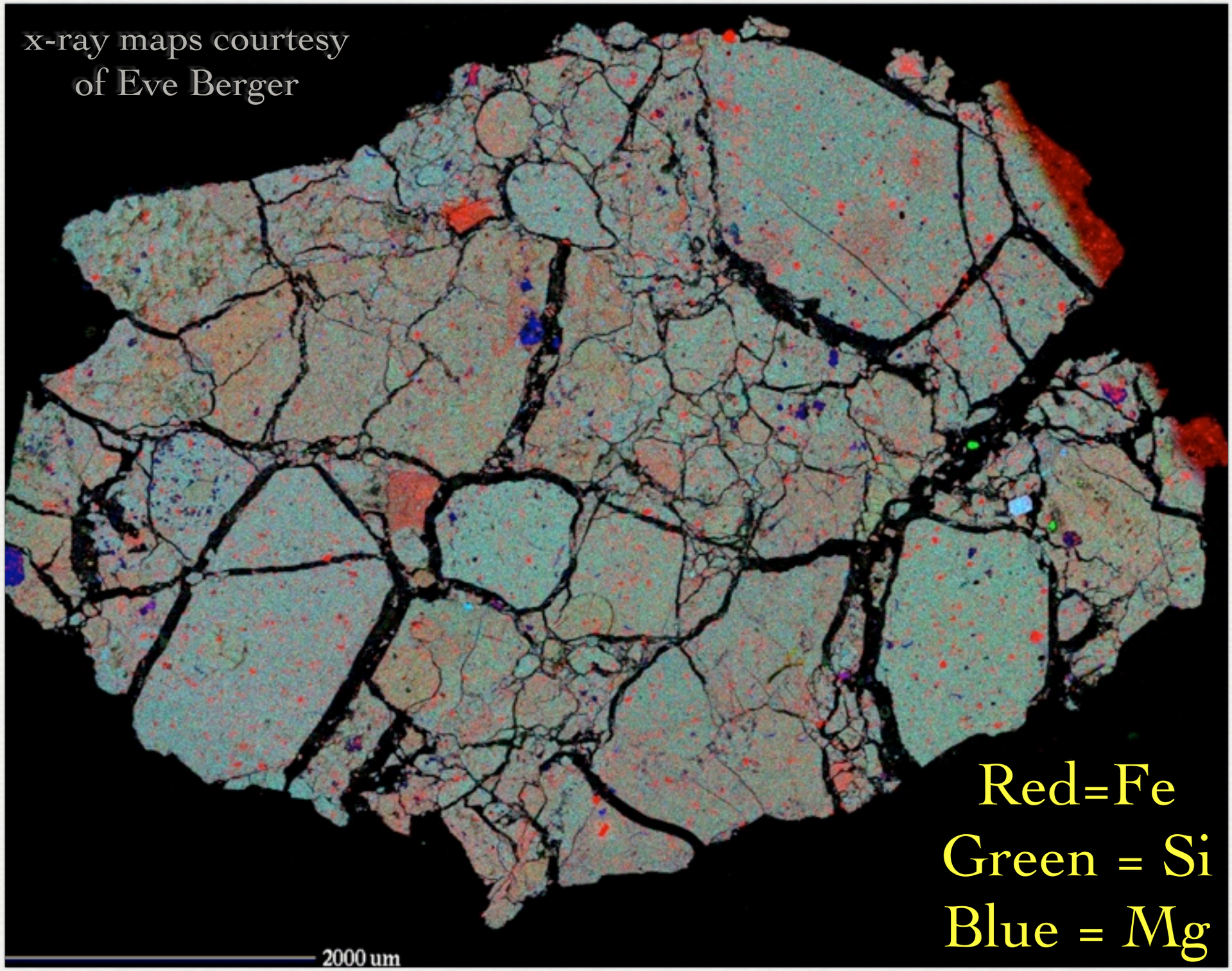
Murchison - CM chondrite



Murchison - CM chondrite



Orgueil - CI chondrite

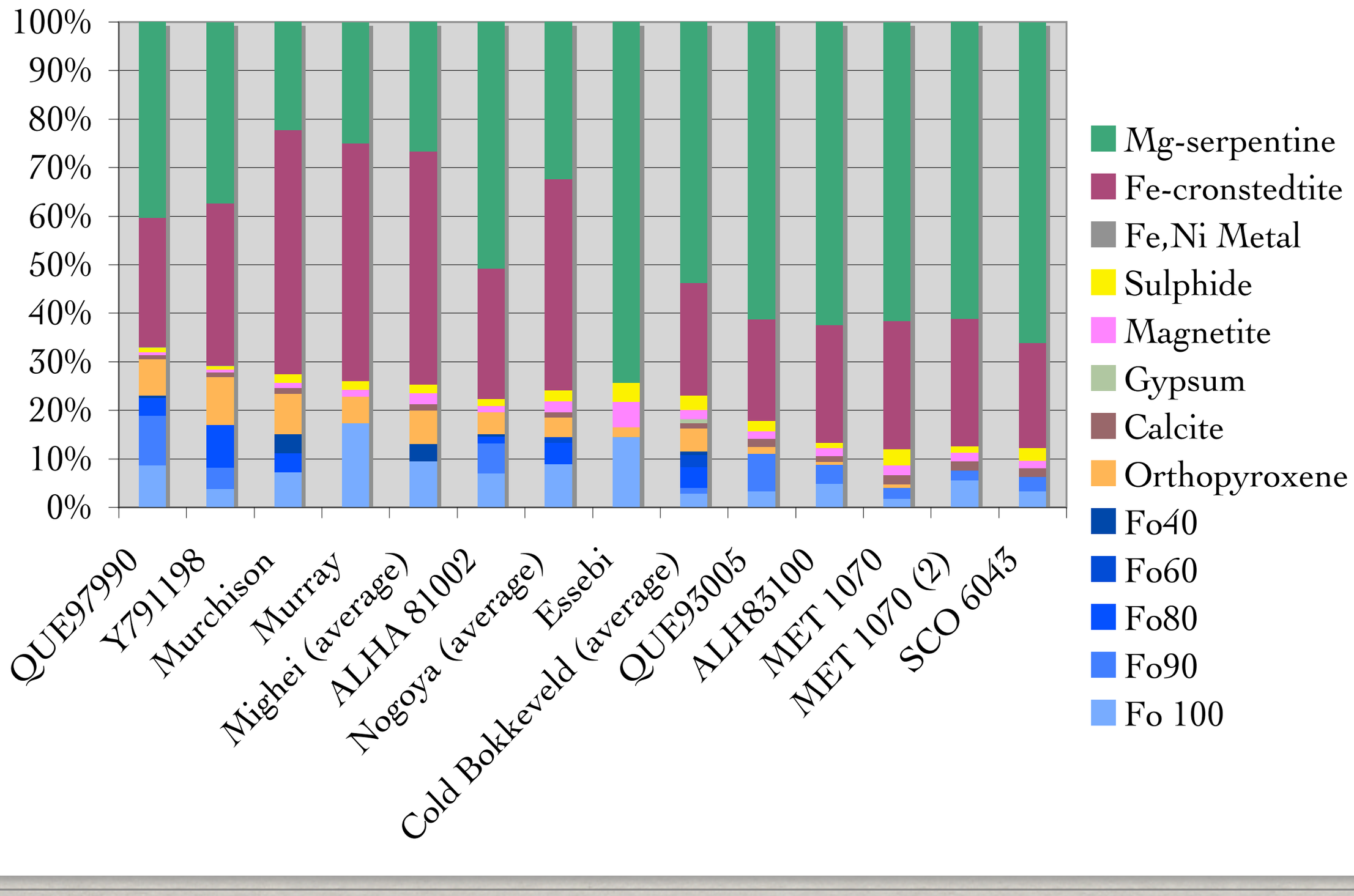


Orgueil - CI chondrite

Modal Abundance

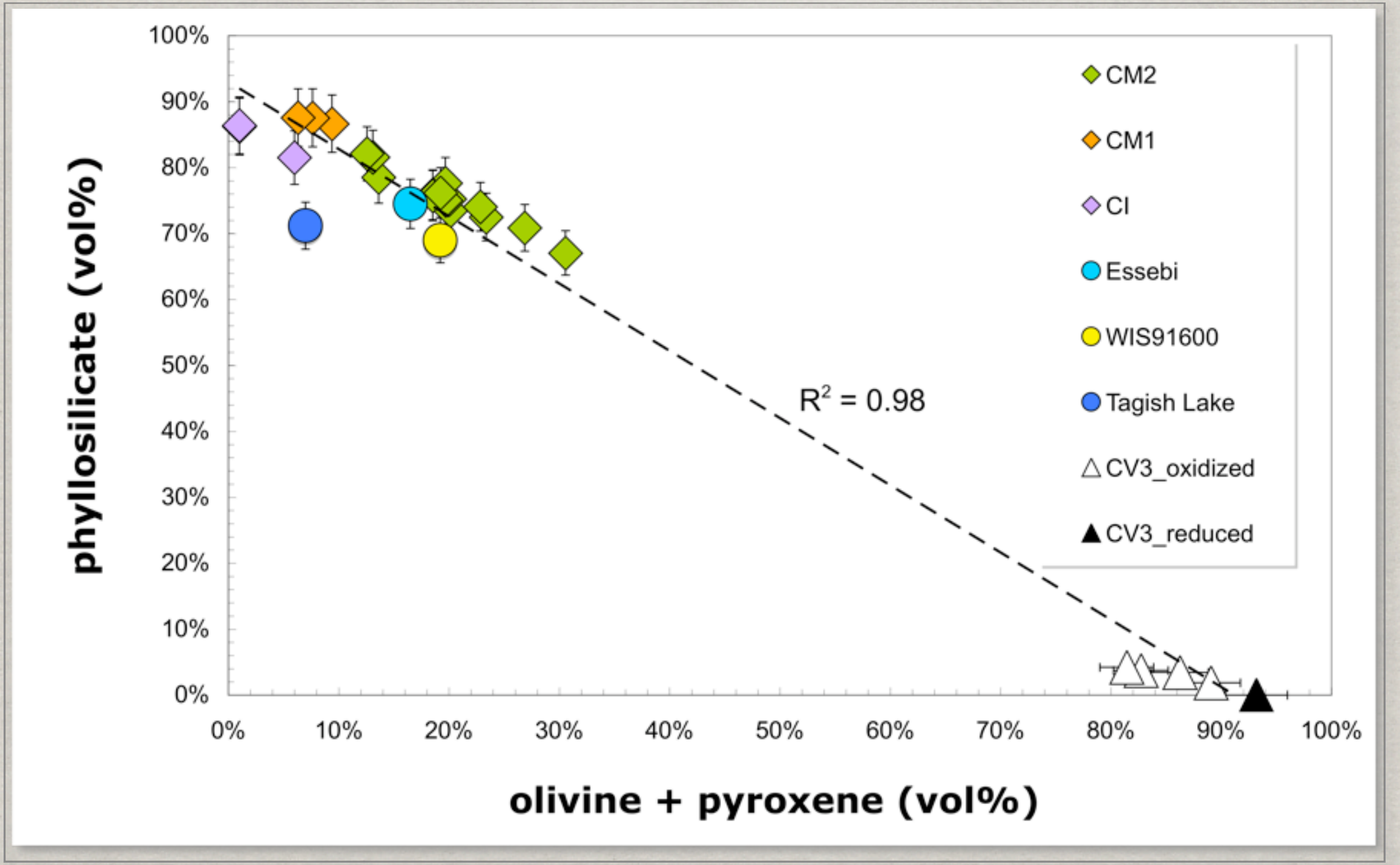
- How much is really there?
  - Can see variation of hydrated minerals in different meteorite types
- X-Ray Diffraction allows quantification of modal abundances of minerals at >1vol%

Modal Abundance - CM



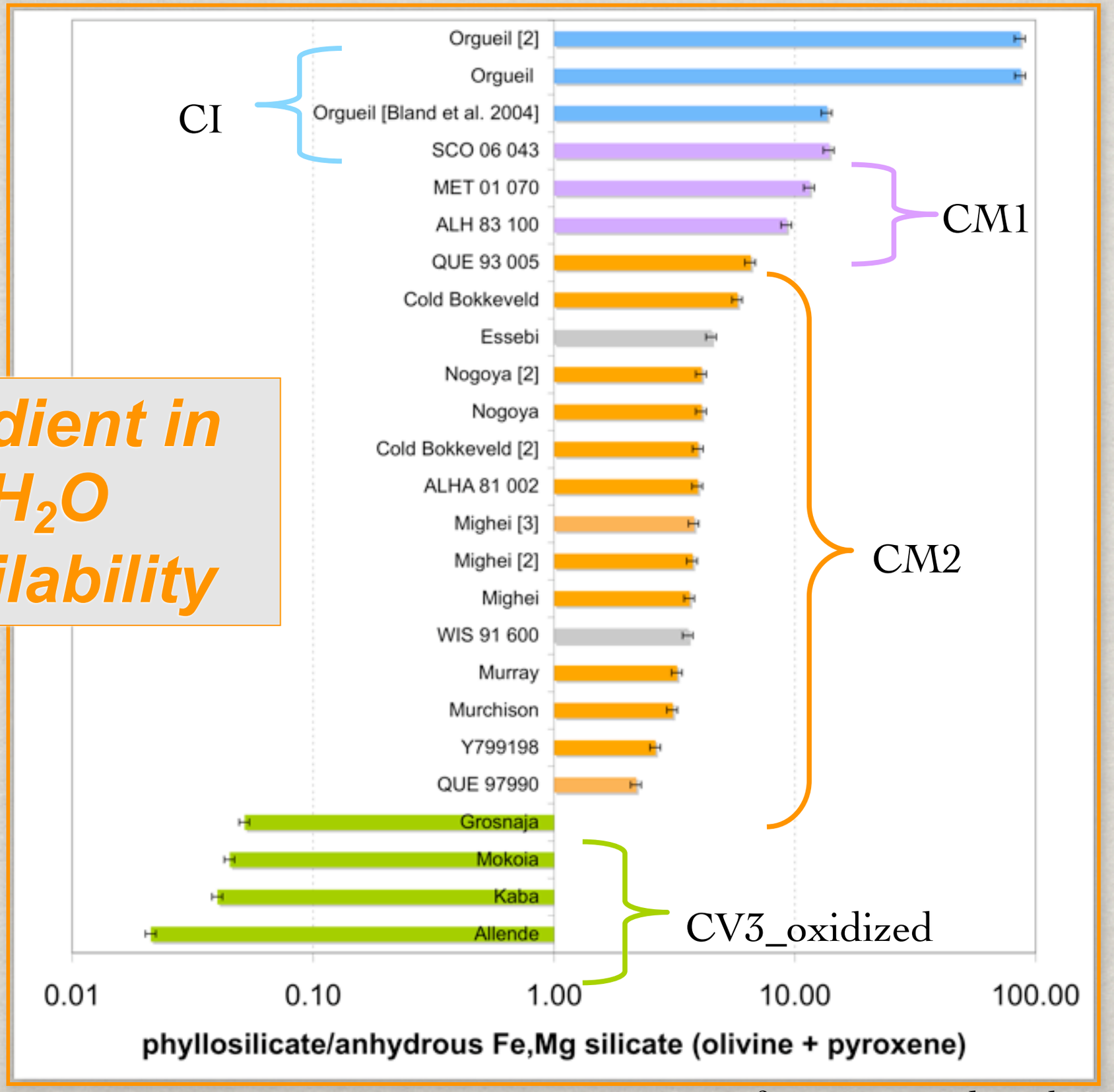
Data from Howard et al. 2009, 2011

Modal Abundance



Data from Howard et al. 2009, 2010, 2011

Degree of aqueous alteration



Gradient in H_2O availability

Data from Howard et al. 2009, 2010, 2011

Implications (?) for Spectra

- Phyllosilicates in carbonaceous chondrites (CV, CM, CI) vary in composition
  - Fe-rich generally more abundant in CV and CM2
    - CMs contain Cronstedtite - Fe^{+2}/Fe^{+3} bearing
  - Mg-rich abundant in CM1 and CI
- Modal abundance varies
  - CV - < 5 vol% (but alteration could have formed anhydrous mineralogy)
  - CM2 - 65 to 80 vol%
  - CM1 - ~88 vol%
  - CI - 80 to 85 vol%