MINERALOGY

CONTENT

- What is a mineral?
- What is mineralogy?
- How do you identify a mineral?
- Why is it important?
- Analytical tools
- Case study – My master
- Distribution of minerals

WHAT IS A MINERAL?

- Natural occuring
- Crystalline
- Inorganic solid substance
- Specific physical and chemical properties

NATURALLY OCCURING

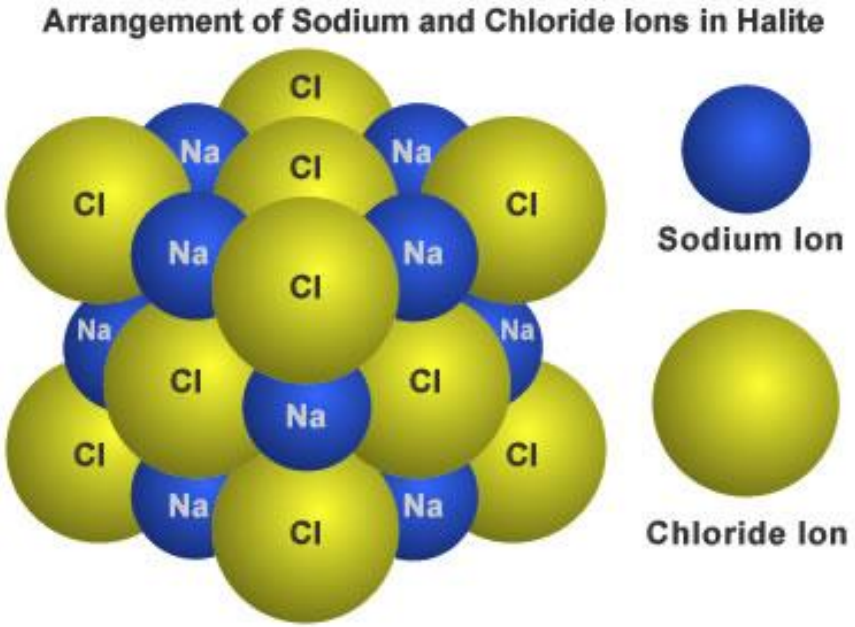
Natural

Non-natural

Cement, steel and glass are all non-natural materials, but made by natural minerals

CRYSTALLINE

Form crystal structures with an ordered internal structure



INORGANIC SOLID SUBSTANCE

Must be of an inorganic solid substance.

An example is water – water is liquid i.e. not a mineral

But when it freezes to ice its an ***inorganic solid substance*** i.e. a mineral!

PHYSICAL AND CHEMICAL PROPERTIES

- Chemical composition varies within a limited range of elements
- Only elements with similar size and charge can enter the compositional sites
- Feldspar

$NaAlSi_3O_8$ – $KAlSi_3O_8$

Albite

$Na^{+1} \Leftrightarrow K^{+1}$

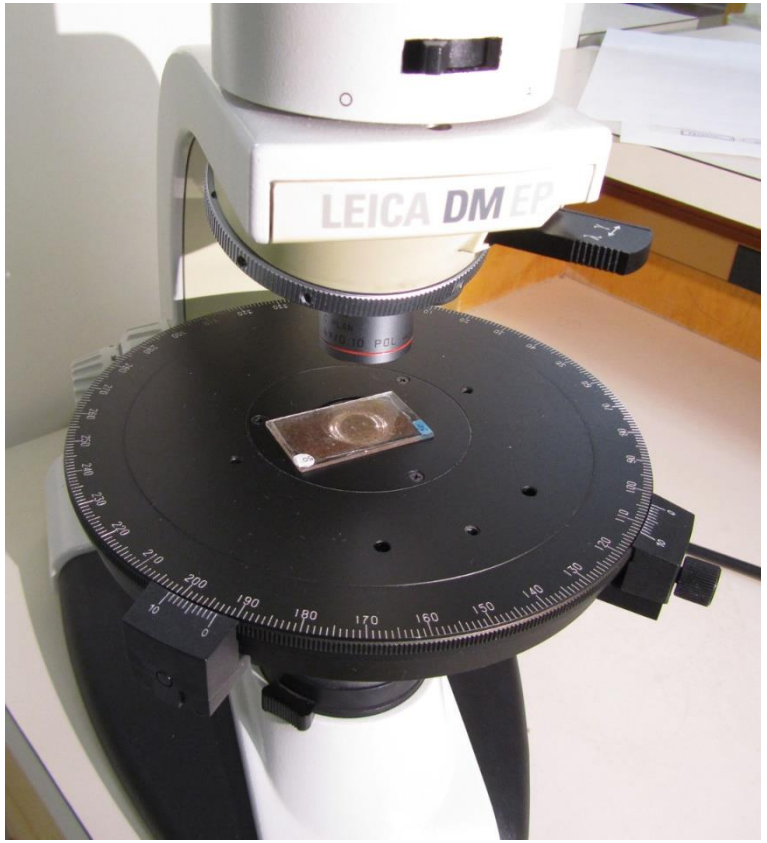
K-feldspar

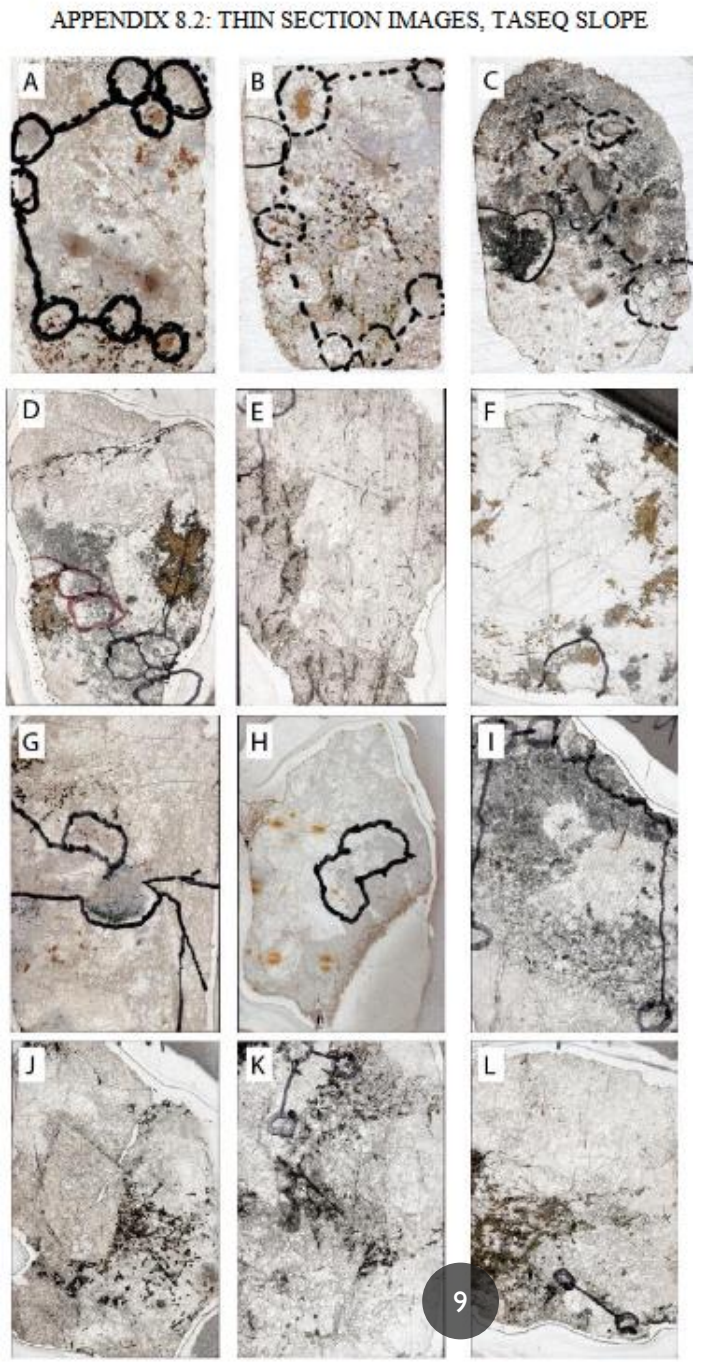
WHAT IS MINERALOGY? HOW DO WE IDENTIFY AND CHARACTERIZE A MINERAL

- A systematic study that deals with the characteristics of the individual and group of minerals.
- Physical and optical mineralogy
  - Optical
  - Hardness
  - Cleavage
  - Color and luster
  - Streak
- Crystallography
  - Internal structure
  - Crystal forms

OPTICAL MINERALOGY

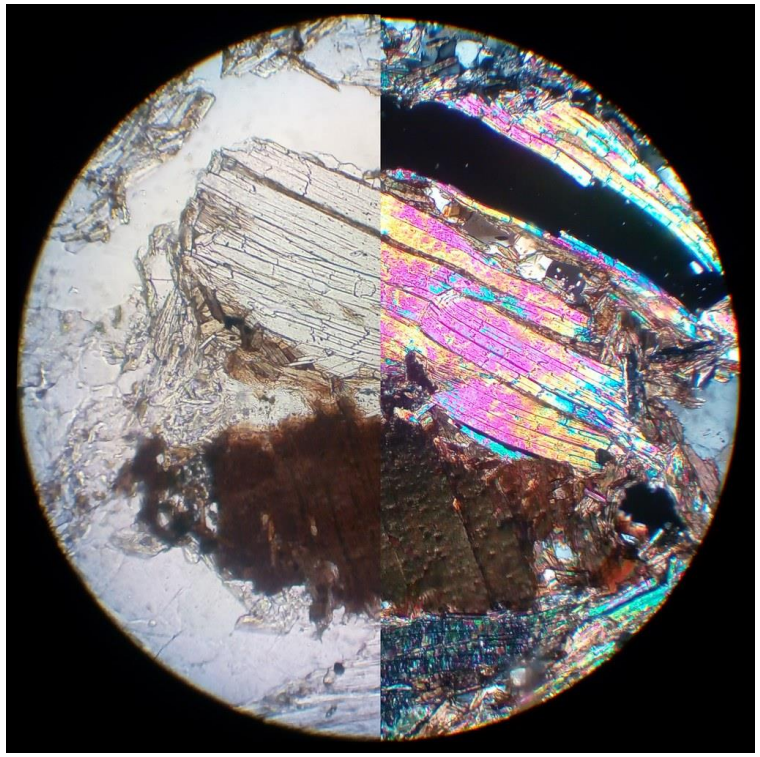
- Mapping areas of interest
- Making it easier to track back and revisit for further analyses





OPTICAL MINERALOGY

- Optical characterisation
- Identifying minerals
  - Relief
  - Color - Birefringence
  - Extiction



HARDNESS

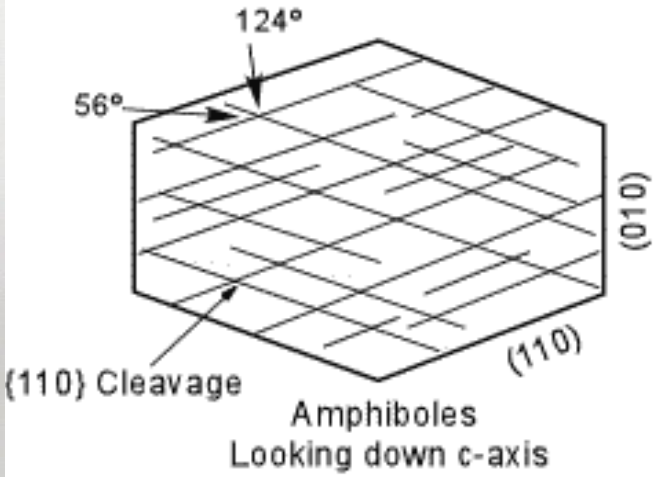
- Important paramenter for physically determine the mineral
- Relative hardness
- Mohs hardness scale

CLEAVAGE

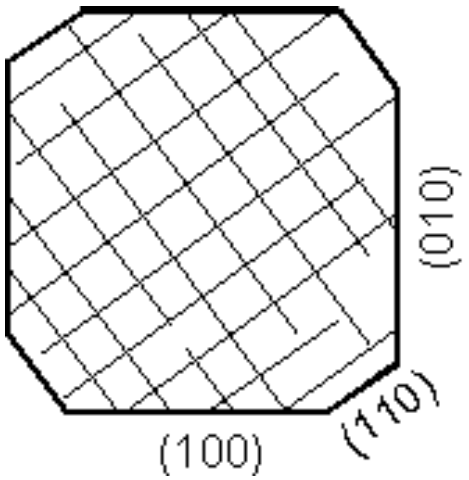
Amphibole

Minerals have different cleavage – which can be characteristic the mineral

Amphibole



Pyroxene



Pyroxene

COLOR AND LUSTER

Color is the most commonly used differentiator between minerals…

… but maybe the worst one

STREAK

- Common to use among magnetic minerals and in general with dark colored minerals

WHY IS MINERALOGY IMPORTANT?

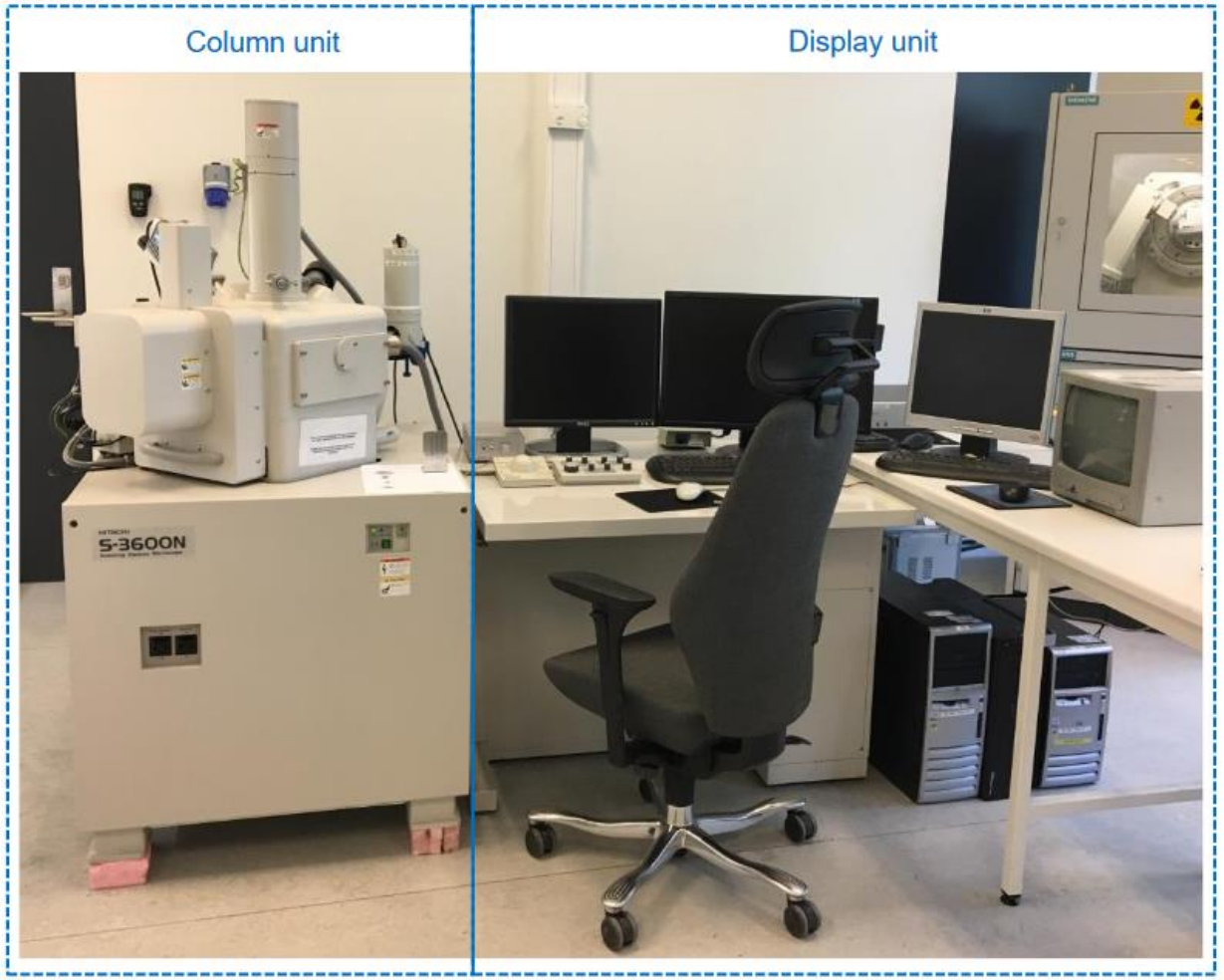
- World is gradually becomming more dependant on Earth's natural resources.
- Rare Earth Elements – Rare Earth Minerals
- Part of the «Green Shift»
- Mineralogy is understanding minerals and where they form
- Part of the value chain for REE
- China is the main contributer of REE of the world
- Gemstones

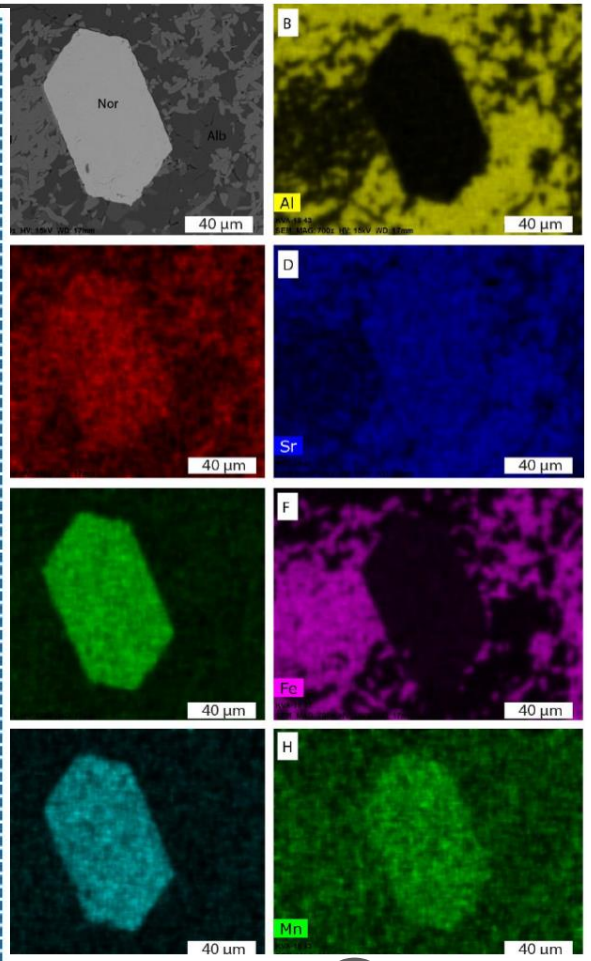
ANALYTICAL TOOLS IN MINERALOGY

- Scanning electron microscope (SEM)
- Powder X-ray diffractometer (PXRD)
- Single-crystal X-ray diffractometer (SXRD)
- Electron probe micro-analyzer (EPMA)
- Laser ablation inductively coupled plasma mass spectometry (LA-ICP-MS)

SCANNING ELECTRON MICROSCOPE (SEM)

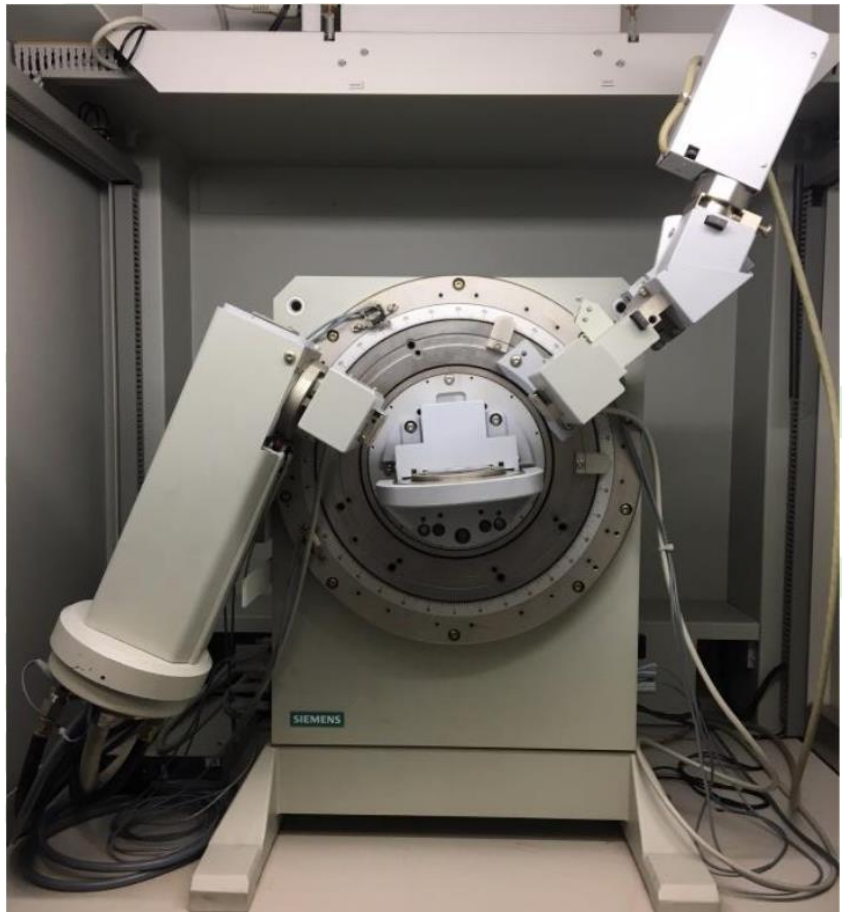
- Semi-quantitative chemical element data
- Mapping of elements
- Quick
- Energy-dispersive X-ray spectrometry (EDS)
- Limitations: Overlapping peaks





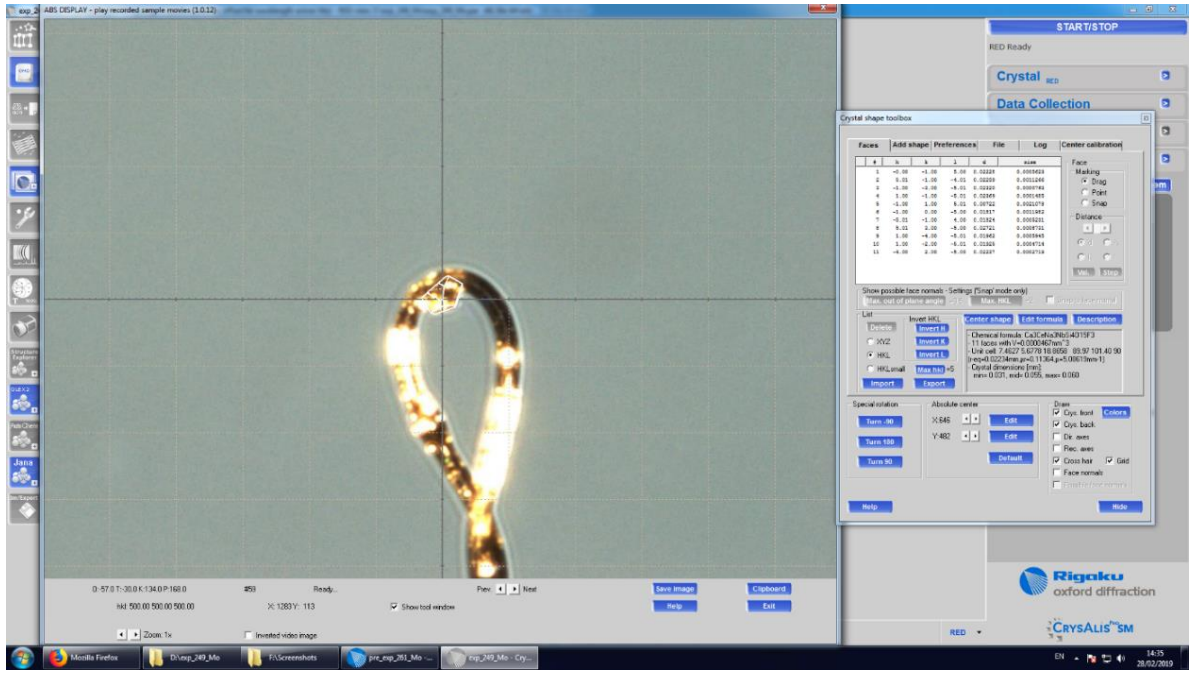
POWDER X-RAY DIFFRACTOMETER (PXRD)

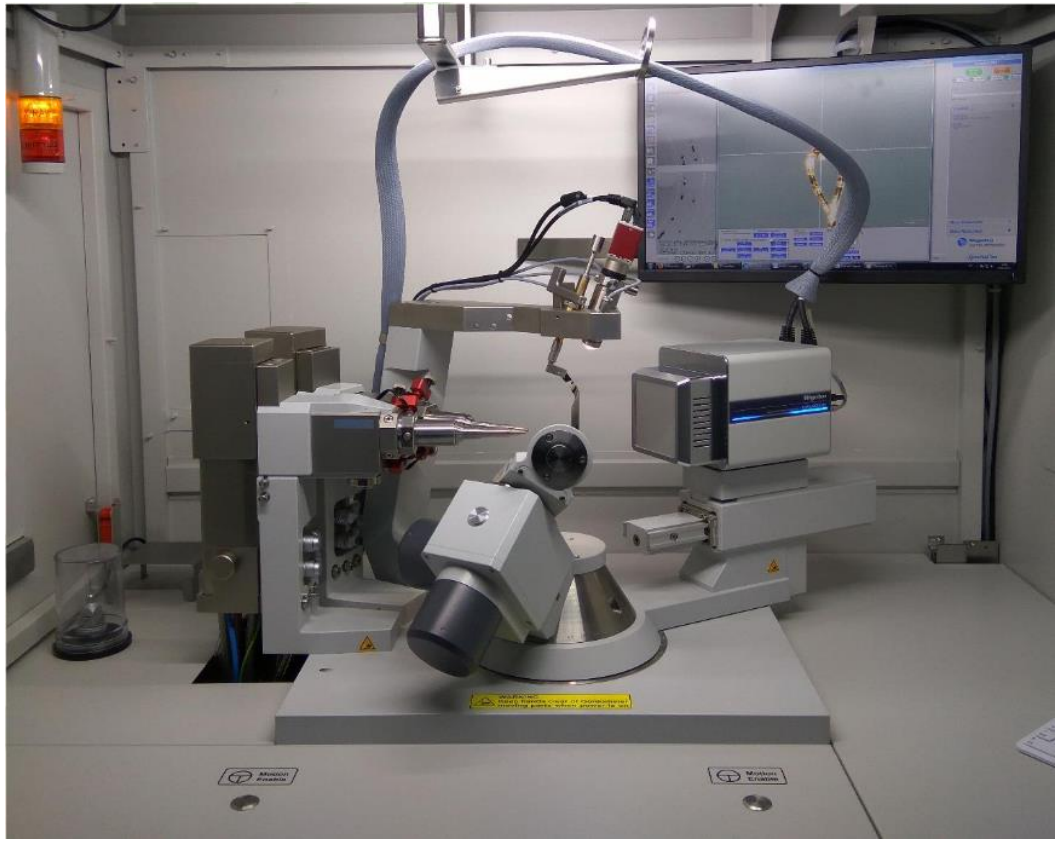
- Gives structural data of the mineral
- Quick
- Less useful with the introduction of Single-Crystal X-ray Diffractometer
- Used in combination with SEM data to get a initial impression of chemical and structural composition



SINGLE-CRYSTAL X-RAY DIFFRACTOMETER (SXRD)

- Gives high precision structural data
- Extracting a single crystal from material – time consuming
- Enough to be able to do analysis
  - preferred material below 100µm



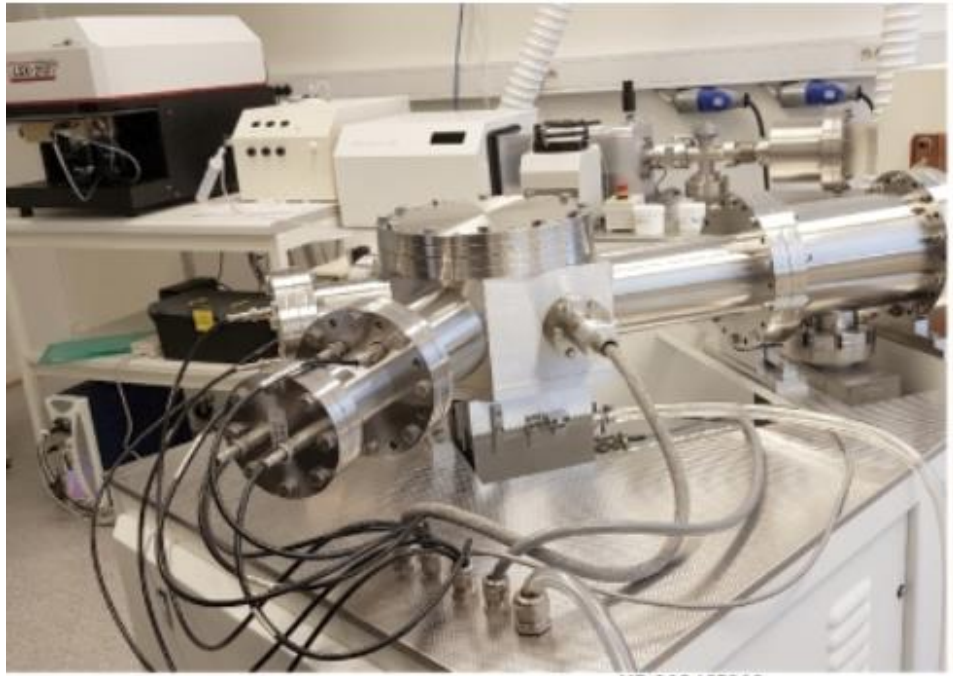


ELECTRON PROBE MICRO-ANALYZER (EPMA)

- High sensitivity quantitative chemical data
- Quantify major and minor components of the mineral
- Time consuming
- Data in combination with SXRD data gives a structural and chemical characterization of mineral
- Wavelength dispersive x-ray detector (WDS)
- EDS vs. WDS

LASER ABLATION INDUCTIVELY COUPLED PLASMA MASS SPECTOMETRY (LA-ICP-MS)

- Used to determine trace elements in the samples
- Complements the SXRD and EPMA data with the minerals trace elements



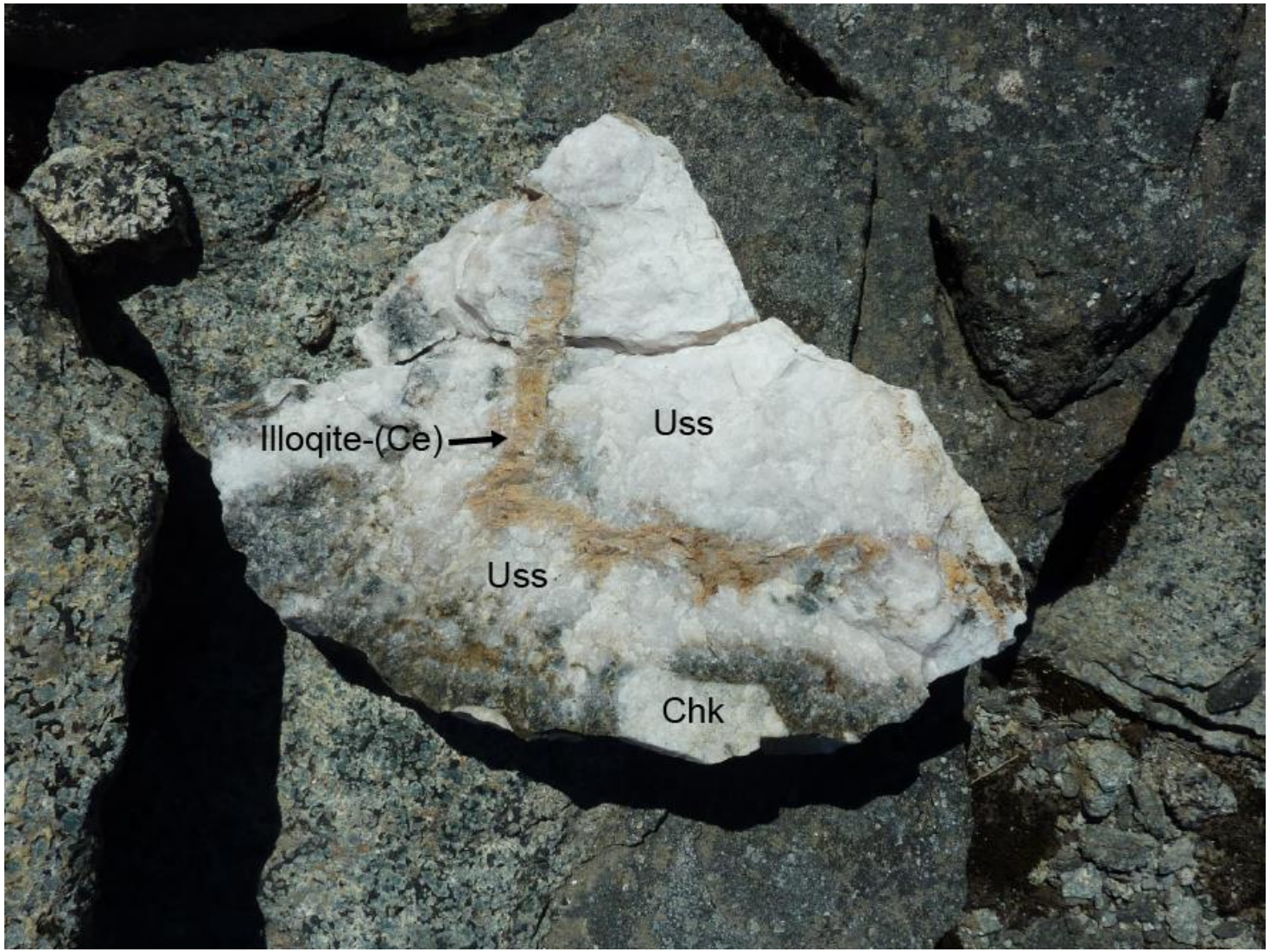
HR-MC-ICPMC

Q-ICPMC

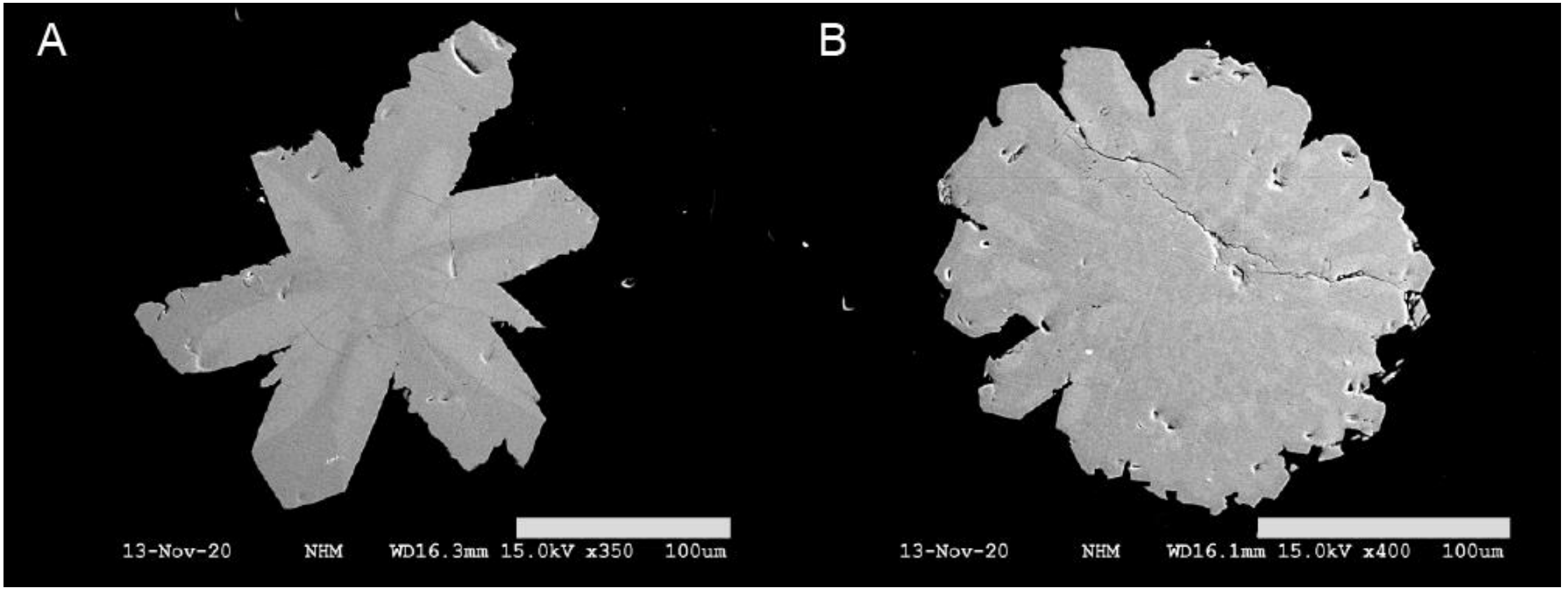
CASE STUDY - MY MASTER

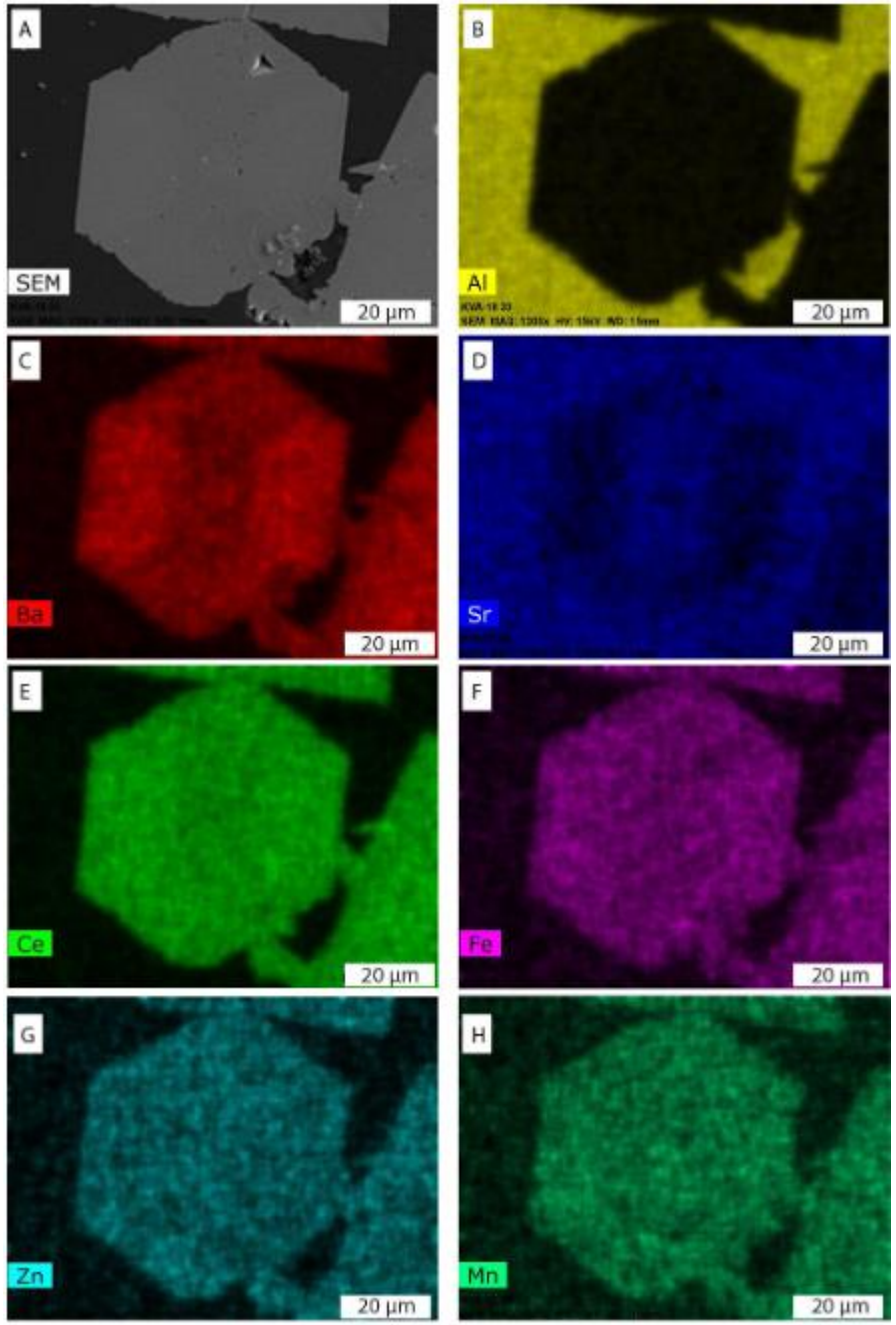
- Fieldwork in Greenland
- Analyzing data
- Describing new mineral
- Illoqite-(Ce)

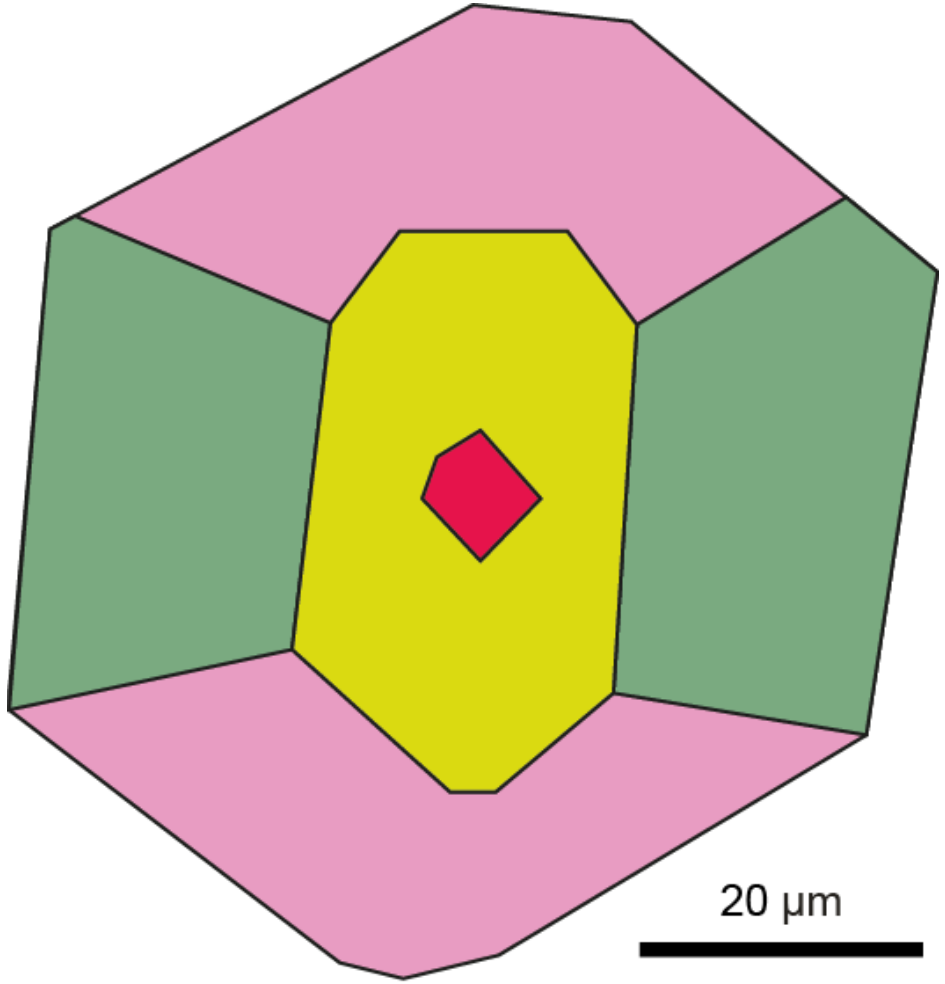
FIELD WORK



CHEMICAL DATA





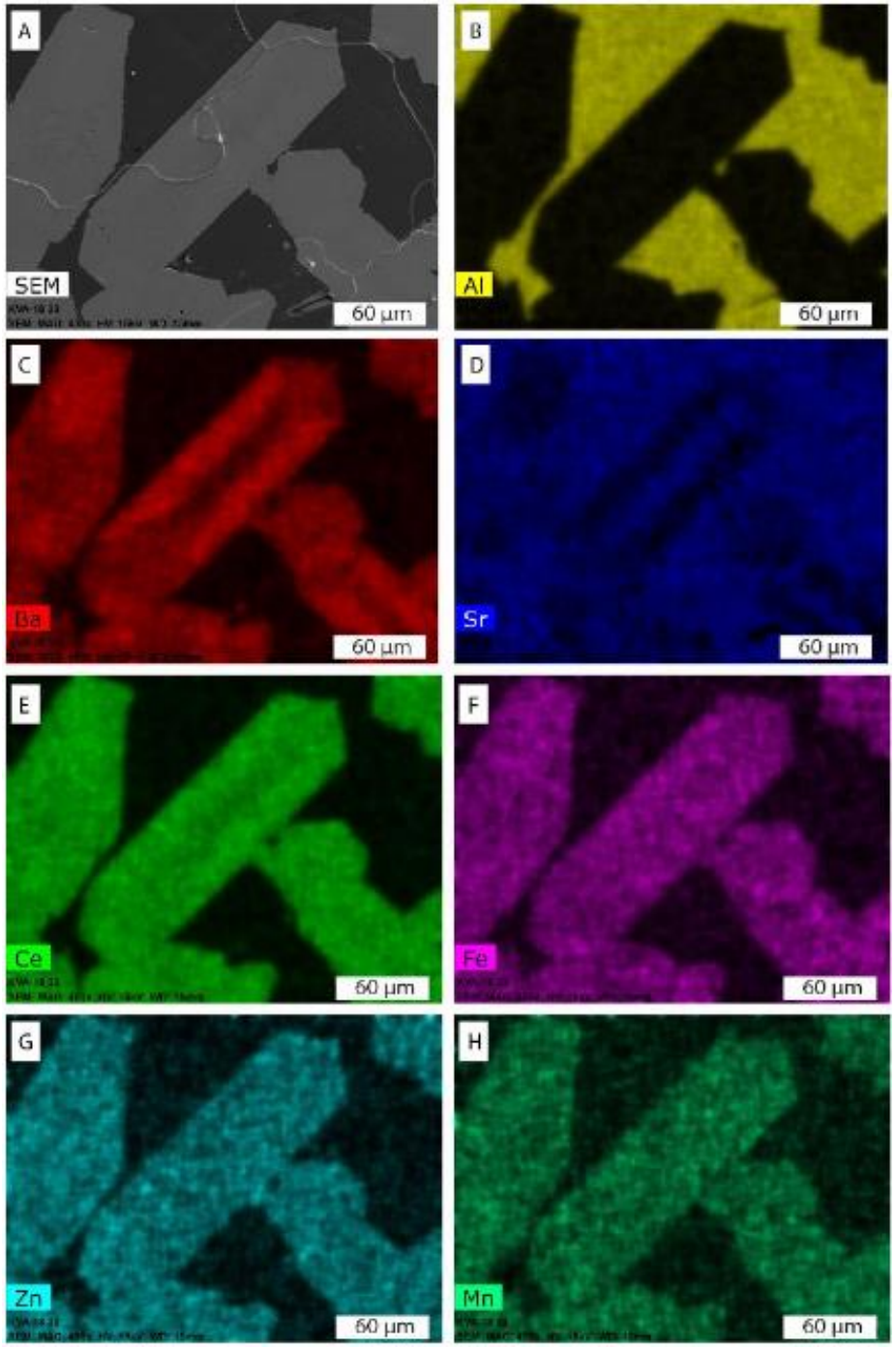


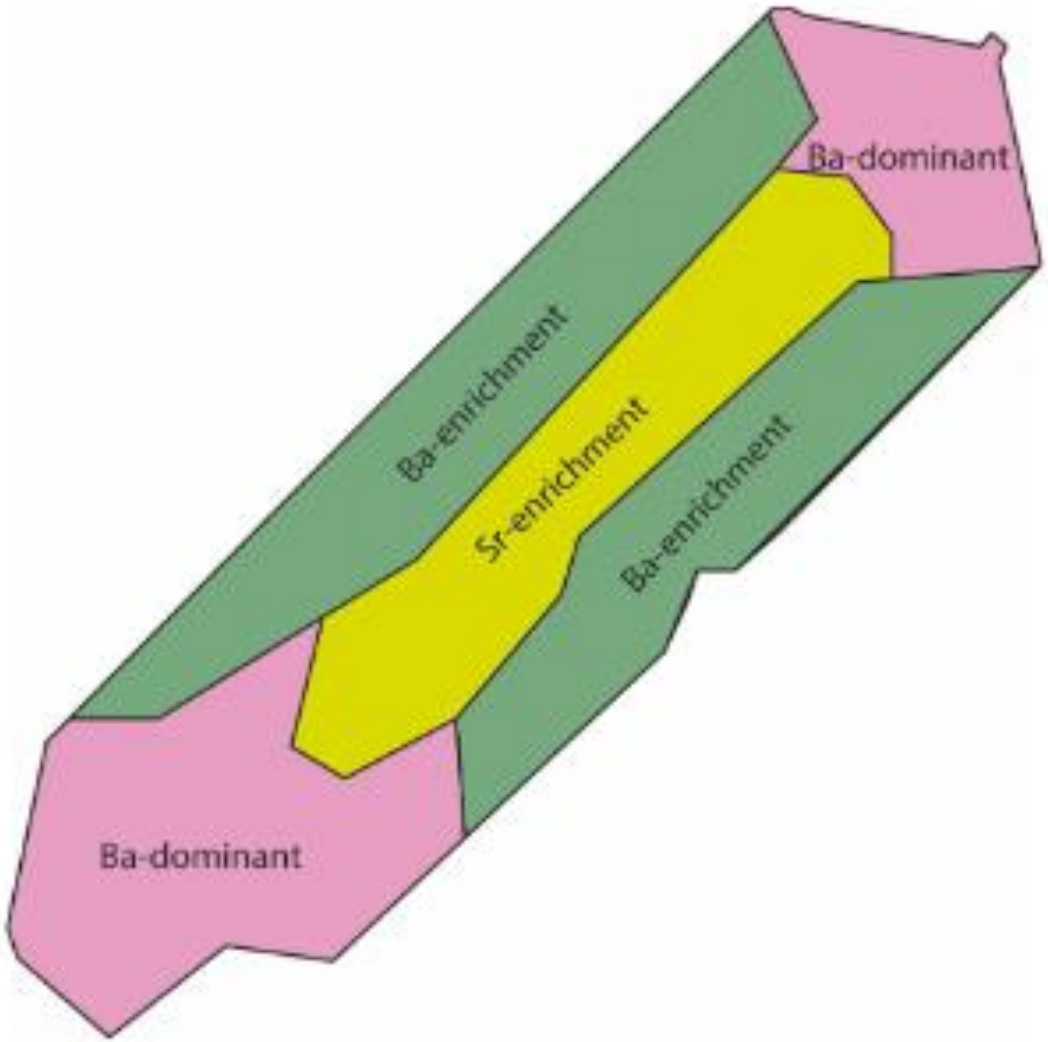
Ba/Sr: 1.05

Ba/Sr: 1.28

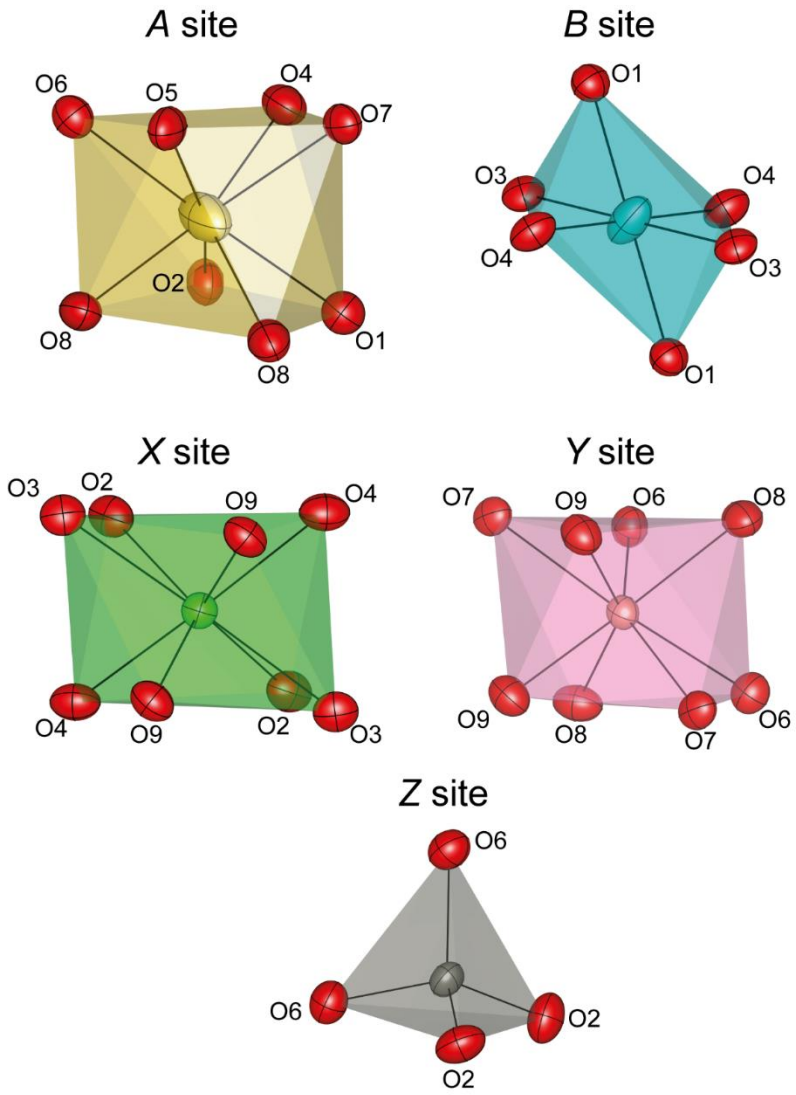
Ba/Sr: 0.49

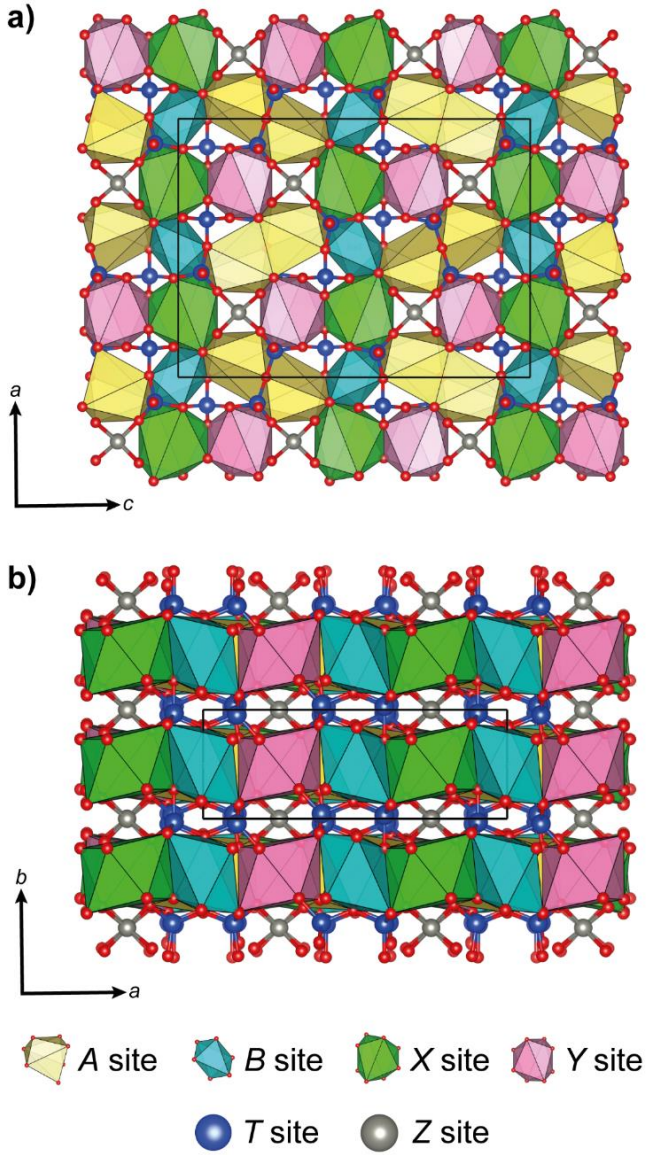
Ba/Sr: 3.04


A
SEM
60 µm
B
Al
60 µm
C
Ba
60 µm
D
Sr
60 µm
E
Ce
60 µm
F
Fe
60 µm
G
Zn
60 µm
H
Mn
60 µm


Ba-dominant
Ba-enrichment
Sr-enrichment
Ba-enrichment
Ba-dominant

STRUCTURAL DATA





NORDITE GROUP

	A	*B*	*X*	*Y*	*Z*	*T*	*O*
Nordite group							
Nordite-(La)	Na_2	Na	Sr	La	Zn	Si_6	O_{17}
Nordite-(Ce)	Na_2	Na	Sr	Ce	Zn	Si_6	O_{17}
Ferronordite-(La)	Na_2	Na	Sr	La	Fe	Si_6	O_{17}
Ferronordite-(Ce)	Na_2	Na	Sr	Ce	Fe	Si_6	O_{17}
Manganonordite-(Ce)	Na_2	Na	Sr	Ce	Mn	Si_6	O_{17}
Illoqite-(Ce)	Na_2	Na	Ba	Ce	Zn	Si_6	O_{17}

	A	*A'*	*B*	*X*	*Y*	*Z*	*T*	*O*
Unassigned member								
Meieranite	Na	Sr	Na	Sr	Sr	Mg	Si_6	O_{17}

ILLOQITE-(CE)

- Named after the Greenlandic word illoq – which means cousin
- Minerals often need a prefix and a suffix – in this case the *REE* site determines the suffix (Ce), while this is a new mineral so does not require a prefix.
- Empirical formula:

$$Na_{3.03}(Ba_{0.59}Sr_{0.32}Ca_{0.04})_{\Sigma 0.95}(Ce_{0.68}La_{0.31}Nd_{0.09}Pr_{0.04})_{\Sigma 1.12}(Zn_{0.42}Fe_{0.34}Li_{0.14}Mn_{0.09})\Sigma_{0.99}Si_{5.97}O_{17}$$

- Simplified formula:

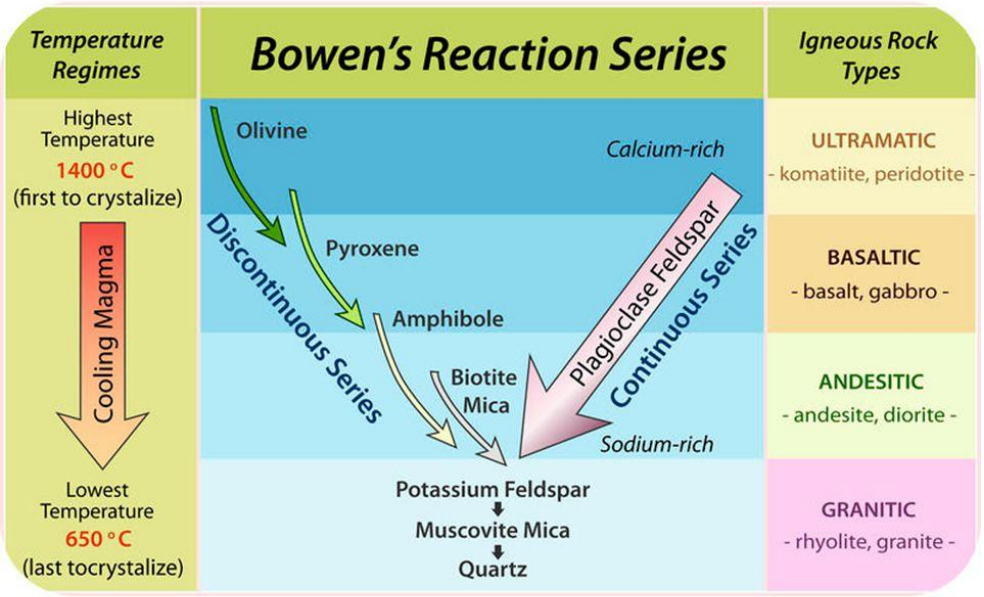
$$Na_3(Ba,Sr)(Ce,La,Nd)(Zn,Fe,Li)Si_6O_{17}$$

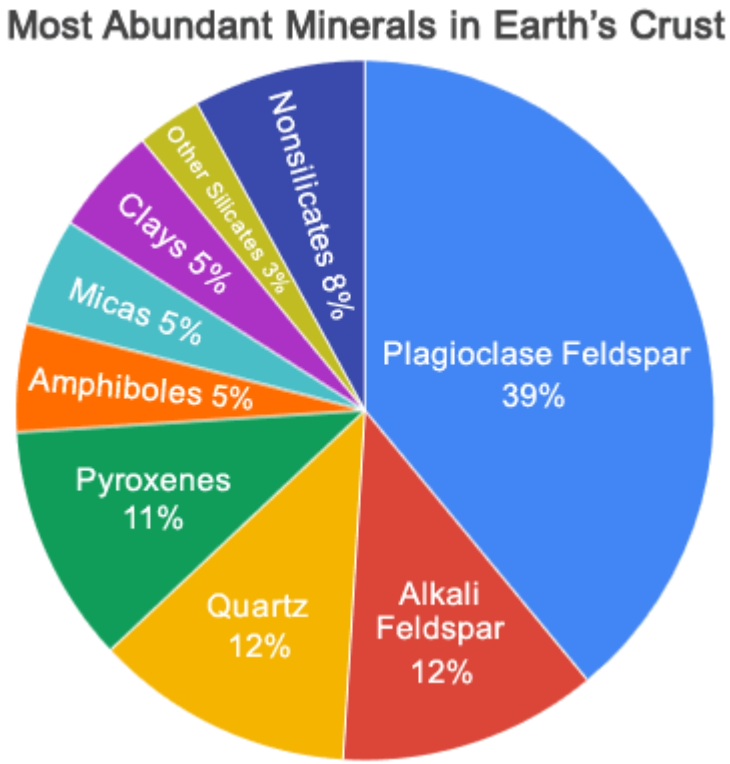
MINERAL DISTRIBUTION ON EARTH

More than 5000 mineral species

Only a few minerals are so called rock-forming minerals

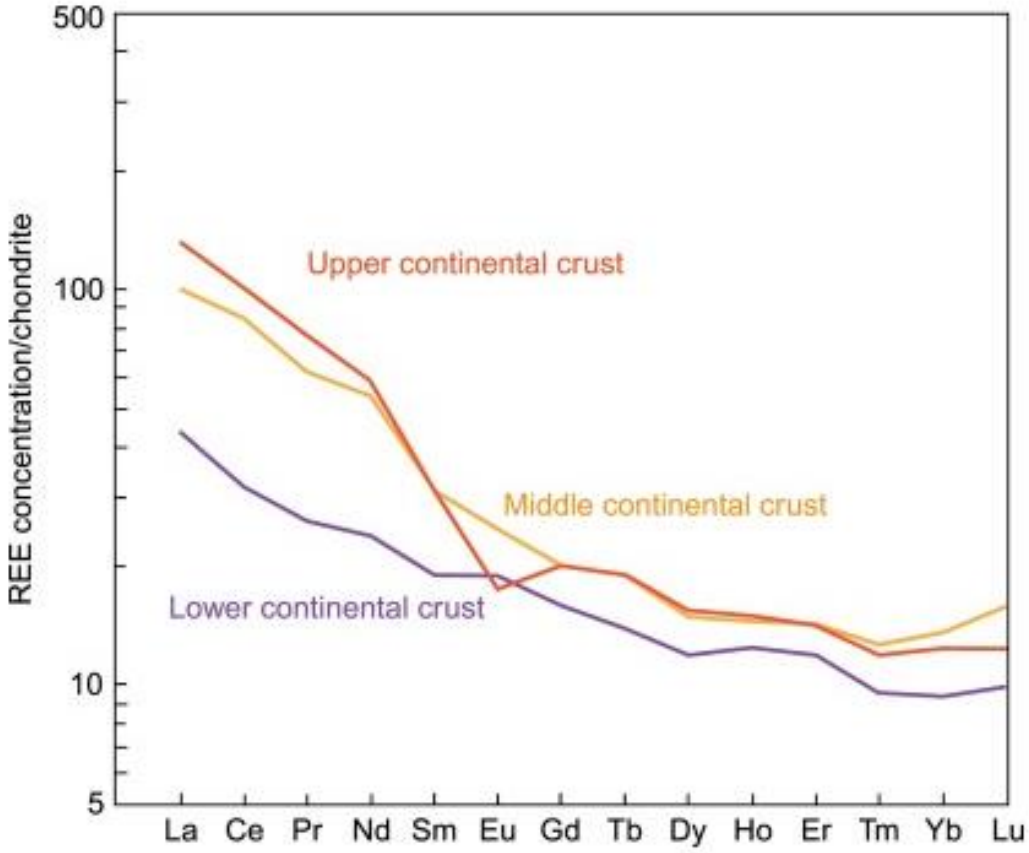
Quartz, feldspar, amphibole, micas, olivine, garnet, calcite and pyroxene

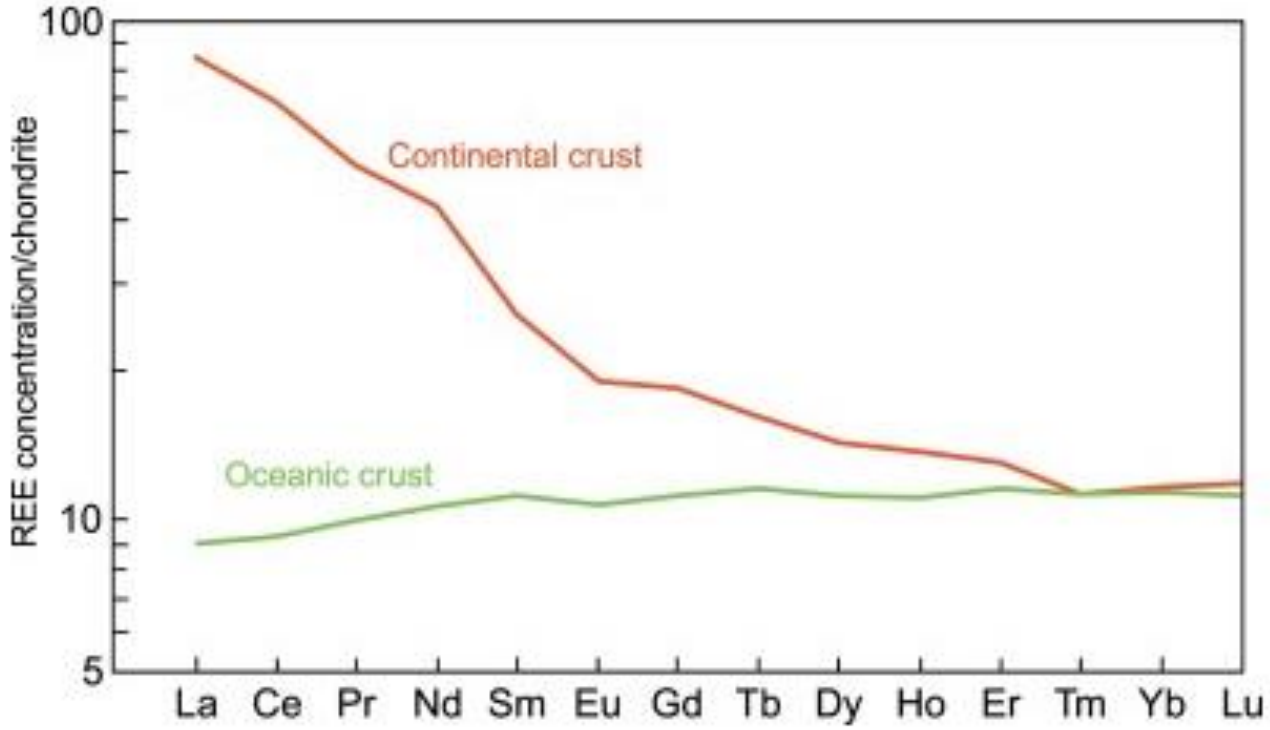




From Ronov and Yaroshevsky (1969)

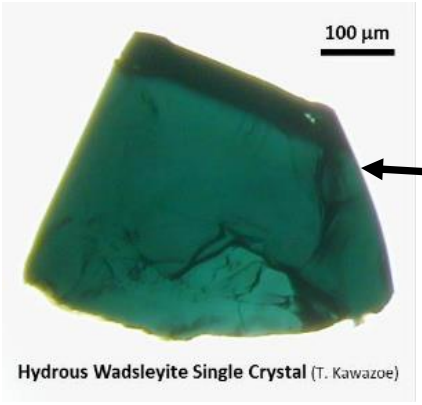
REE DISTRIBUTION IN THE EARTH'S CRUST

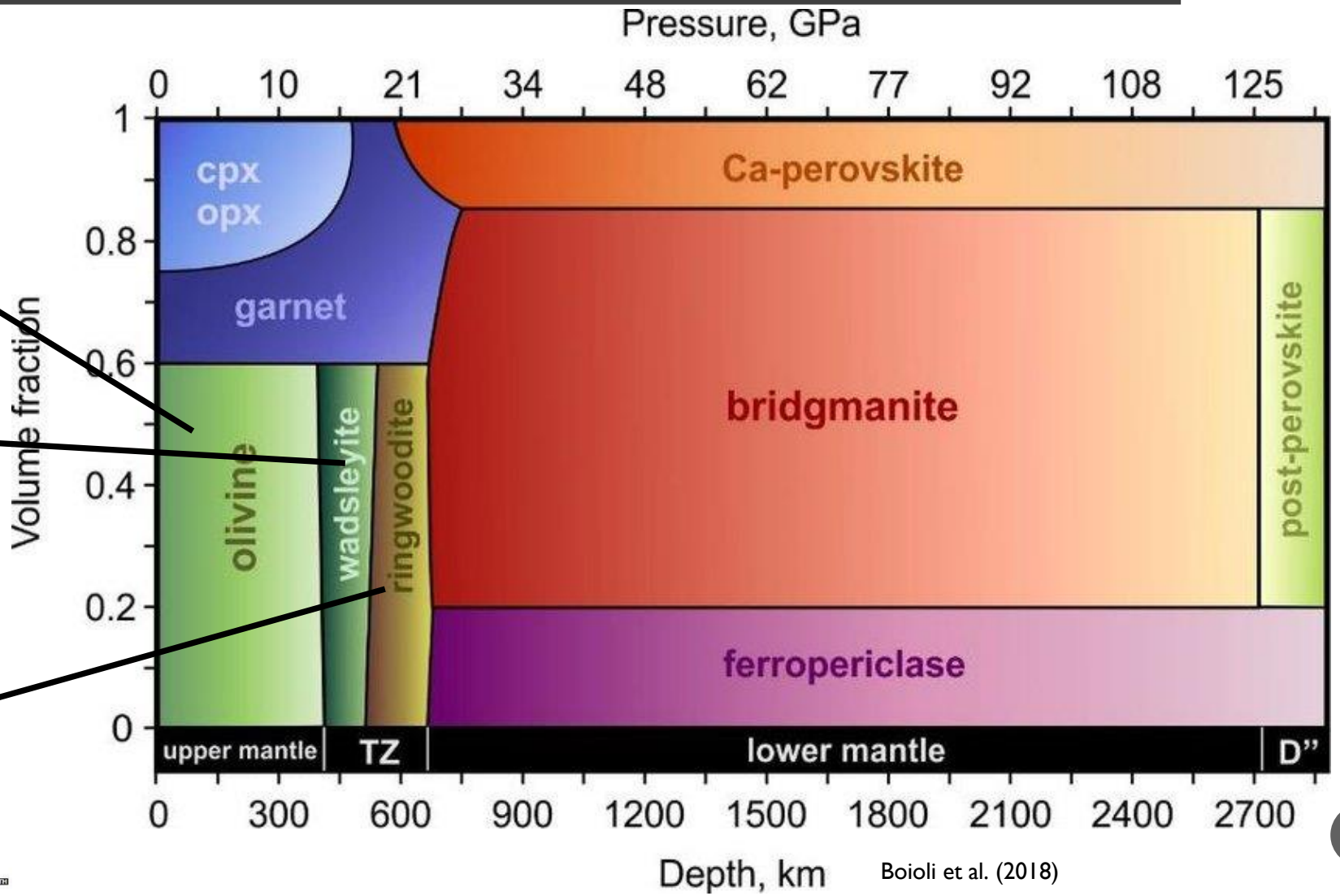




From Hoshino et al. (2016)

MINERAL DISTRIBUTION

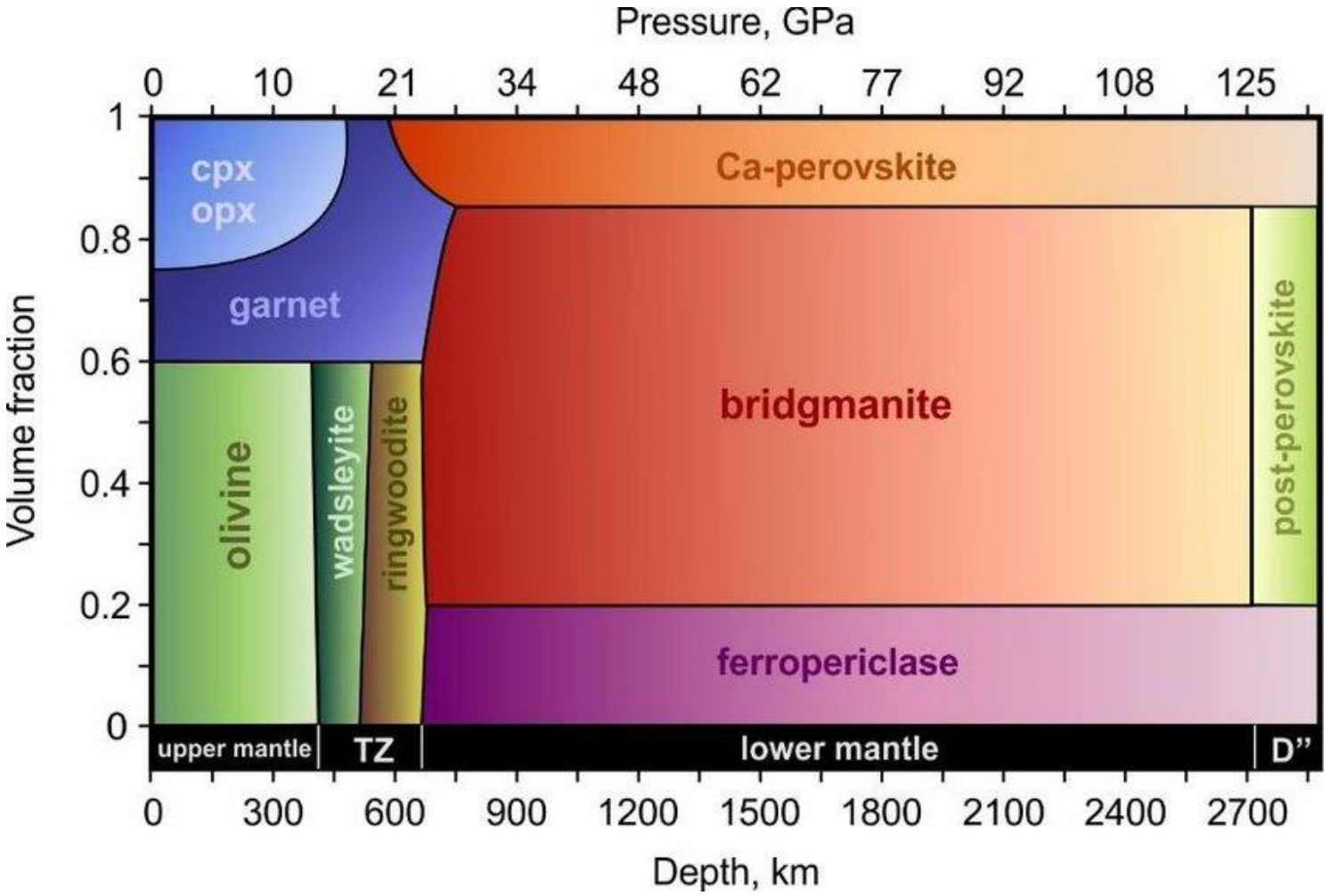




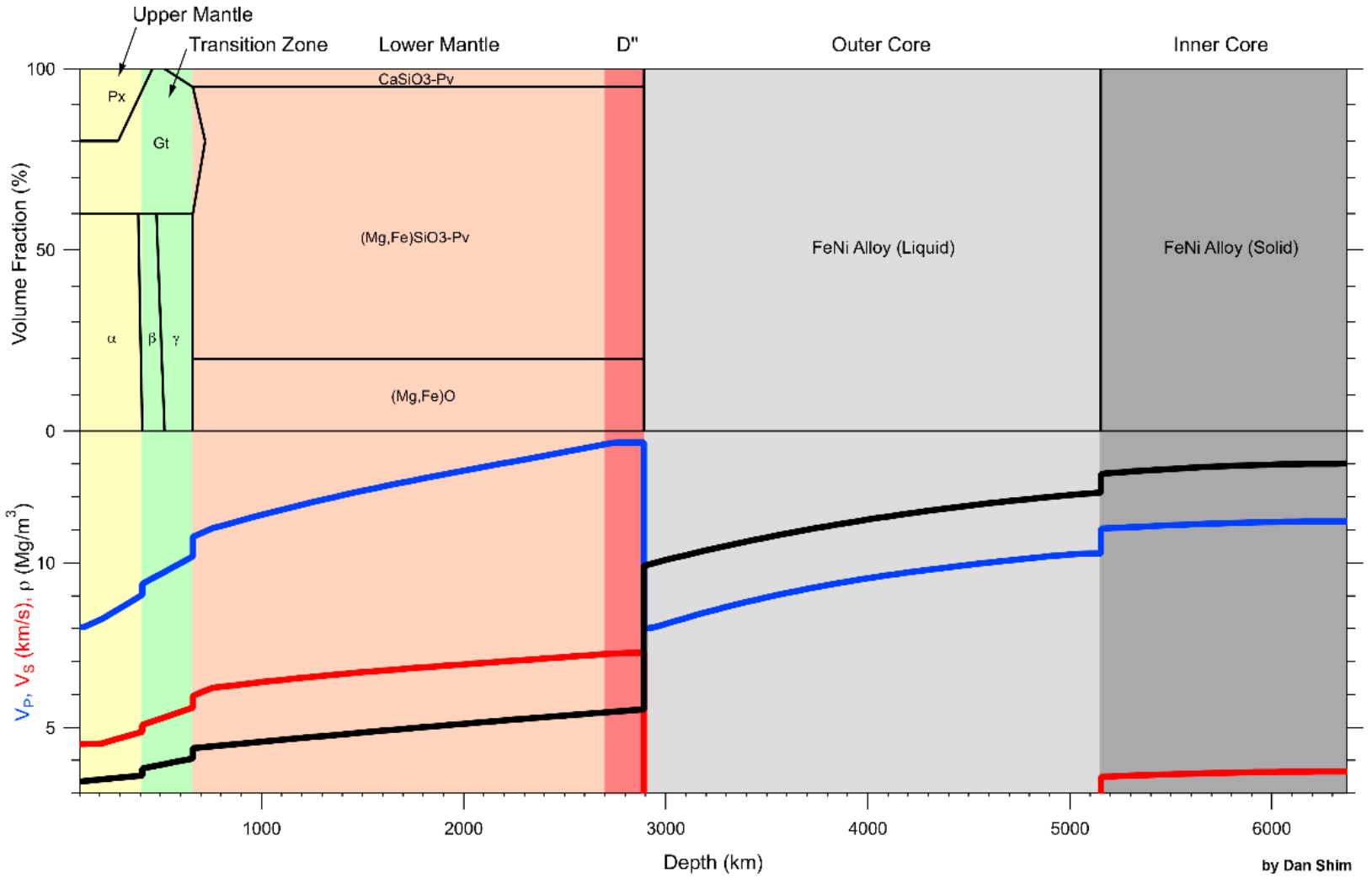
Boioli et al. (2018)

BRIDGEMANITE

- Most abundant mineral on Earth (93% of lower mantle)
- For along time unknown
- Discovered from the Tenham meteorite



MINERALS AND SEISMICS



SUMMARY

- Mineral is defined by a set parameters: naturally occuring, crystalline, inorganic solid substance and defined physical and chemical properties
- Mineralogy is the systematic study that deals with the characteristics of individual and group of minerals.
- A mineral is identified by several paramaters: optical mineralogy, cleavage, hardness, streak and color are the main physical properties you can identify.
- Analytical tools: SEM, PXRD, SXRD, EPMA, LA-ICP-MS
- Illoqite-(Ce)
- Mineral distribution of the earth