

Location of lead in the Earth's Mantle

Julien Dubrail^a, Laurent Gautron^a, and Steeve Gréaux^b

*^aUniversité Paris-Est, Laboratoire des Géomatériaux et Géologie de l'Ingénieur (G2I),
EA 4119,*

5, bd Descartes 77454 Marne-la-Vallée cedex 2, France. email: dubrail@univ-mlv.fr

^bGeodynamics Research Center, Matsuyama, Japan



General Overview

- Earth : a “living”, dynamic planet > Plate Tectonics, Earthquakes, Volcanism
 - This activity requires energy
 - U, Th actinides radioactive decays: major energy sources
 - Location of these heat sources ??
- =Key point to constrain the thermal and dynamic behaviour of the planet

General Overview

High Pressure Mineral Physics

- U, Th form separate phases ?

- incorporate main mantle mineral phases ?

- Lead Isotopes: Final stable decay products

$^{232}\text{Th} \rightarrow$
 ^{208}Pb with a half-life of $14.01 \cdot 10^9$ y

$^{235}\text{U} \rightarrow$ ^{207}Pb with a half-life of $0.738 \cdot 10^9$ y.
 $^{238}\text{U} \rightarrow$ ^{206}Pb with a half-life of $4.468 \cdot 10^9$ y.

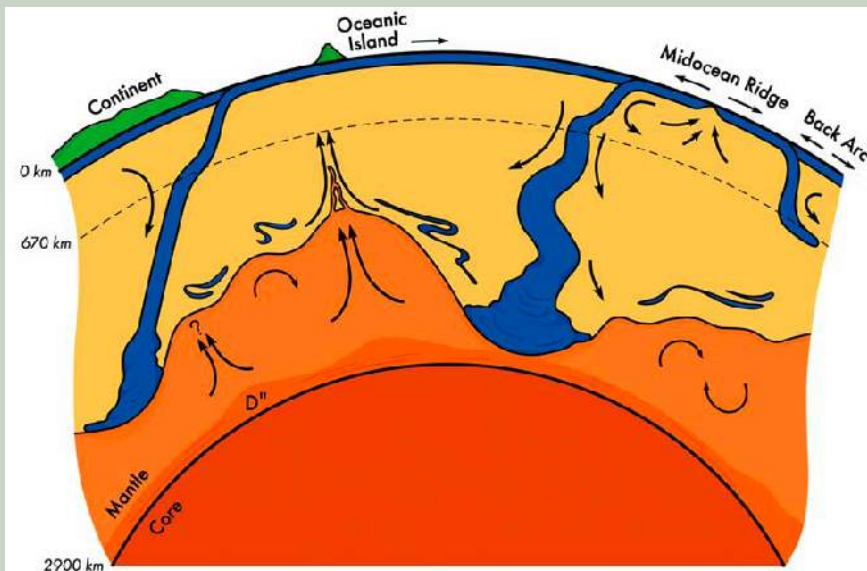
- Location ?

Study of Lead mineralogy

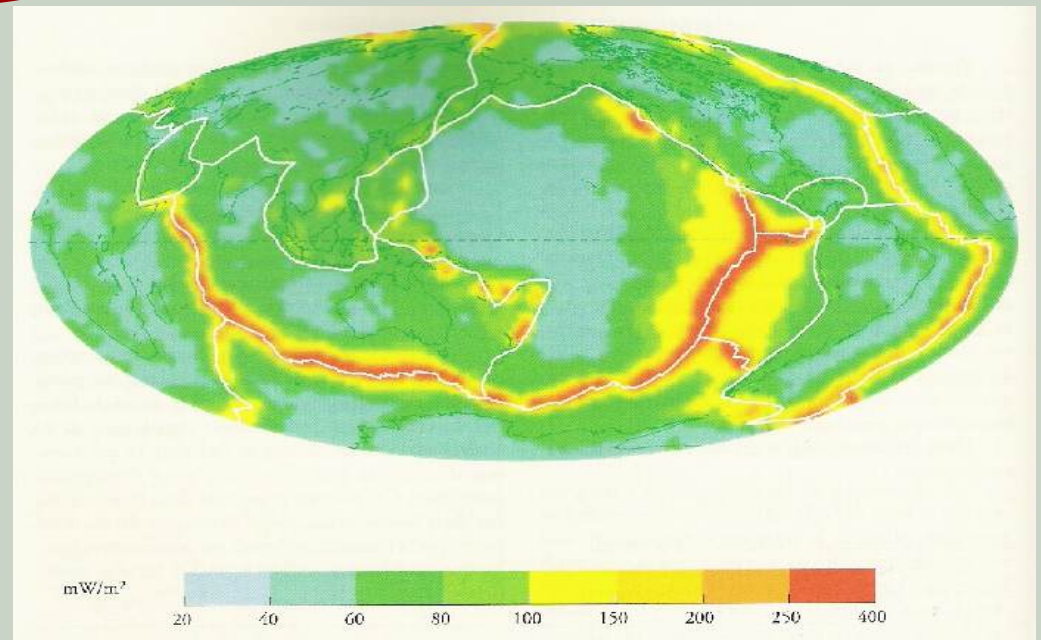
Part I. To keep track of the radioactive energy sources

Part II. Study magma genesis, related to some extent to the Pb paradoxes

Heat flux at the
Earth's surface:
44 TW




Convection in the Earth Mantle



Map of the Heat flux coming from inside the Earth (after Pollack, 1993)
 Mean value: 80 mW/m^2
 Maximum at Ocean Ridges

**Heat loss from the surface:
44 TW**

• **13 TW cooling of the Earth** 
• **31 TW radioactive decay of
U, Th and K**

Crust 6TW

Mantle 22 TW

upper mantle 9TW

lower Mantle 13 TW

Core 3 TW

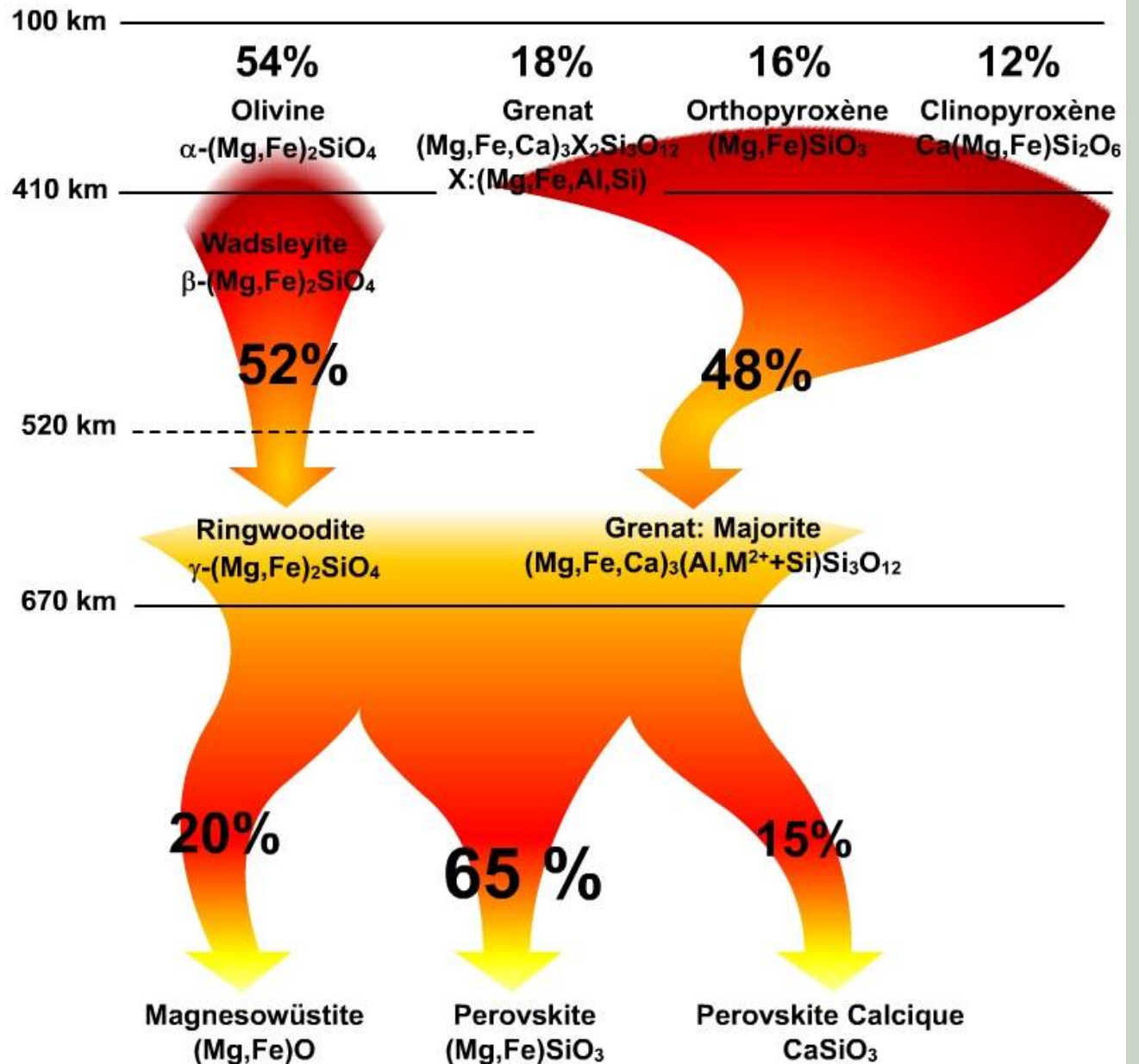
Isotope	Half-life 10 ⁹ years	Heat produced per gram (cal/y)	Composition (ppb)
U ²³⁸	4,50	0,74	20
U ²³⁵	0,71		
Th ²³²	13,90	0,20	80

Concentrations in the Earth Mantle

**Turcotte et al. (2001): U-Th
systematics**

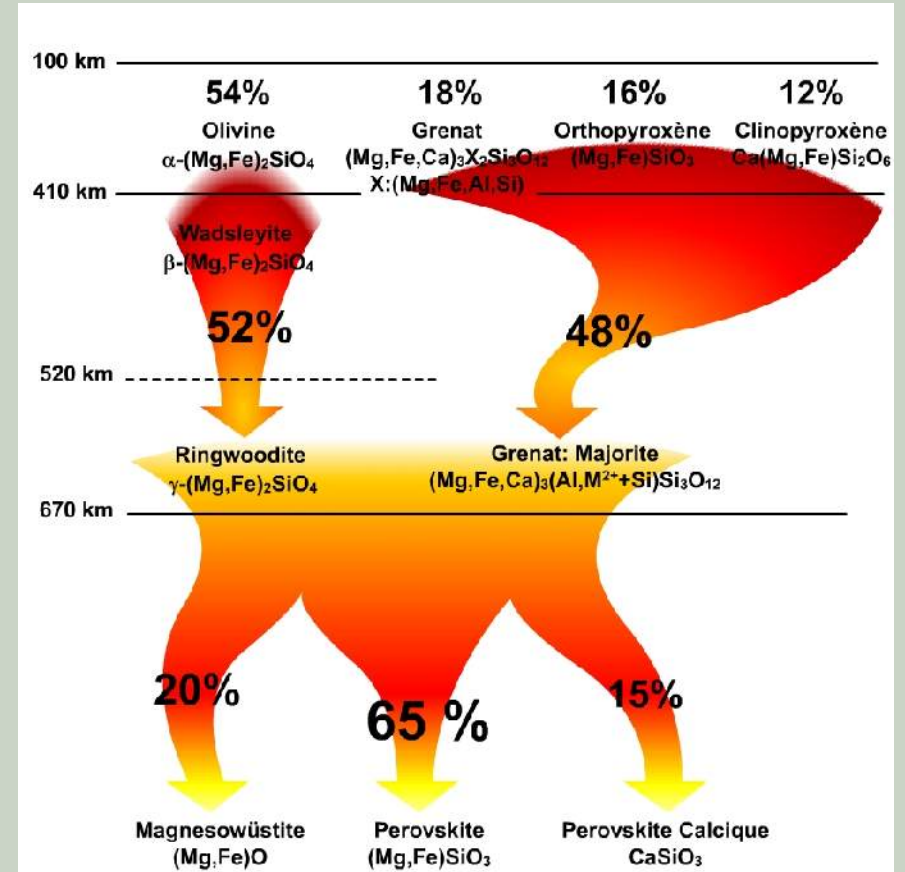
**~55 wt% of U and Th are stored in the
lower mantle**

**then up to 40,000 billions tons of U
and Th stored in the lower mantle**



- Ca good candidate for its substitution by Pb
- CaSiO_3 perovskite is the third most important phase of the lower mantle

Element	Charge	Coordination	Ionic Radius
Ca	2+	VIII	1.12 Å
		XII	1.34 Å
Pb	2+	VIII	1.29 Å
		XII	1.49 Å
	4+	VIII	0.94 Å

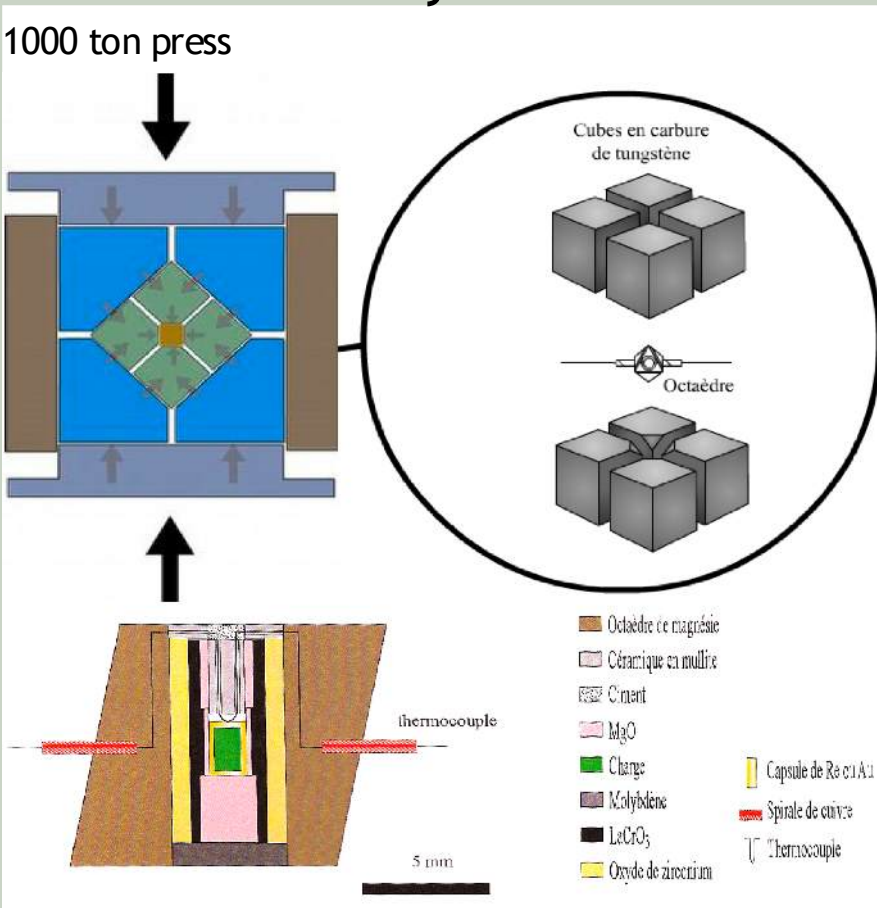


Method:

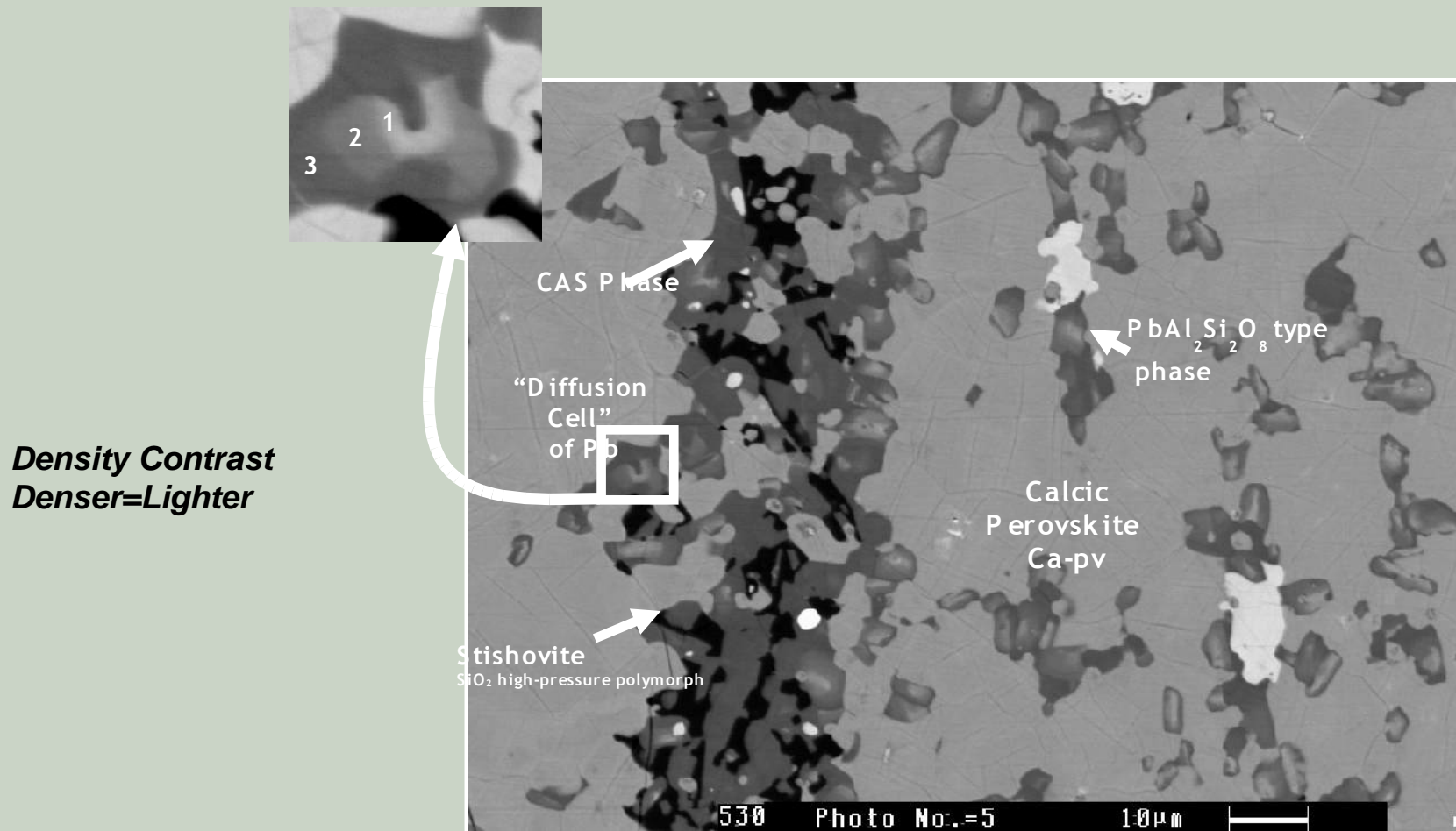
- Synthesis in Multi-anvil Press (*CNRS-INSU, National Instrument*)
- Chemical composition: analytical scanning electron microscopy SEM-EDX analysis
- Structure: X-Ray Micro-Diffraction (*Brucker, Delft, The Netherlands*)

Multi-Anvil:

- up to $P=25$ GPa, $T=2000$ K
 - duration: up to 12 hours
 - close to thermodynamic equilibrium
 - chemical reactions
- “Large volume” apparatus: sample size 1 mm^3

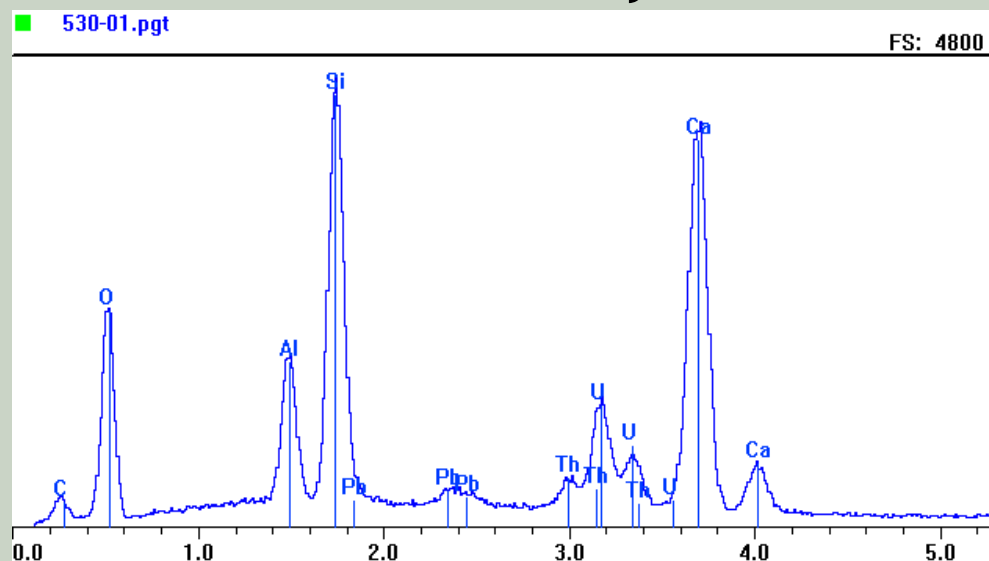


Sample starting composition: grossular $\text{CaAl}_2\text{Si}_2\text{O}_8$ (50% mol) + PbO_2 (25 mol%) + UO_2 (25 mol%)
 $P=18\text{-}17\text{GPa}$ and $T=1700^\circ\text{C}$



Backscattered electron image

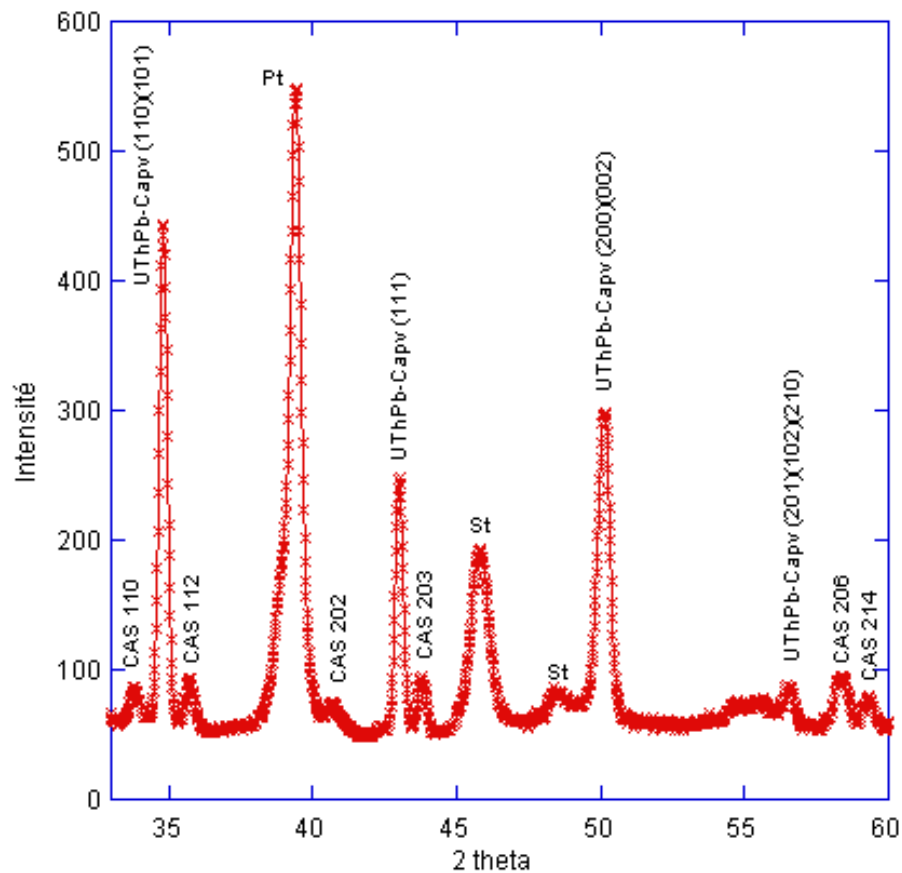
SEM-EDX Analysis



Element	Line	K Ratio	W t%	At%	Compound	Cmpd W t%
Ca	KA1	0.2275	24.77	17.32	CaO	34.66
U	MA1	0.1092	14.09	1.66	UO2	15.98
Th	MA1	0.0382	4.89	0.59	ThO2	5.56
Pb	MA1	0.0148	1.98	0.27	PbO	2.14
Si	KA1	0.1144	14.87	14.84	SiO2	31.82
Al	KA1	0.0352	5.21	5.41	Al2O3	9.85
O	KA1	0.2736	34.19	59.90		
Total			100.00		Total	100.00

X-ray MicroDiffraction (100 μm square region)

Microdiffraction des rayons X sur échantillon #530



(U,Th,Pb)- CaSiO_3 pv
 Tetragonal structure
 $P4/mmm$
 $a = 3,63 \text{ \AA}$ $c = 3,66 \text{ \AA}$

" CaSiO_3 perovskite incorporates important quantities of U, Th and Pb

"Microdiffraction results show that the U-Pb rich CaSiO_3 keeps a tetragonal perovskite structure with a $P4/mmm$ space group.

Fluids at HP-HT : Origin of mantle derived volcanic rocks

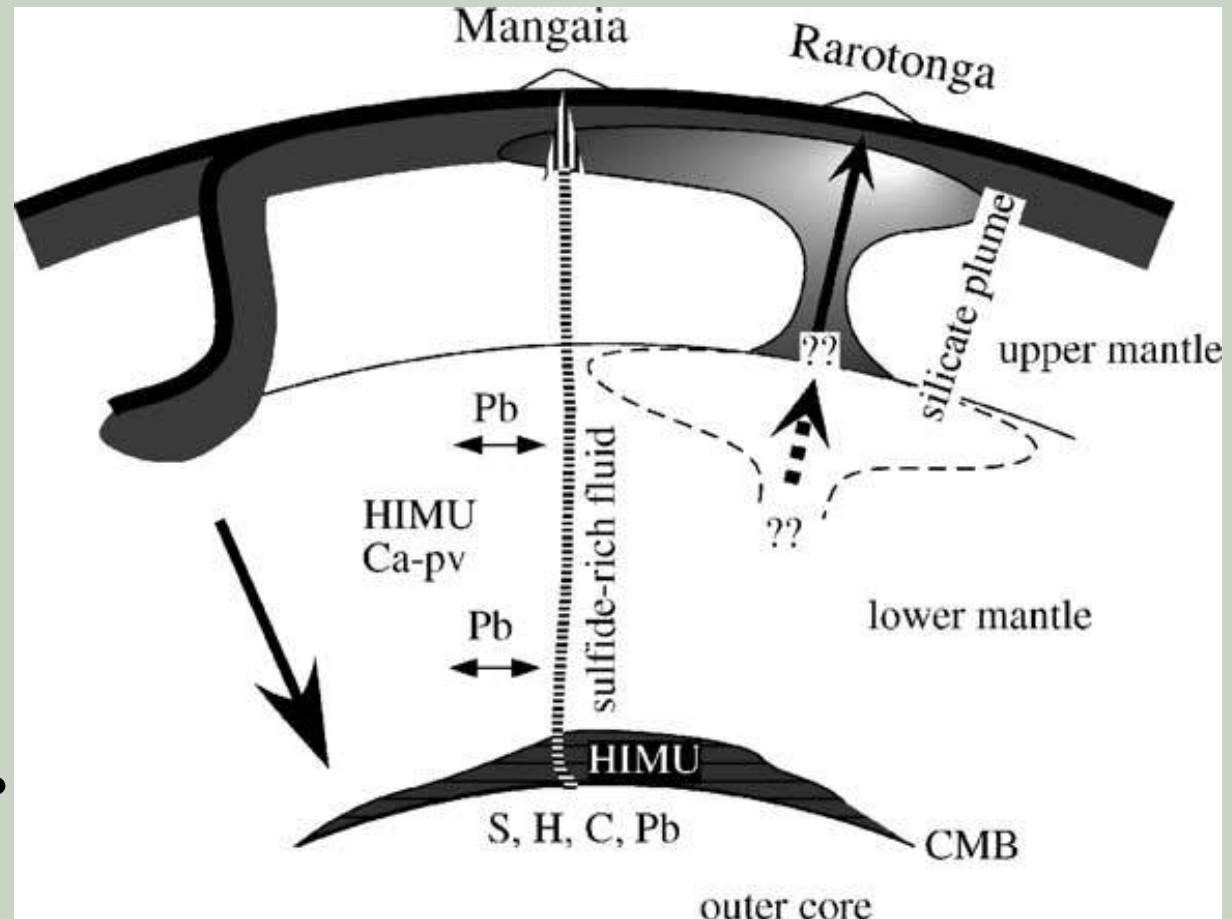
- Mg-Perovskite and Ca-perovskite coexist with magma at the pressures of the lower mantle
- partitioning between minerals and melts is essential in the study of magma generation in the Earth's Interiors
- Ca-perovskite is a candidate source material for the generation of high component of ocean island basalts
- HIMU: for high $\mu = {}^{238}\text{U} / {}^{204}\text{Pb}$ ratio



Magmas are an important source of informations about conditions of the Earth's interior

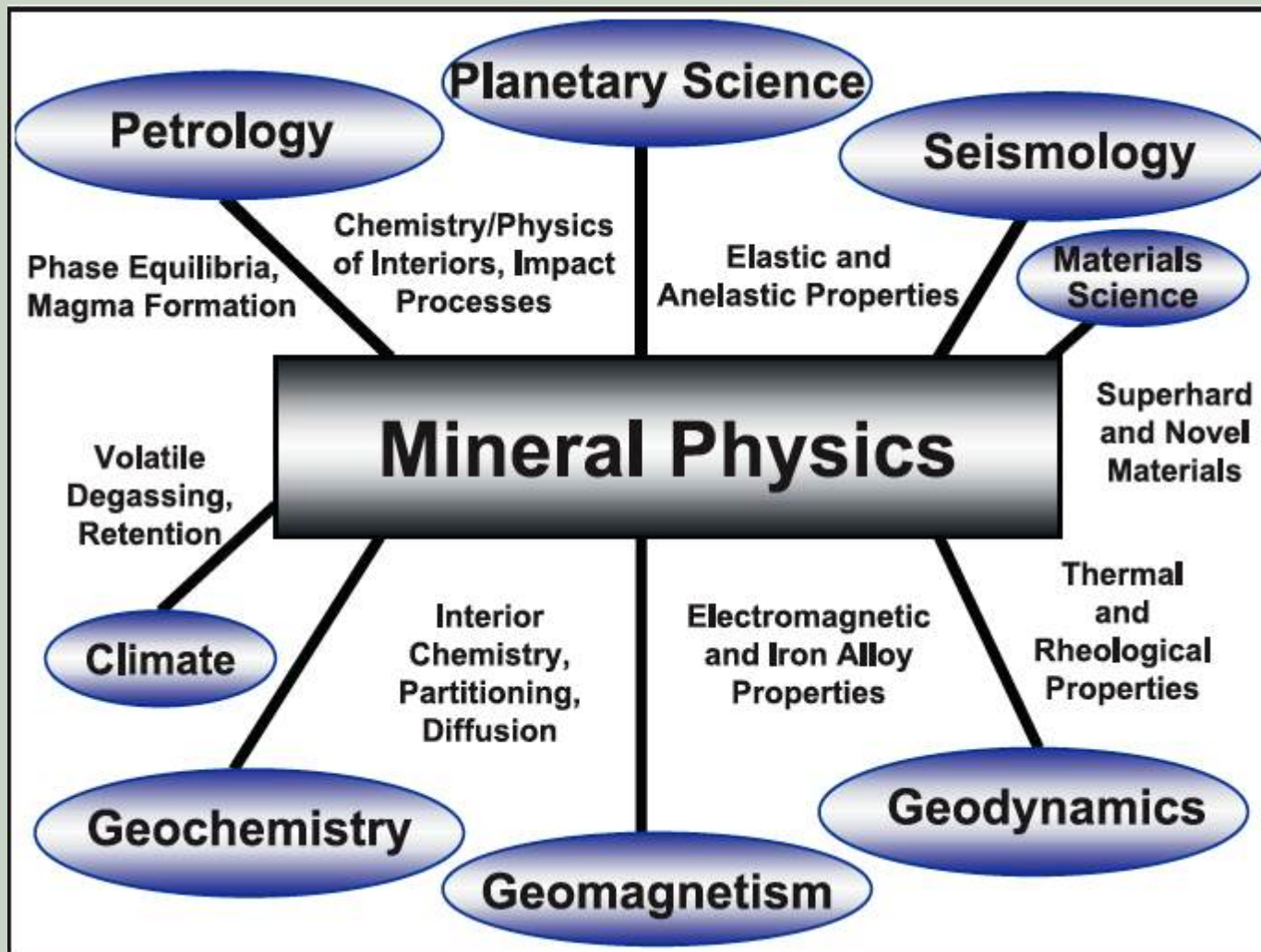
Origin of HIMU component

- Keypoint to reveal the origin of HIMU lavas is to understand how they have obtained radiogenic Pb isotope characteristics in the mantle
- Pb a chalcophilic element: highly associated with sulfides
- Partition coefficient between Ca-perovskite and sulfide melts at HP-HT: solid-liquid experiments in MAP with MgO monocrystalline capsule**

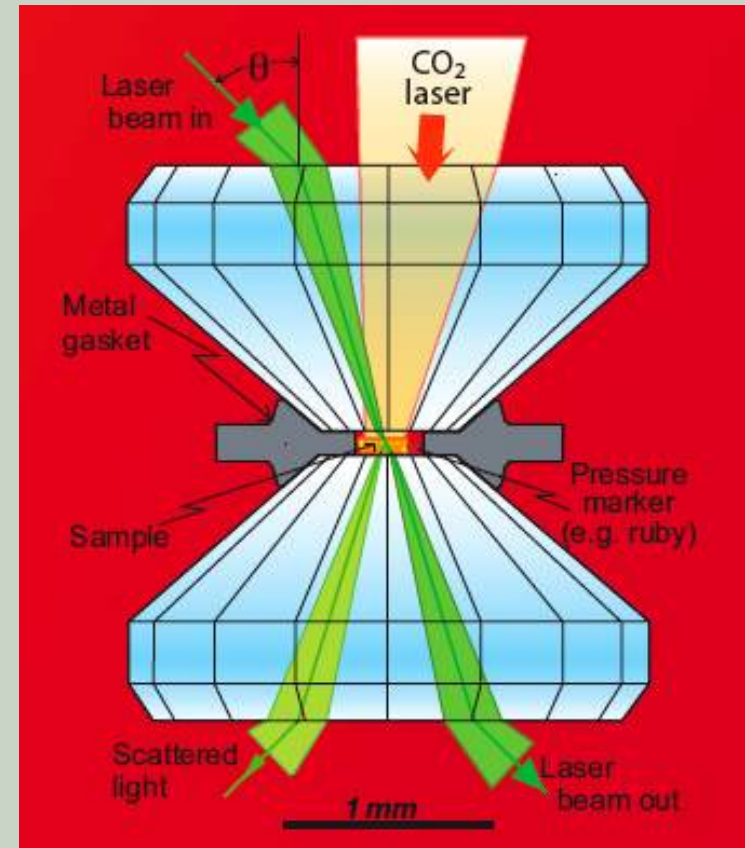


Origin of the HIMU component, After Yurimoto et al., 2004

Obrigado !



- Lower mantle and Core P,T conditions
- Diamond transparency: structural characterisation



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