The mantle metasomatism: diversity and impact
What the mantle xenoliths tell us?

Mantle metasomatism

Physical and chemical processes that are implemented during the flow of magmas and / or fluids within the upper mantle.

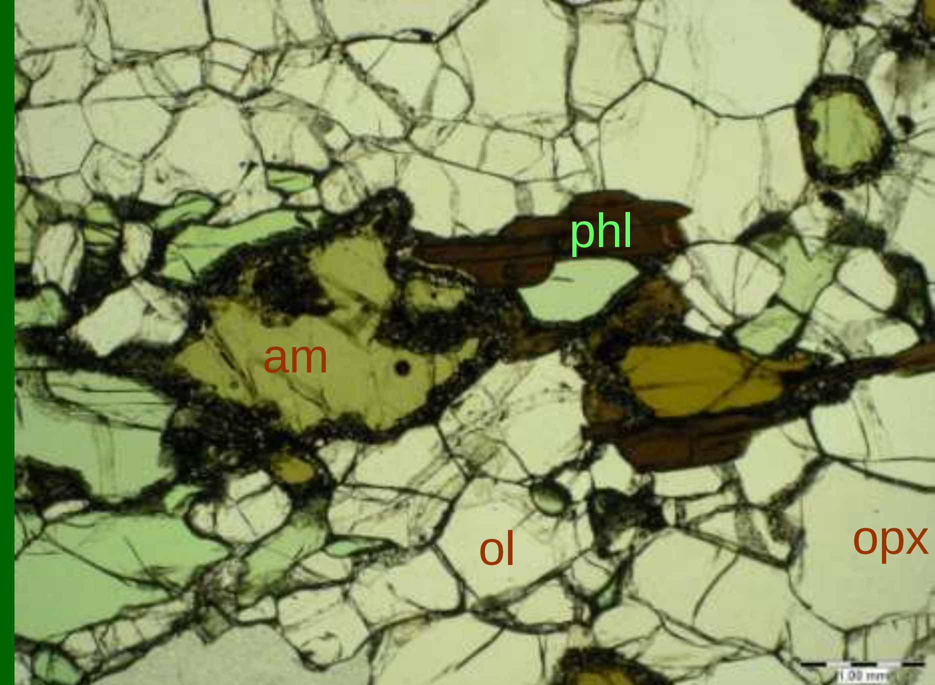
The main changes affecting the mantle wall rocks (peridotites: lherzolites, harzburgites and dunites):
changes in texture, recrystallization, formations of new minerals and chemical exchanges leading to the enrichment (rarely depletion) of mantle peridotites in incompatible trace elements (REE, HFSE and LILE: large-ion lithophile element).

Flow: general meaning (both pervasive at grain boundaries and focused in dykes or veins)

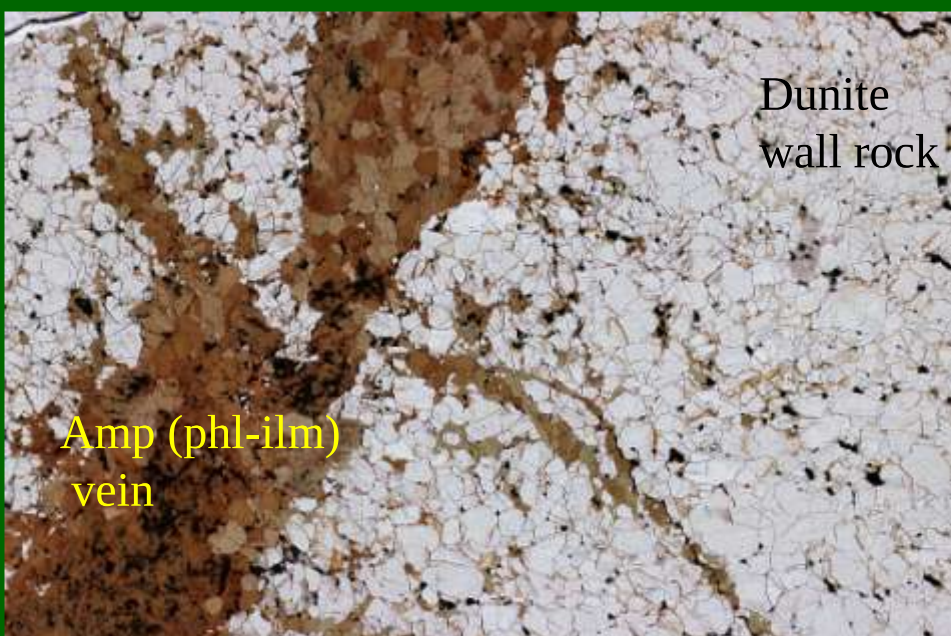
METASOMATISM OF THE PHANEROZOIC MANTLE

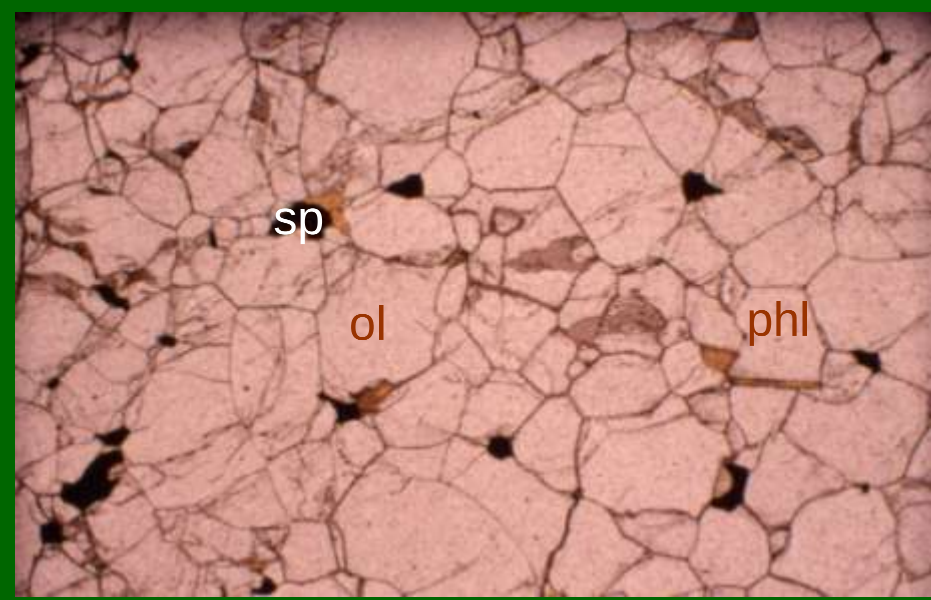
MOSTLY
SPINEL
PERIDOTITES:
Ol-Opx-Cpx-Sp

Metasomatism of the upper mantle in asthenospheric upwelling zones (Plumes, rifting zones, Asthenospheric windows…)



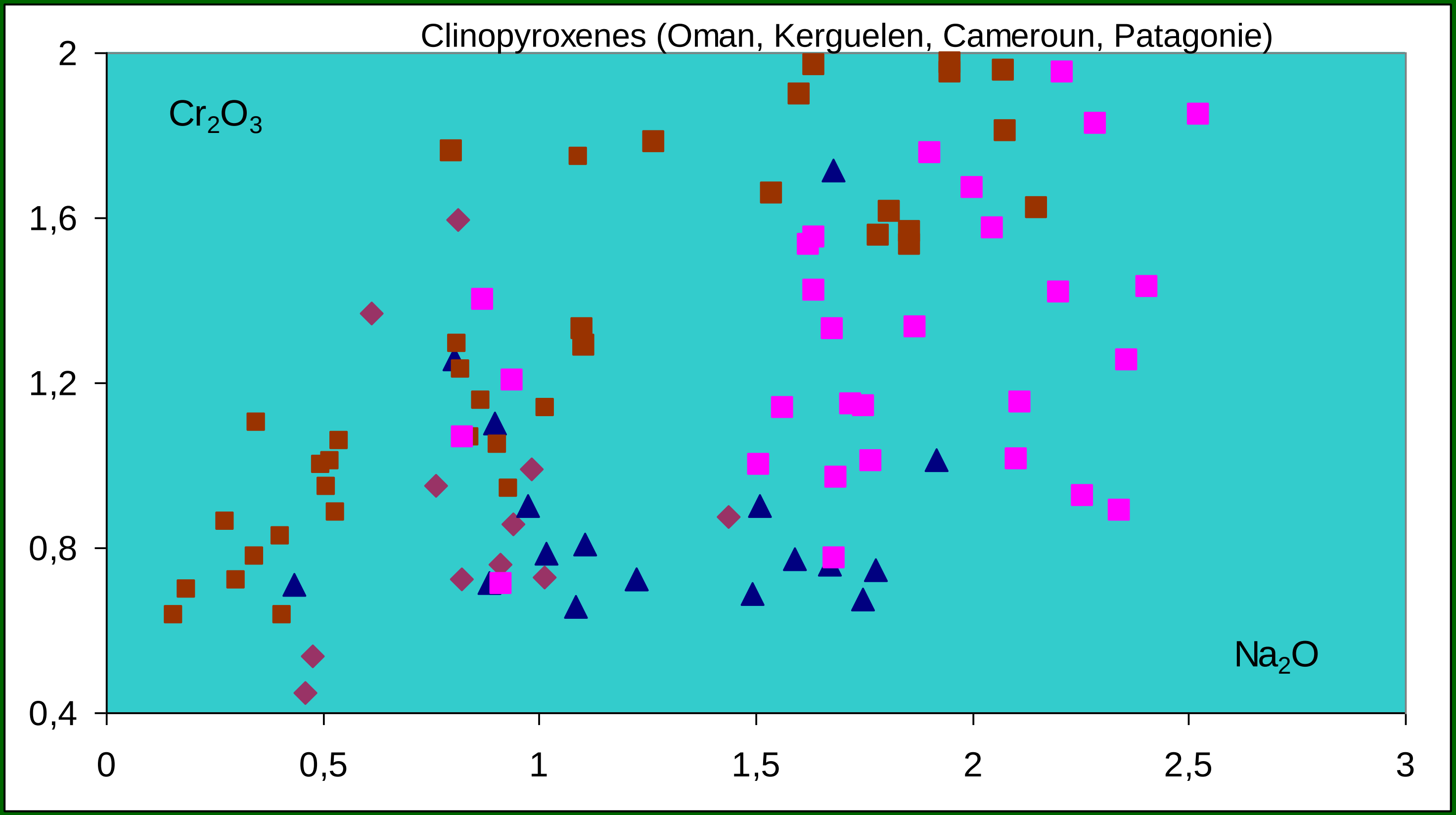
Mineralogical changes





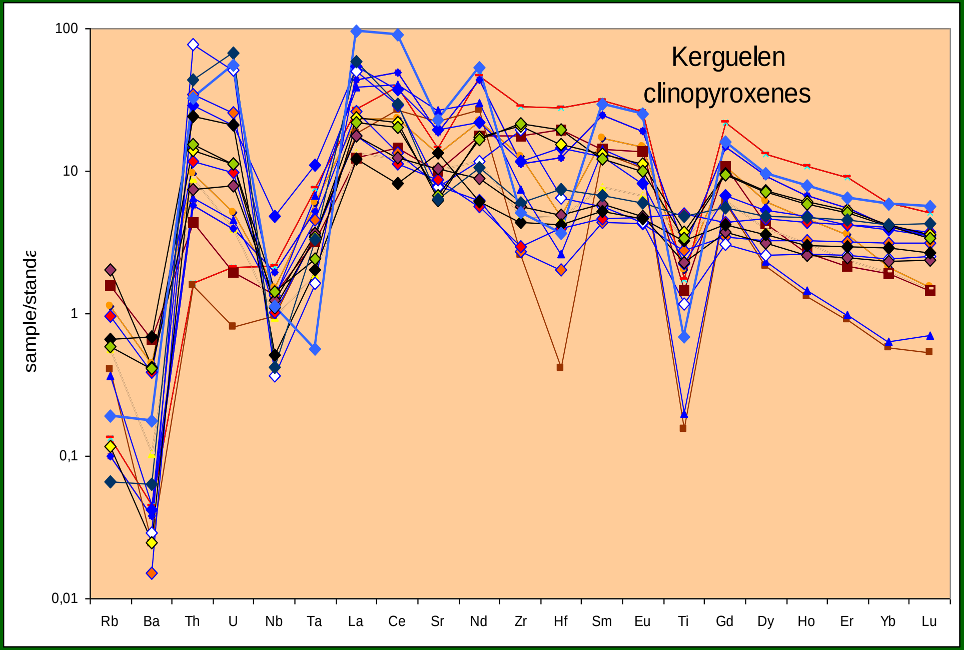
Spinel peridotites

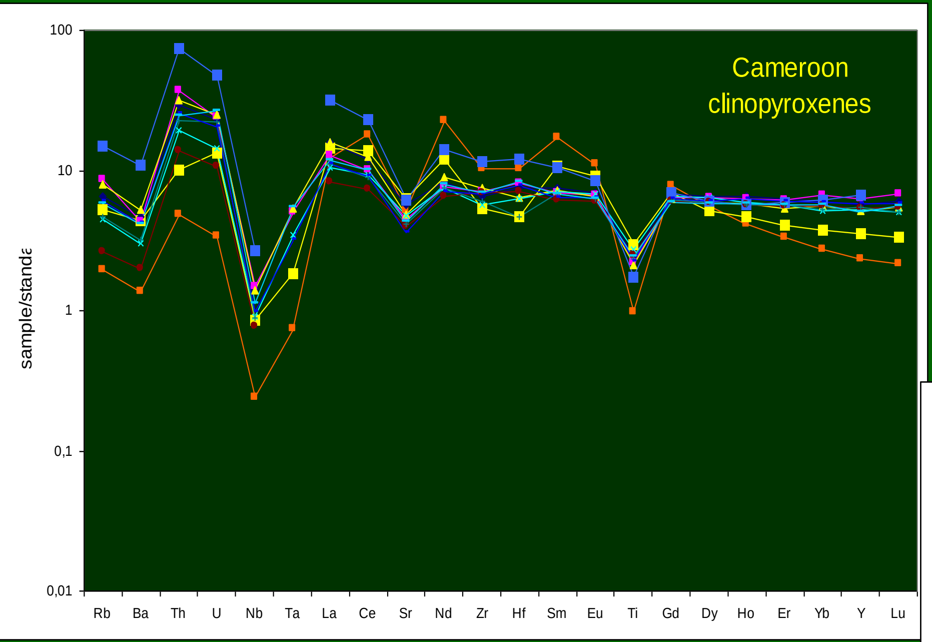
Cpx: asthenospheric upwelling contexts

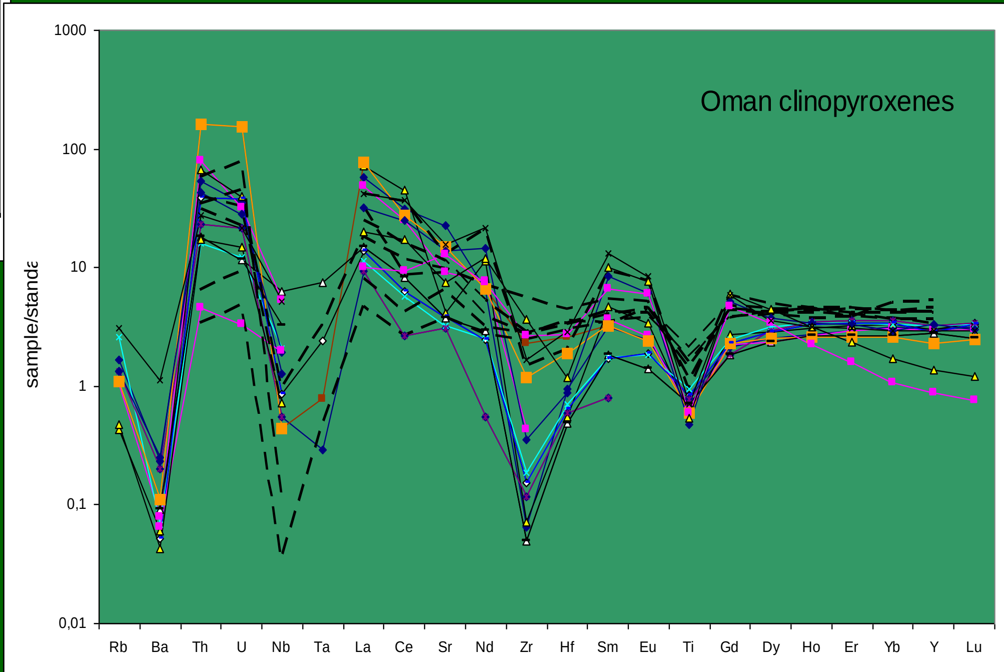


Chemical changes

Cpx: asthenospheric upwelling contexts



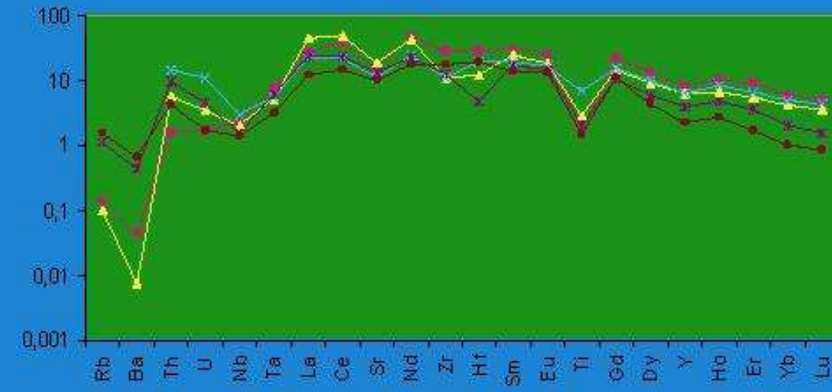




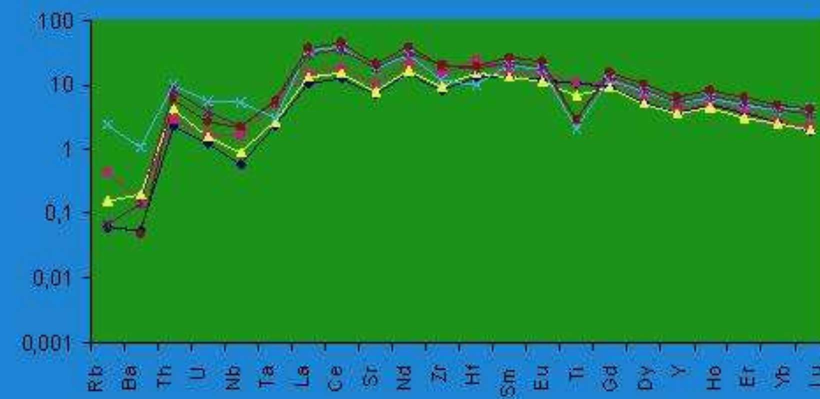
Chemical changes

Clinopyroxenes
Poikilic harzburgites vs Kerguelen alkaline magmas

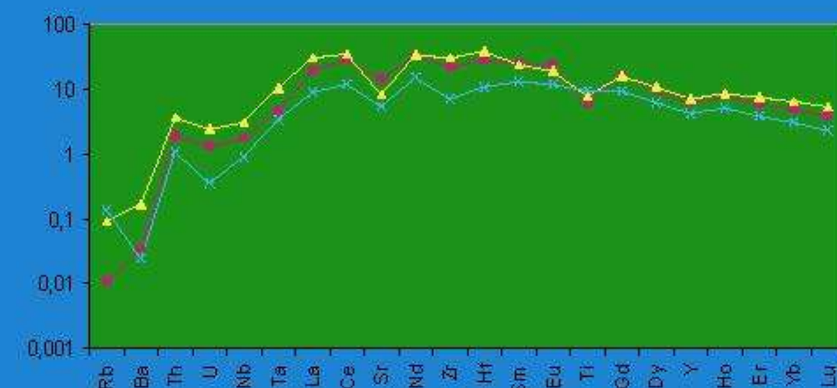
Poikilitic harzburgites



Pyroxenites:
Alkaline mantle cumulates



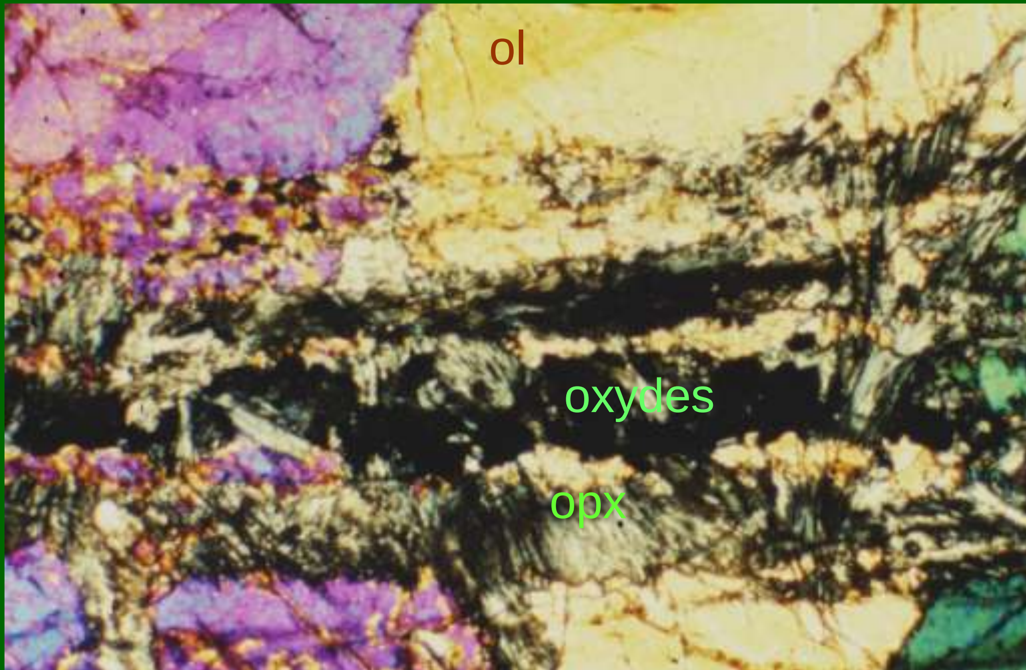
Megacrysts in
Alkaline lavas

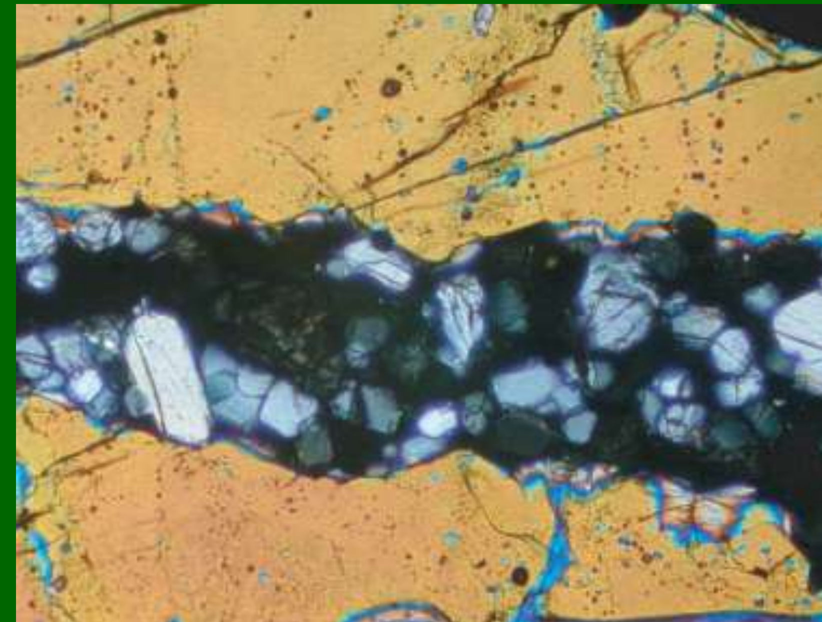


- Metasomatism in zones of plate convergence

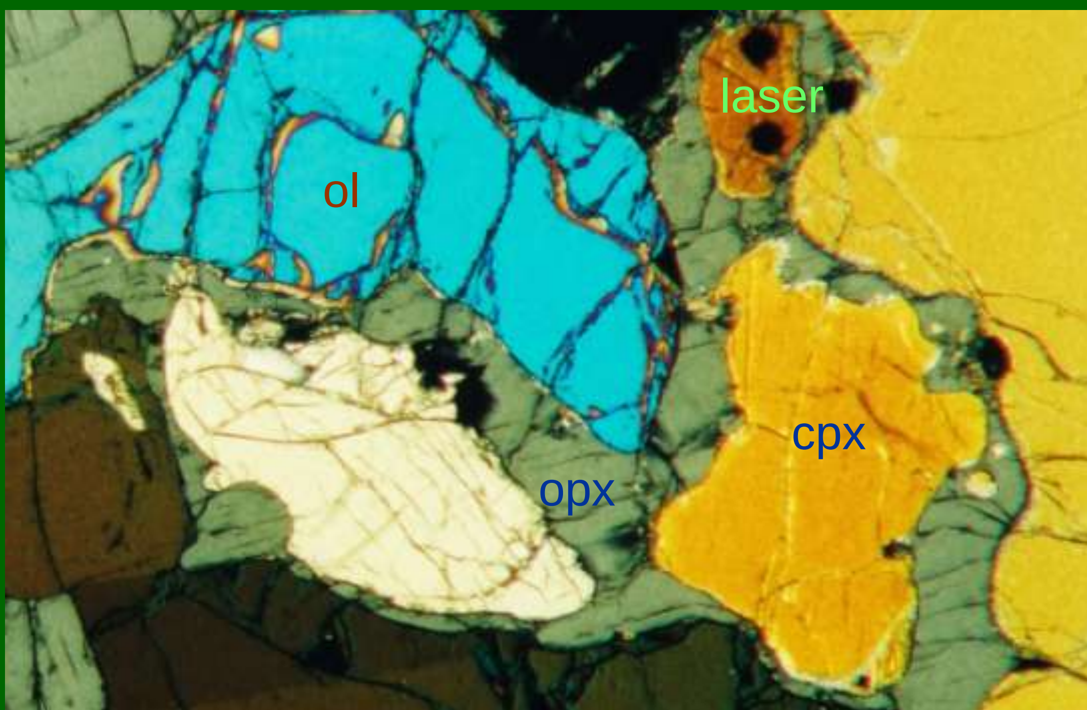
(dehydration and sometimes melting of slabs:

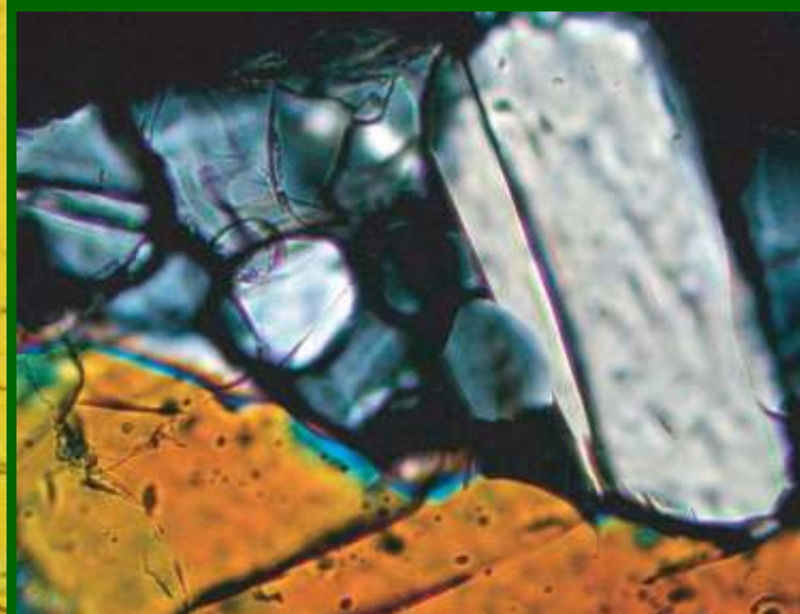
effects on the mantle wedge)



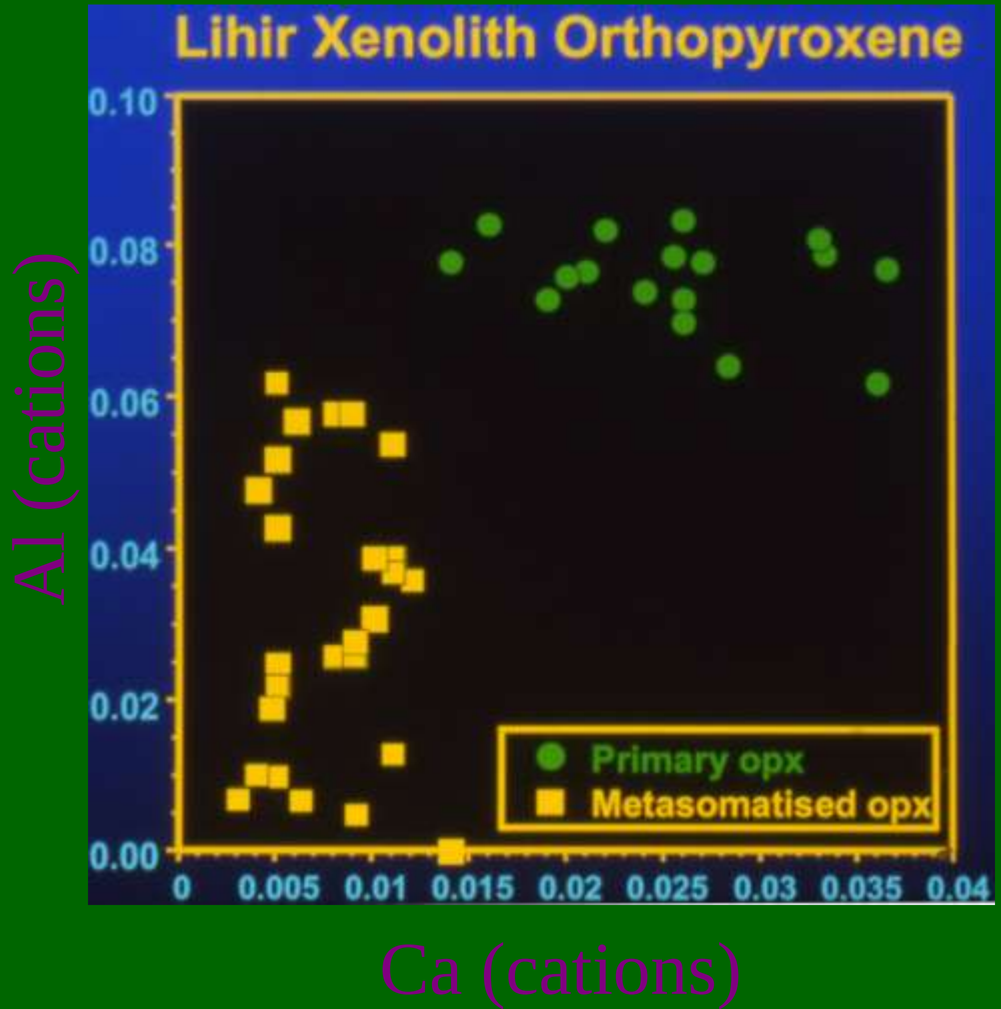


Mineralogical changes





Lihir : Mantle wedge

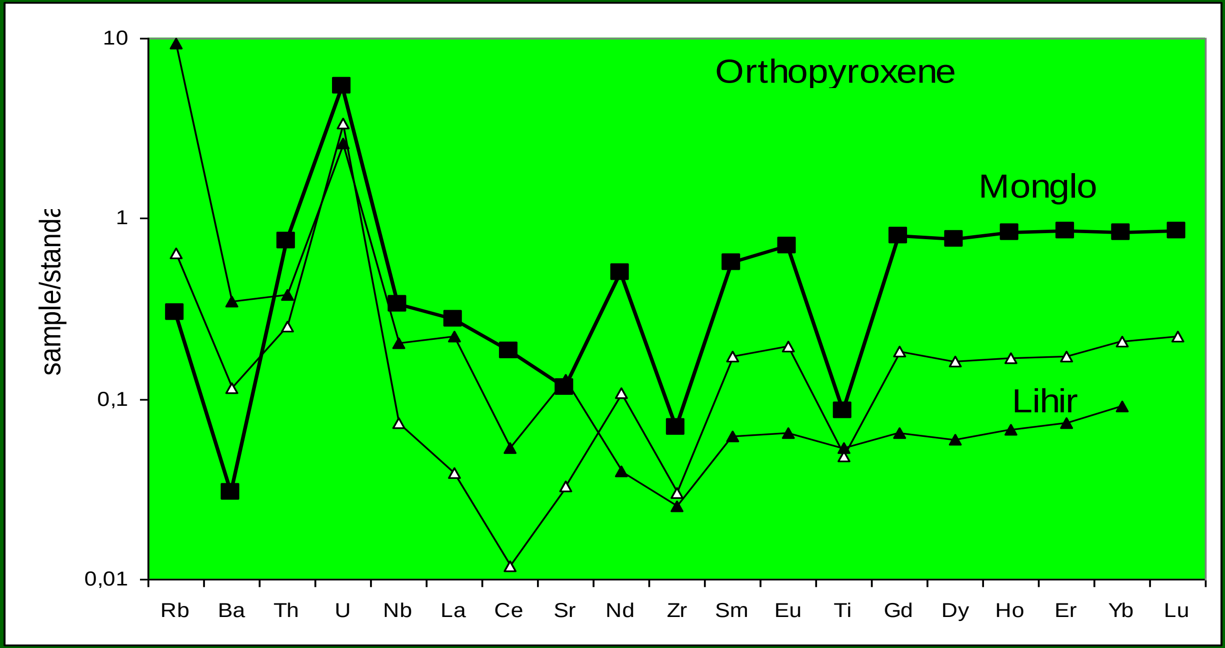


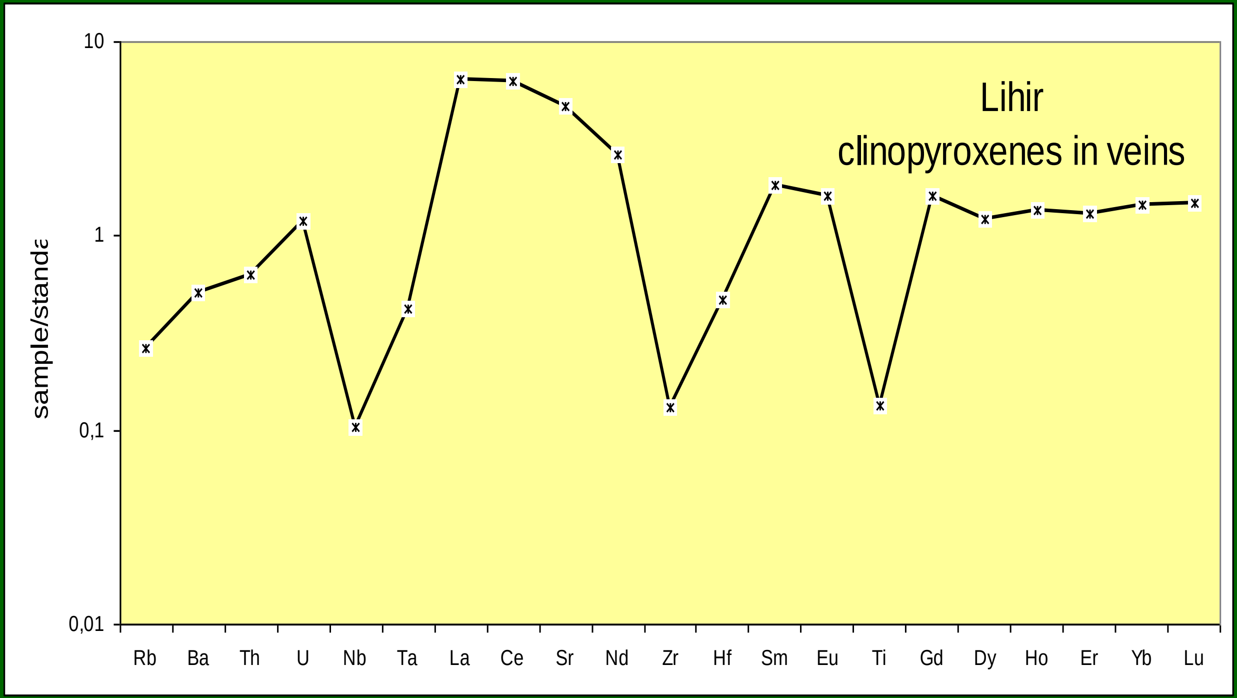
Chemical changes

Pyroxenes from veins:

Lihir : Mantle wedge

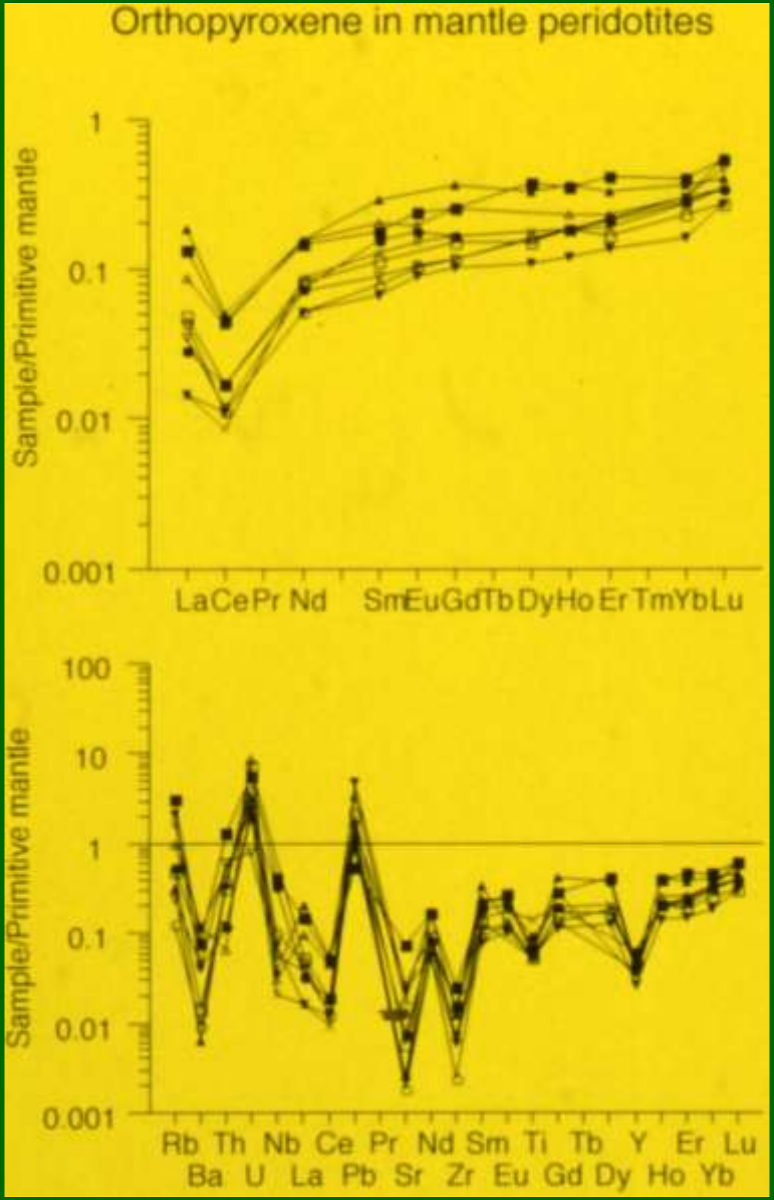
Chemical changes





Chemical changes

Lihir : Mantle wedge



Pyroxenes from peridotitic wall rocks

Main metasomatic agents

- Context of asthenospheric uplift: mostly intraplaque settings

Mafic alkaline and high alkaline silicated melts (more or less rich in CO_2 - carbonatitic, Fe-Ti basaltic, tholeiitic, ultramafic melts…)

- Context of subduction:

Hydrated Liquids (fluids) commonly SiO_2 –rich

Related to the deshydratation process of the slab

(adakites, basalts…)

MANTLE WEDGE ZONES

Mineralogy :
Opx-Am-Cpx-Ol-Phl-Sp-Su-Mt

Geochemistry :
Majors
Opx2 and cpx2 poorer in Al
than cpx1 et opx1
Phlogopite low in Ti
Amphibole mostly less sodic
at a fixed mg#

Traces
U/Th high
Amphibole and phlogopite
Low in Nb and Ta

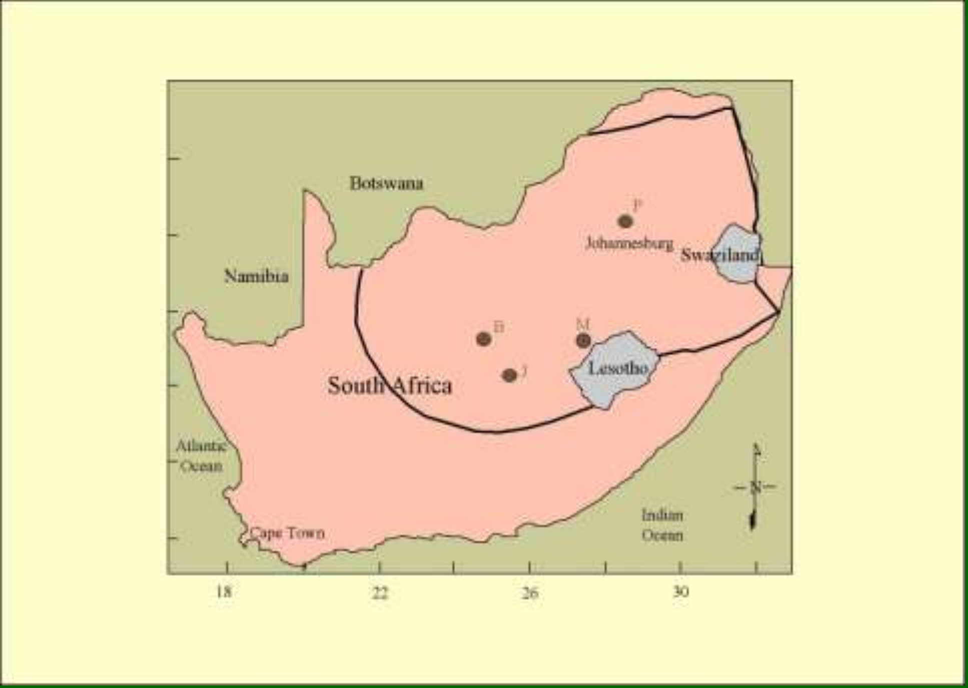
ASTHENOSPHERIC UPWELLING ZONES

Mineralogy :
Cpx-Phl-Am
KNaFs-Pl-Ol-Sp-Ru-Ap-Ilm-Arm
Cb-Gl-Su

Geochemistry :
Majors
Cpx: Commonly enrichment in Cr and Na,
sometimes only Na or Na and Ti

Traces
U/Th variable (commonly U/Th<1)
Amphibole and phlogopite
are Nb and Ta-rich

Precambrian mantle with a focus on the Archean mantle from South Africa

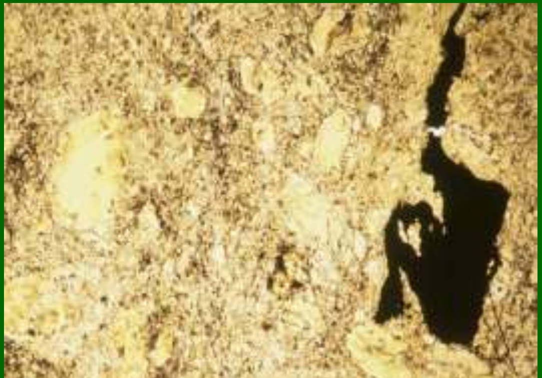


Mostly garnet peridotites in kimberlites

Coarse grained

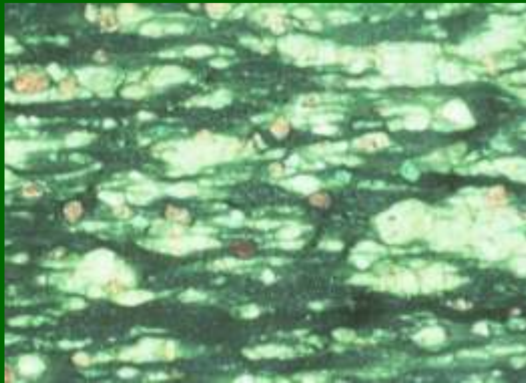
MARID

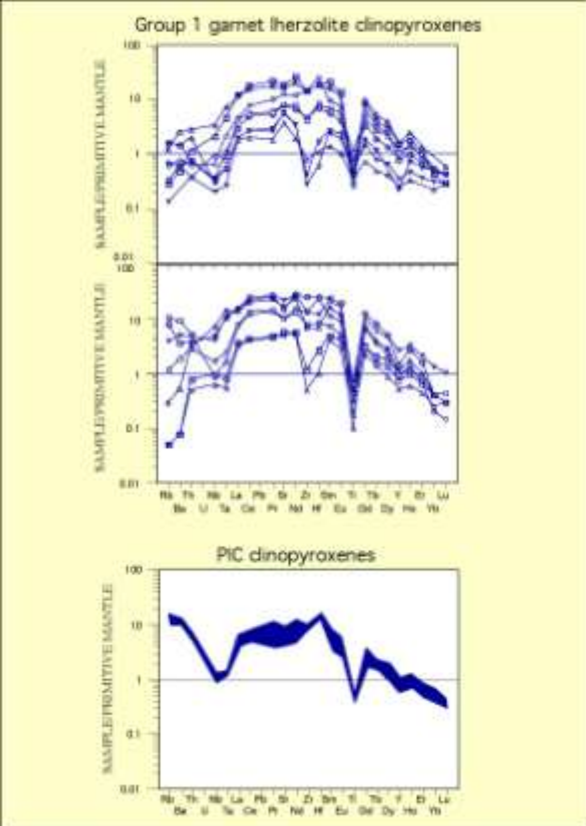
Garnet lherzolites



PIC

High-T Sheared (near the LAB)

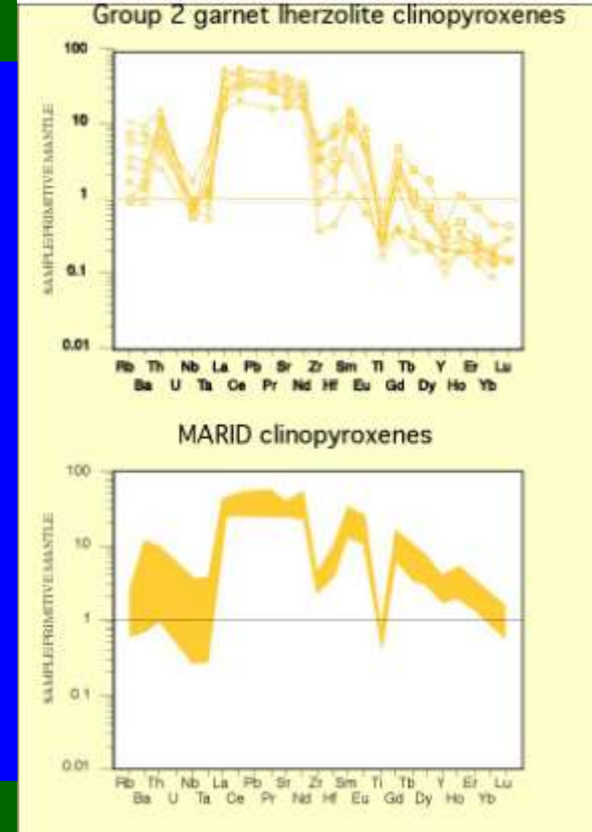




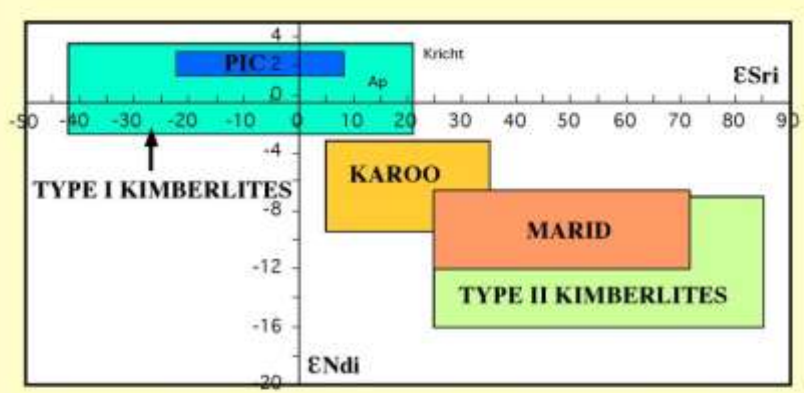
The melts responsible for the modal metasomatism of the group 1 and group 2 garnet lherzolites have similarities with the melts responsible for the formation of the PIC and MARID rocks, respectively.

These melts are high alkaline mafic silicate melts.

A genetic link between PIC rocks and Group I kimberlites and between MARID rocks and Group II kimberlites. Genetic relationships between the two mantle metasomatic agents affecting garnet lherzolites from the Kaapvaal Craton and the two groups of kimberlite magmas.



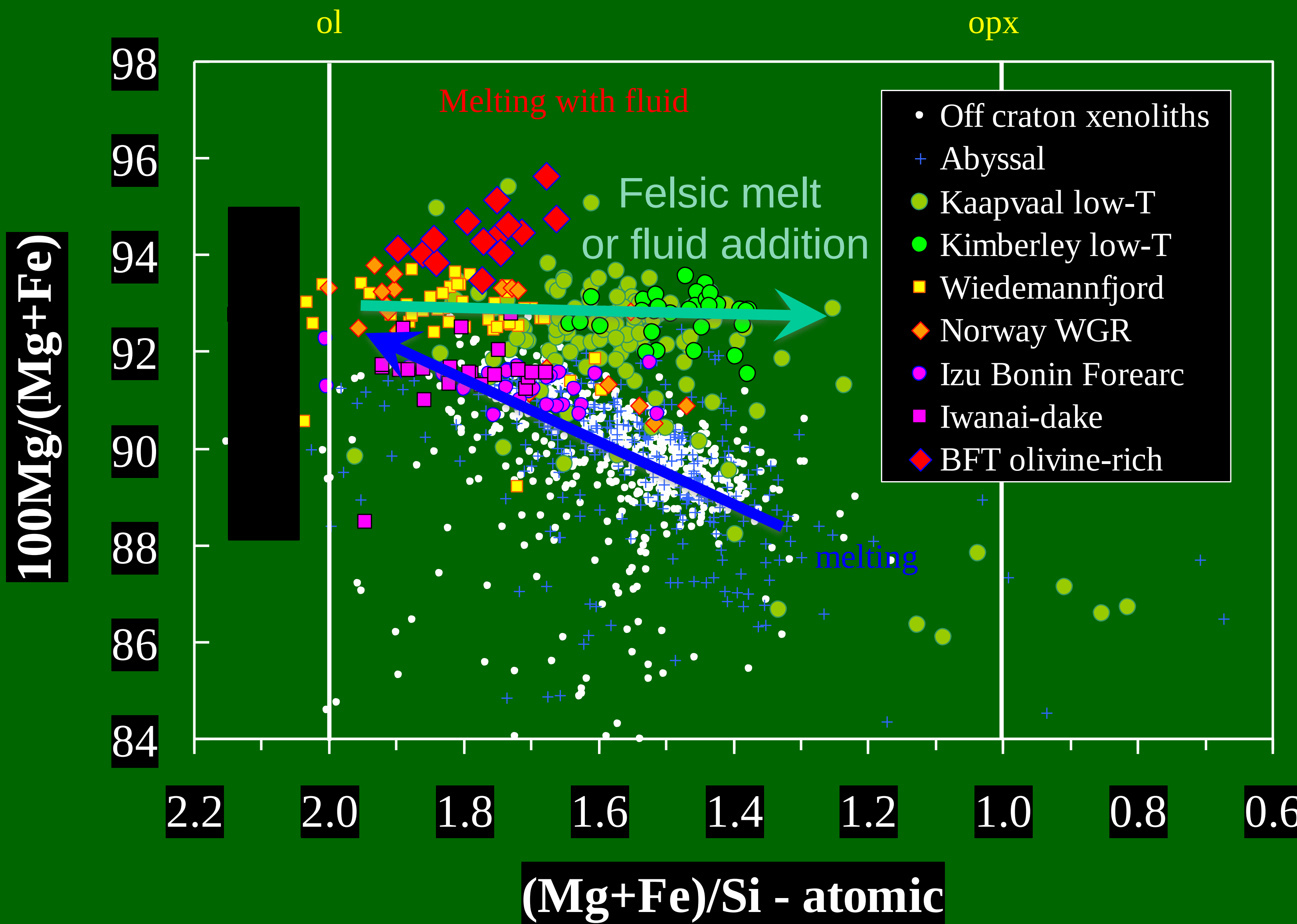
Two types of garnet lherzolites have been distinguished

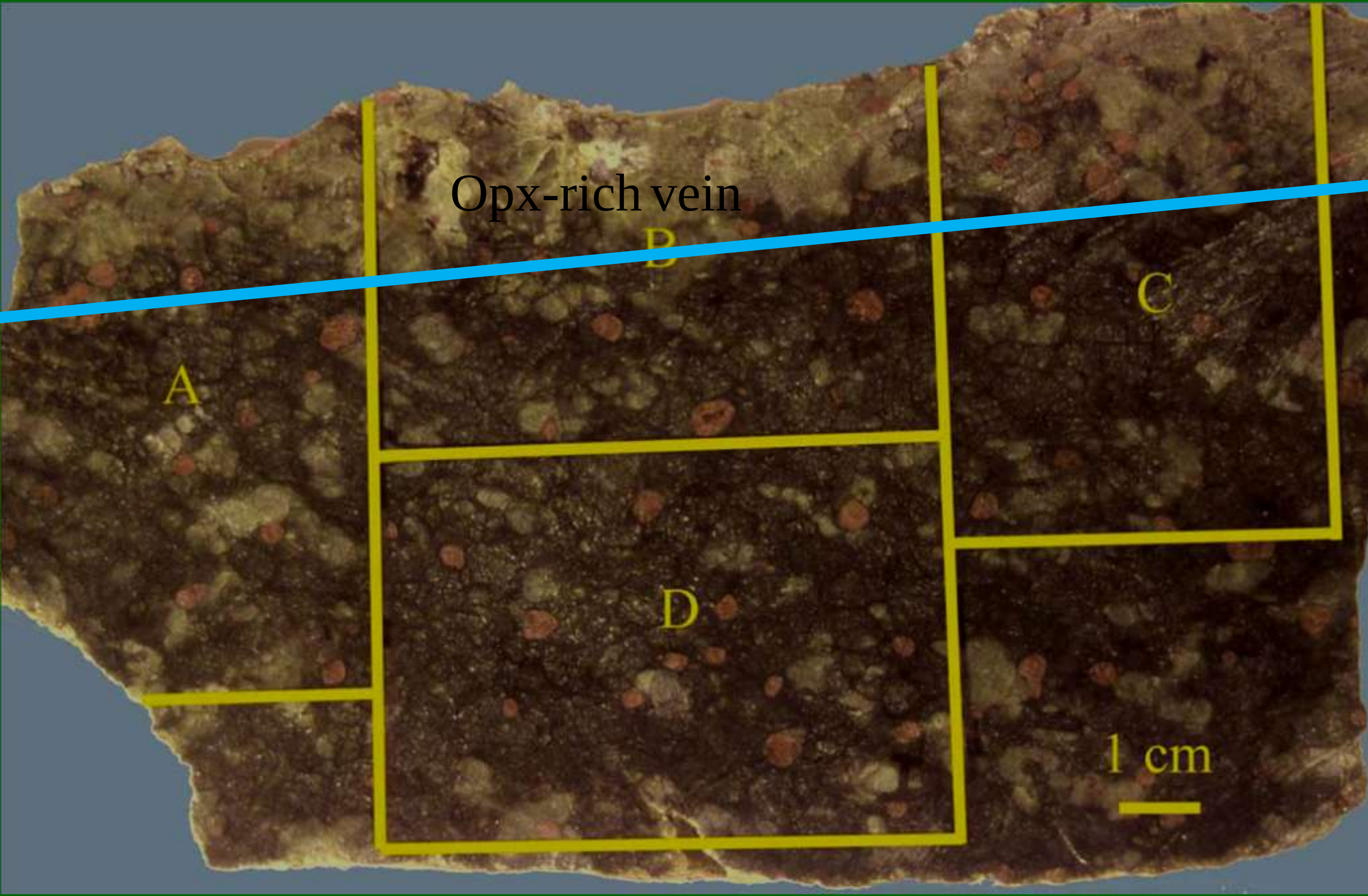


Important modifications of the cratonic upper mantle related to the circulation of kimberlitic melts

Coarse grained (relatively shallow) and high T-Sheared (deep, LAB) garnet lherzolites: same metasomatic history

Kaapvaal Craton: ancient metasomatism




Opx-rich vein
A
B
C
D
1 cm

To summarize in the archean mantle beneath South Africa there is also two main types of metasomatic agents:

- high alkaline melts (kimberlites, orangeites and associated fluids (CO_2, H_2O) and differentiates) mostly linked to asthenospheric upwellings

- Intermediate to Si-rich silicate melts and associated fluids and differentiates probably mostly linked to suprasubduction zones

Conclusions from mantle xenoliths studies:

Even if there is a lot of different kind of chemical and mineral changes associated to mantle metasomatism we may propose two main large types of mantle metasomatism both for old (Archean) and young mantle:

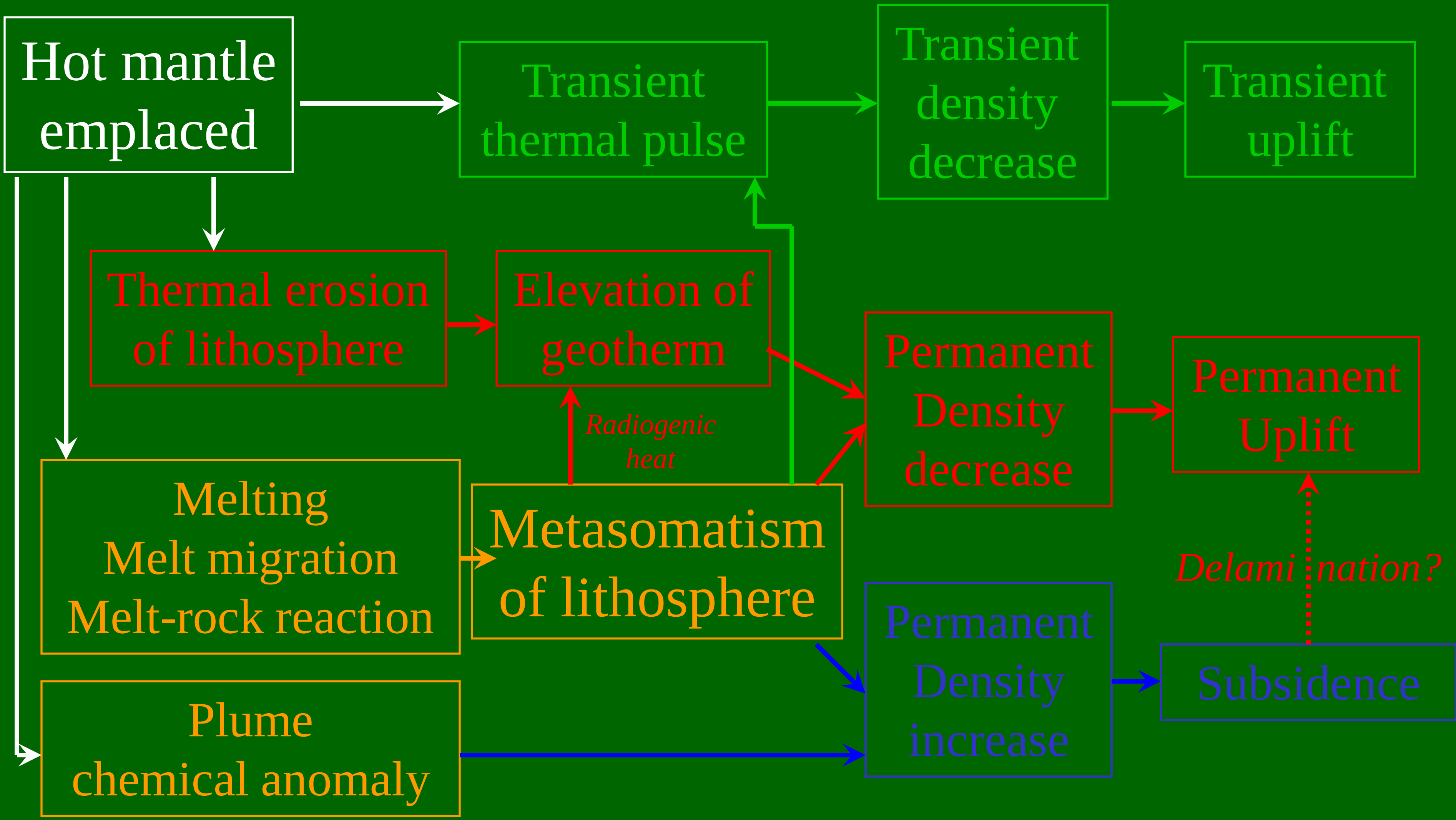
Asthenospheric upwellings-related metasomatism:
mostly linked to the associated magmatic events leading at the end to the uplift of the xenoliths such as by alkaline and kimberlitic lavas (orangeites, lamproites)

Subduction-related metasomatism:
It could be see directly without any later imprints of the previous type if xenoliths were uplifted by calc-alkaline lavas(but rare ex: Kamchatka)
More often you have to be lucky and find the good samples within a lot of samples showing evidences of the first type if your collection was uplifted by alkaline and kimberlites.

- The processes of mantle enrichment by metasomatism could have commonly affected the upper mantle and more than one time through the upper mantle history making difficult to decipher that history (even more complicate if you add mantle depletion processes such as PM).
- They imply changes in the petrological, mineralogical and chemical characteristics of the upper mantle and therefore imply changes in the physical properties of this upper mantle (density, porosity, anisotropy…).
- Finally when pieces of upper mantle are recycled (delamination processes) within the convective mantle they imply changes in the composition of this convective mantle

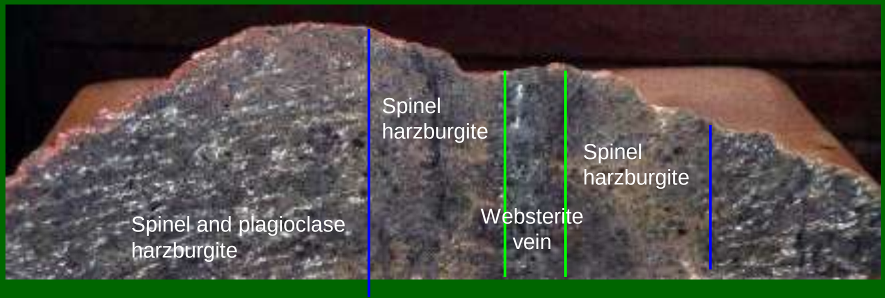
DAVE BELL

PREDICTED CONSEQUENCES OF MANTLE UPWELLING BENEATH CONTINENTAL LITHOSPHERE



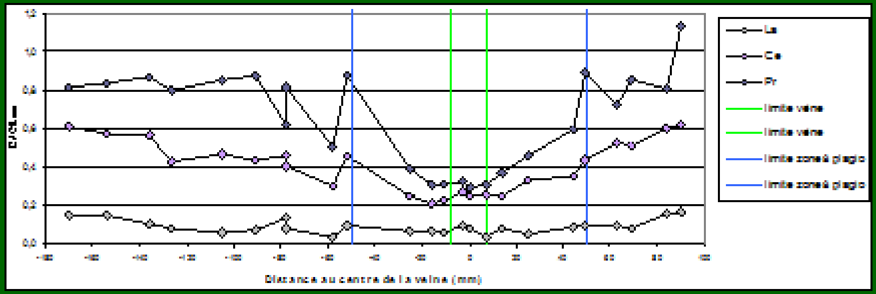
THANKS FOR YOUR ATTENTION

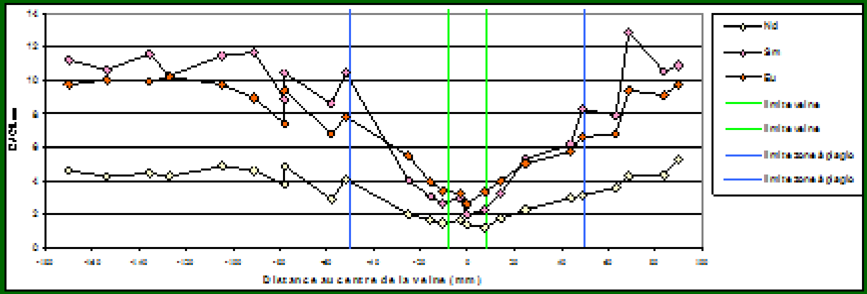
Mantle metasomatism could lead to mantle depletion and not only to mantle enrichment

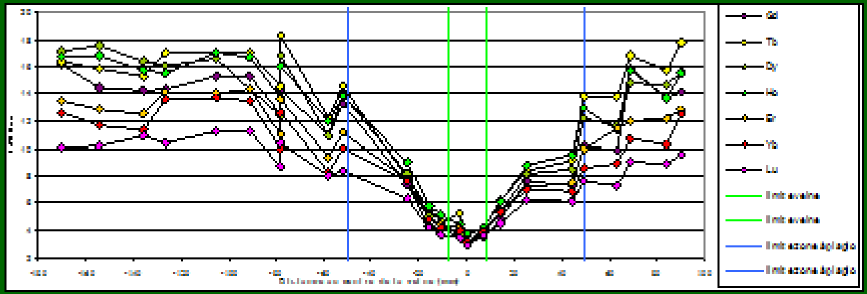


Mantle section of the Trinity Ophiolite (California)

REE vs distance from the vein

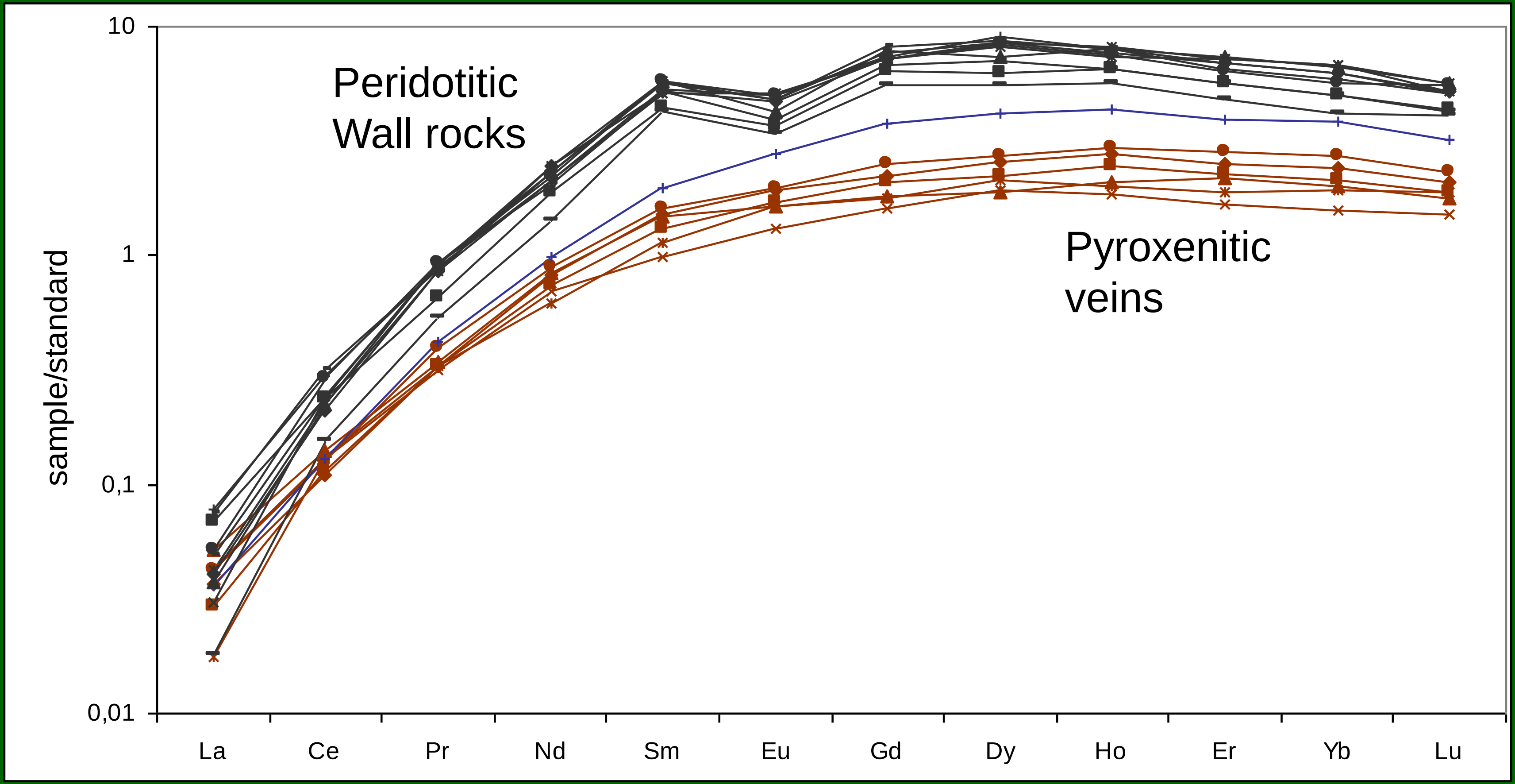




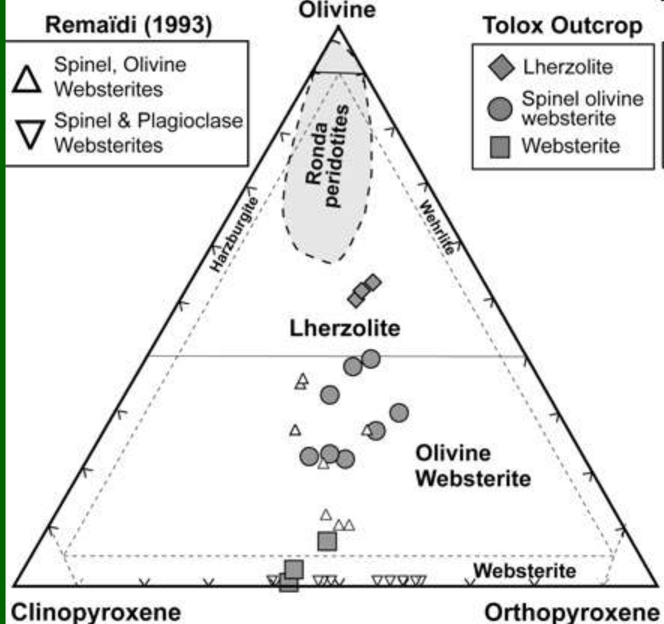


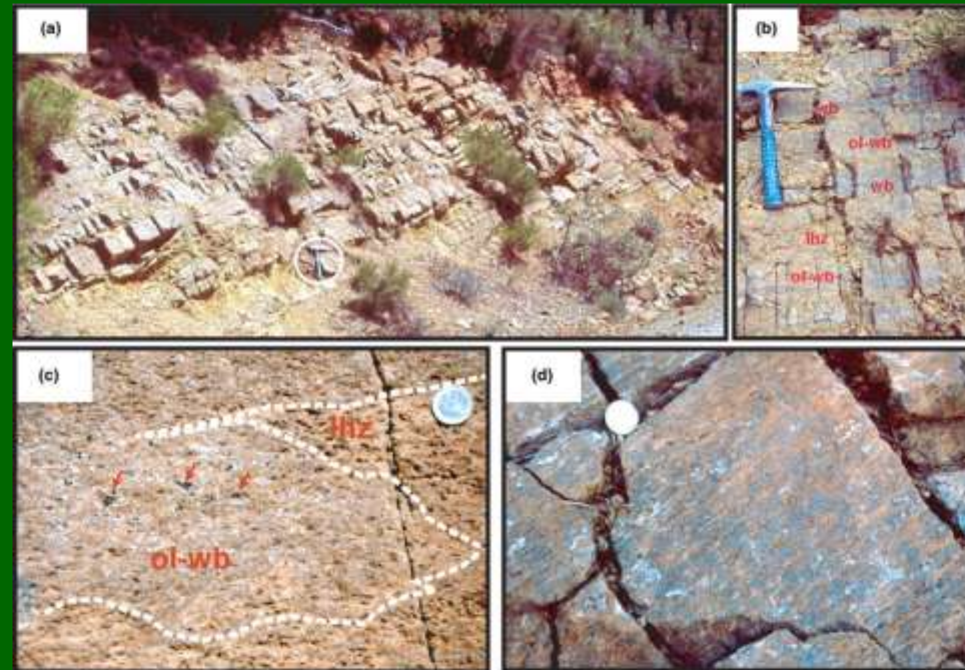
Rarely melt/fluid circulation could result in an impoverishment in incompatible TE

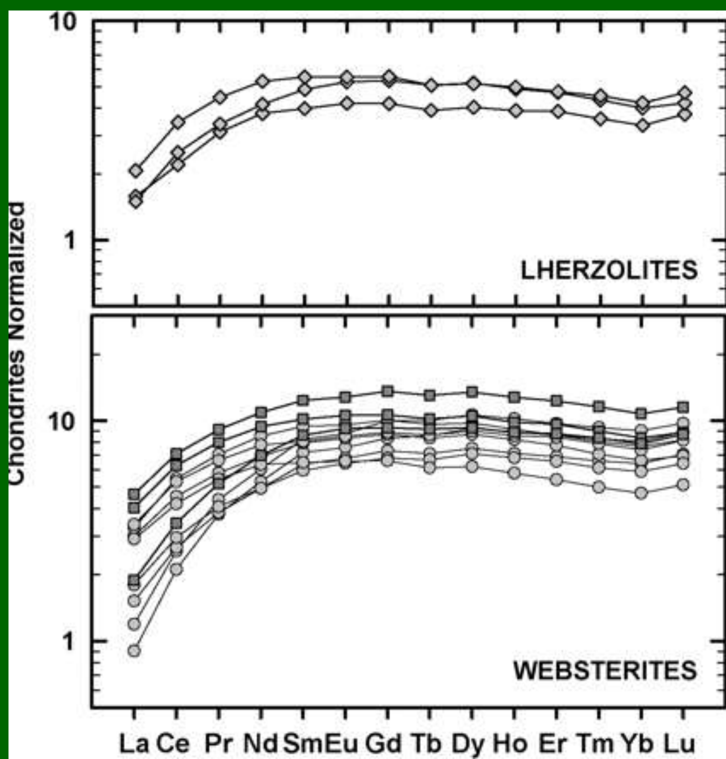
Here circulation of Subduction-related « boninitic like melts »



Peridotitic
Wall rocks
Pyroxenitic
veins
sample/standard
10
1
0,1
0,01
La
Ce
Pr
Nd
Sm
Eu
Gd
Dy
Ho
Er
Yb
Lu







Transformation of peridotites by an influx of sub-alkaline magmas forming websteritic channels where the volume of magma was the higher

Bodinier et al. (2008)

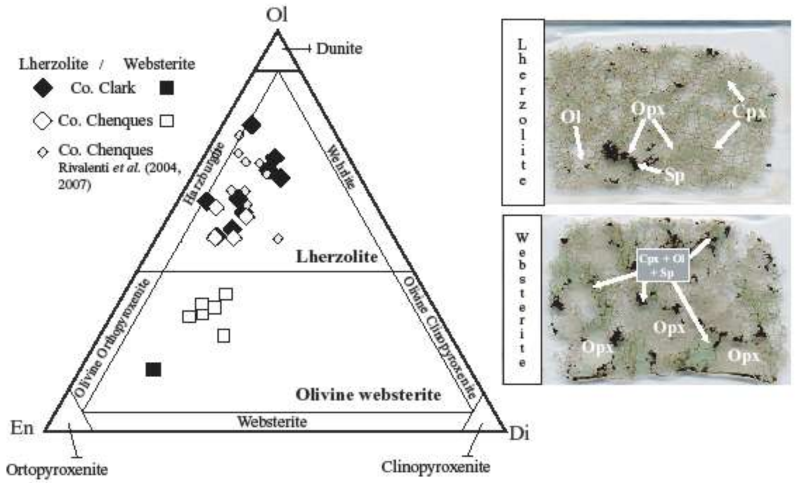


Figure 2

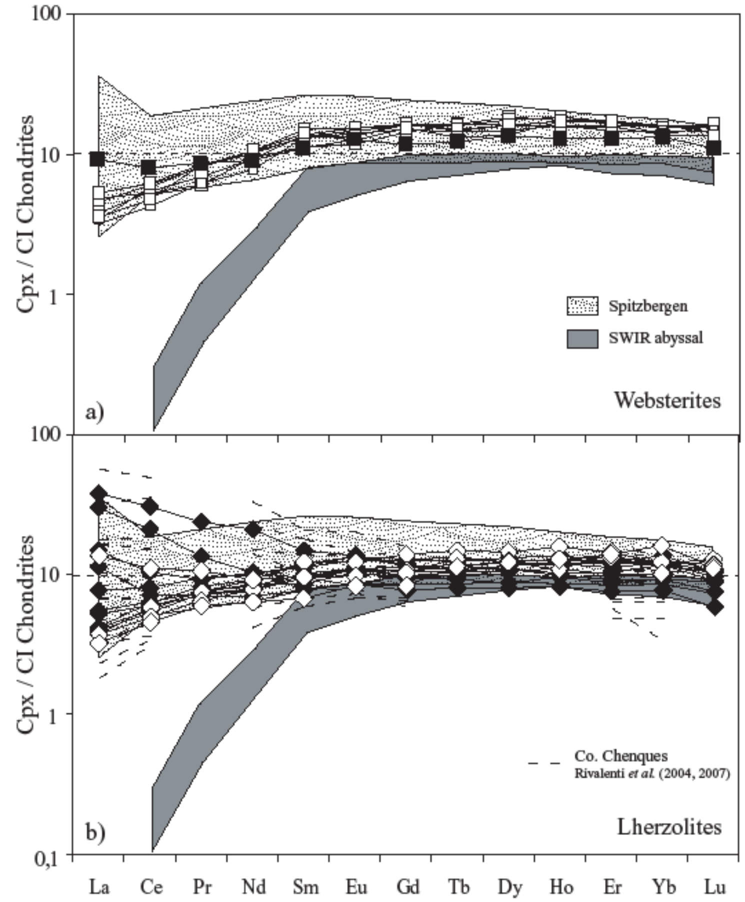


Figure 4

Circulation of subalkaline magmas within the Patagonian upper mantle
Dantas et al., 2009