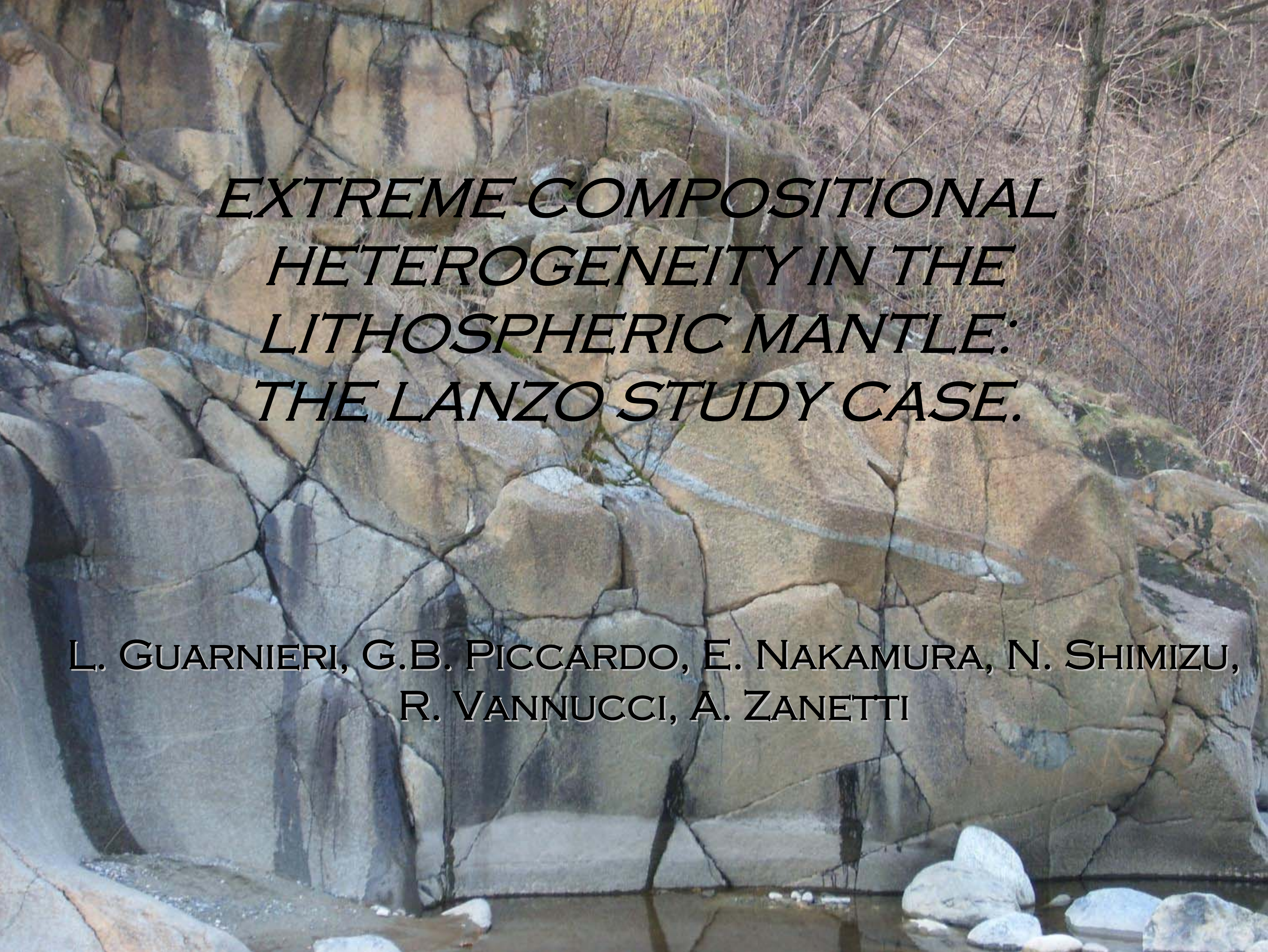


EXTREME COMPOSITIONAL HETEROGENEITY IN THE LITHOSPHERIC MANTLE: THE LANZO STUDY CASE.

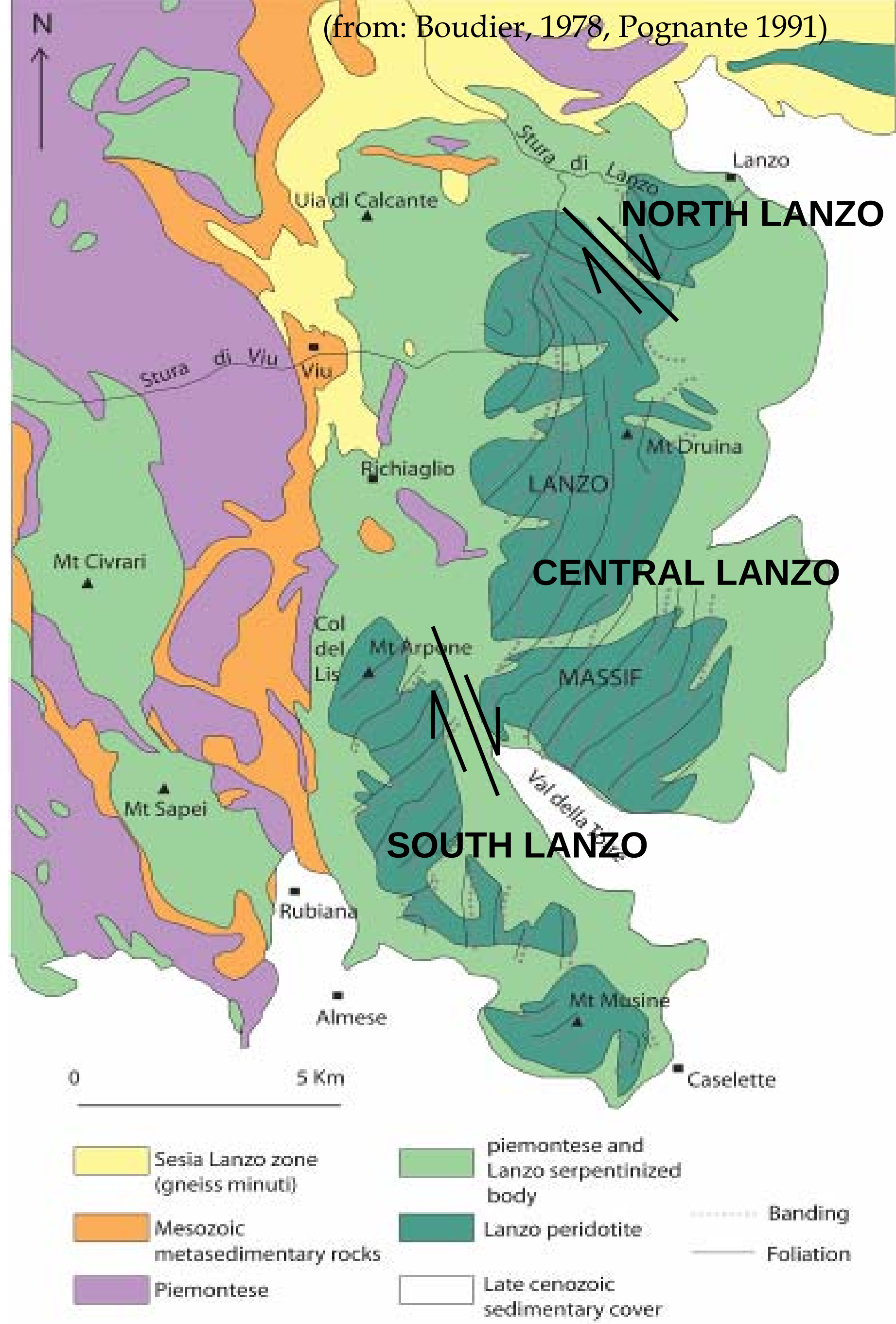
L. Guarnieri, G.B. Piccardo, E. Nakamura, N. Shimizu, R. Vannucci, A. Zanetti

The Lanzo peridotites are primarily overlain by a reduced metamorphic oceanic crust, similarly to other Jurassic ophiolite sequences of the Western Alps and Northern Apennines. This indicates that the Lanzo peridotites were emplaced at the sea-floor during opening of the Jurassic oceanic basin.

Ophiolitic peridotites of Lanzo Massif record composite sequences of tectonic metamorphic events and melt interaction processes that preceded their sea-floor Exposure.

Two main process:
1)The tectonic-metamorphic evolution, characterized by deformation-recrystallization events under decreasing P and T conditions.

2) *The "magmatic evolution"*, characterized by melt-peridotite interation of melts through the extending mantle lithosphere.



The Lanzo Massif

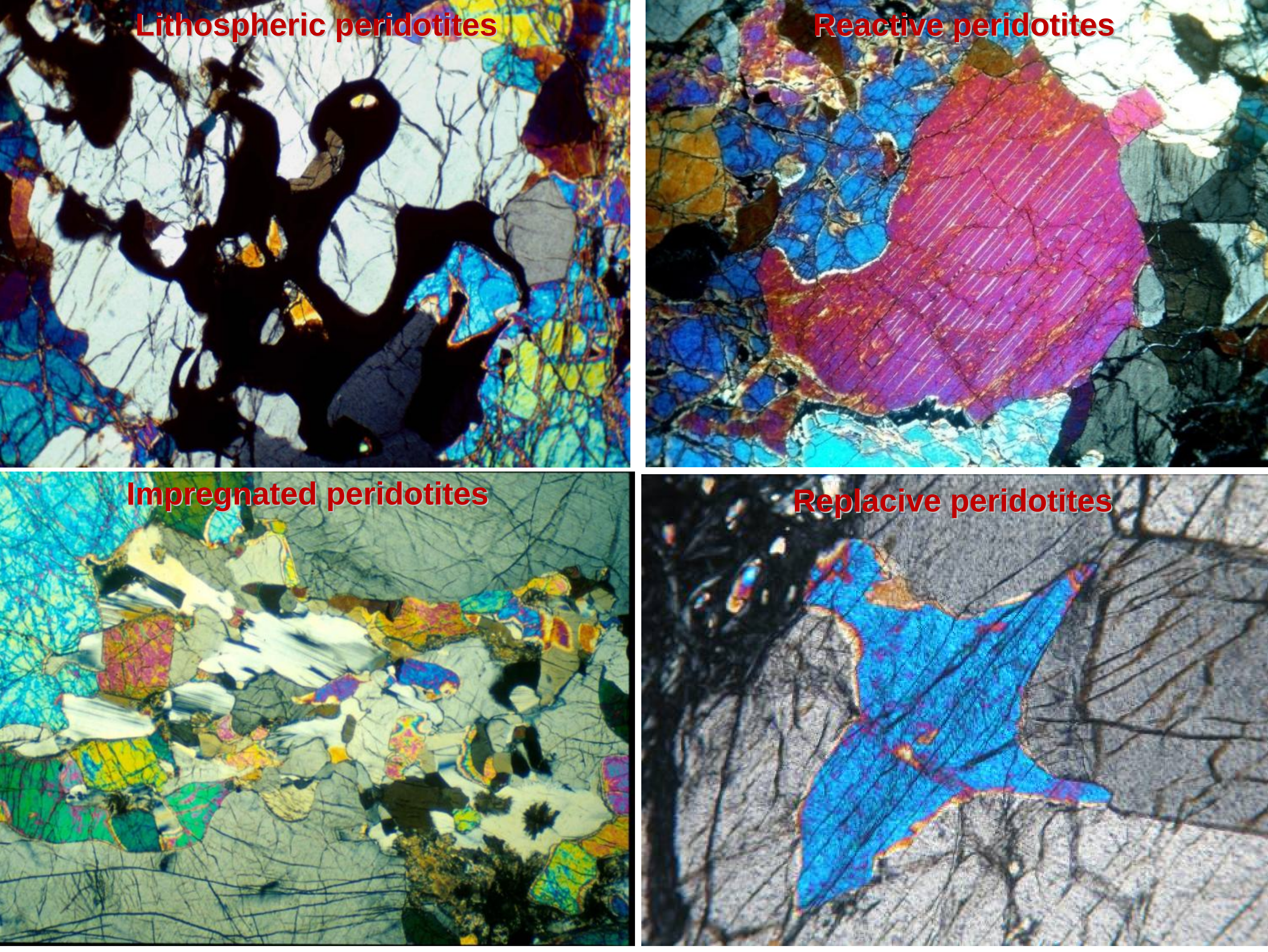
Field and structural–petrographic features indicate extreme heterogeneity in the mantle rocks which vary from

1) Sp-lherzolites and harzburgites showing widespread occurrence of cm- to dm-wide pyroxenite banding;

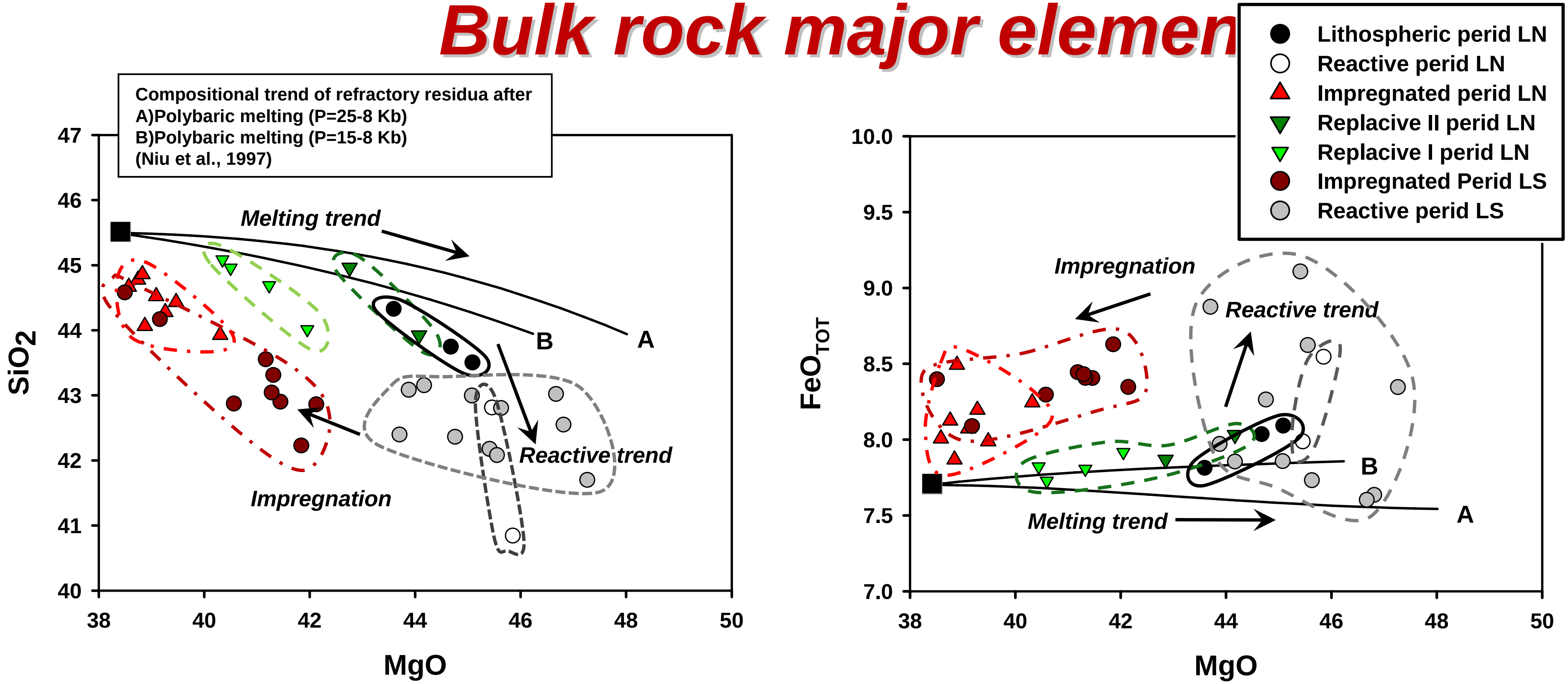
2) Plagioclase-enriched peridotites;

3) Coarse granular spinel peridotites (Spinel lherzolites and pyroxene-depleted Sp-harzburgites)

Field evidence indicates the mutual relationships between the different rock types.
The pyroxenite bearing peridotites represent the pristine mantle protoliths *(lithospheric sp peridotites)* that are replaced by (i) volumes of depleted peridotites showing melt rock reaction structures *(reactive peridotites),*
(ii) decametric-hectometric volumes of plagioclase-enriched peridotites *(impregnated plagioclase peridotites)* and by (iii) metric-decametric volumes and channels of coarse granular spinel peridotites *(replacive sp peridotites).*


Lithospheric peridotites
Reactive peridotites
Impregnated peridotites
Replacive peridotites

Bulk rock major elements



All the samples are depleted in SiO_2 and enriched in FeO with respect to the compositional trends of refractory residua after partial melting

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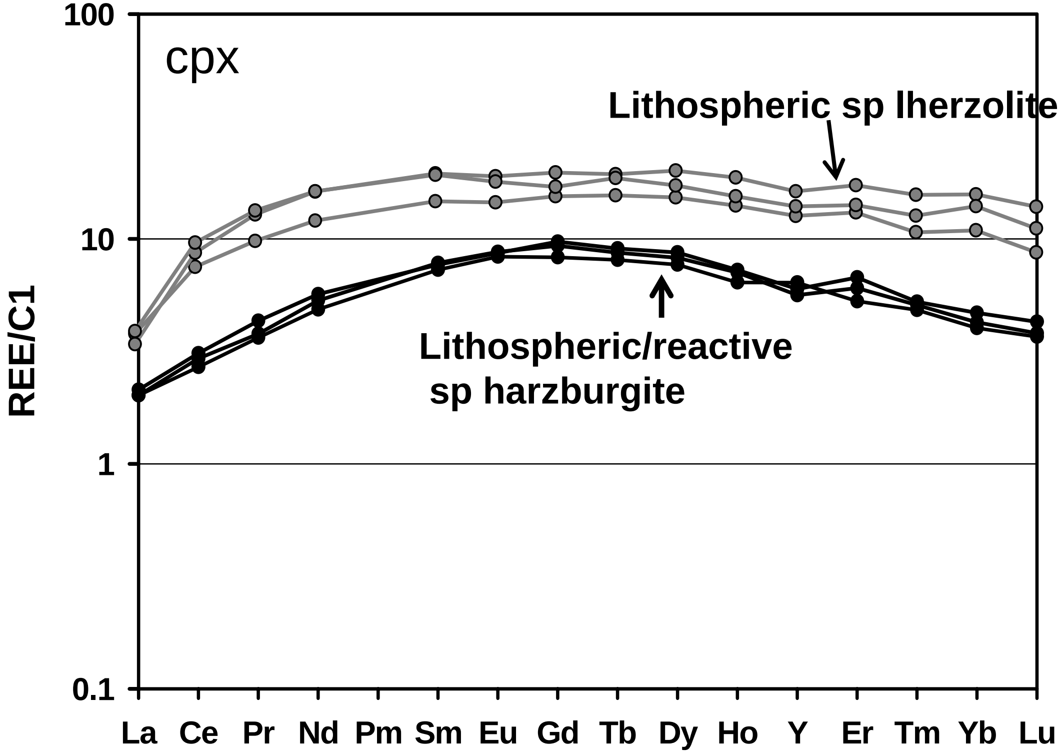
Melt/rock interaction

The process of reactive percolation of silica undersaturated melts produces decreasing SiO_2 and increasing MgO contents, resulting in increasing modal olivine and decreasing modal orthopyroxene towards very olivine rich compositions.

Plagioclase peridotites define a trend, starting from the compositional field delimited by reactive sp peridotites which is characterized by a progressive MgO depletion, SiO_2 enrichment and FeO depletion , consistent with enrichment in magmatic pyroxenes and plagioclase

Cpx trace elements: Lithopheric peridotites

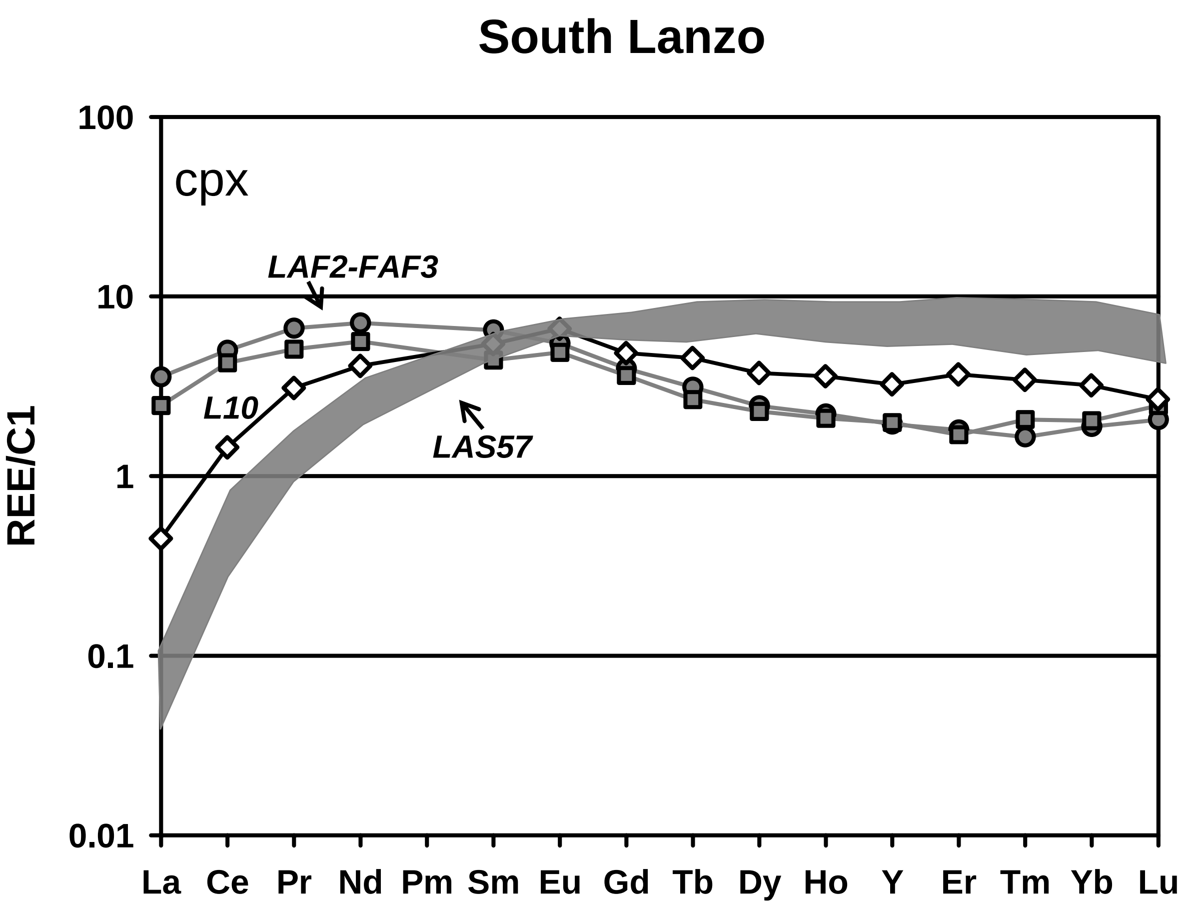


The lithospheric peridotites represent the oldest mantle protoliths that escaped significant interaction with percolating melts

Different groups are present showing different cpx REE patterns

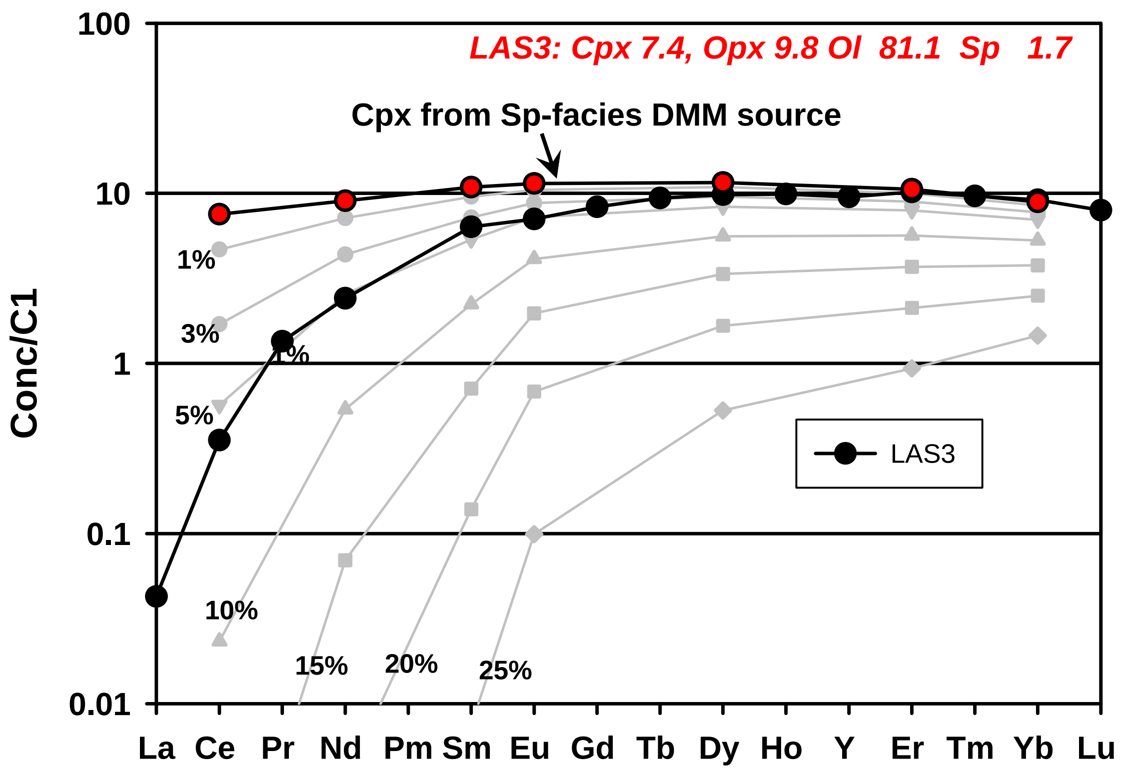
HETEROGENEOUS SUBCONTINENTAL MANTLE

Cpx trace elements: Reactive peridotites



The different samples have clinopyroxenes showing strongly variable C1-normalized REE patterns, even in the case the host peridotites have similar modal compositions and similar clinopyroxene contents.

Clinopyroxenes C1-normalised REE patterns vary from strongly LREE-depleted to sinusoidal LREE/MREE-enriched.



LAS3 cpx (reactive peridotites) well matches the composition modelled for residual Cpx after 5% fractional melting of Sp-facies DMM.

1) This is dramatically different compared to 20-22% partial melting estimated using Niu's modelling
2) LAS3 shows a significant decoupling between bulk rock and mineral chemistry
3) The reactive nature is highlighted by peculiarreaction microstructure

LAS3 WAS REACTIVELY DEPLETED IN PYROXENES AND EQUILIBRATED IN TRACE ELEMENTS WITH A MELT FORMED BY 5% FRACTIONAL MELTING OF A SPINEL-FACIES DM SOURCE

Numerical simulation (Plate model)

Vernieres et al, 1997

Plate model simulations have been performed (Piccardo et al., 2007) with the aim of understanding the nature of percolating melts, and the chemical and physical parameters governing their interaction with the ambient peridotites.

Parameters:

- Ambient peridotites: refractory residuum after 20% fractional melting of sp-facies DMM

- Weight fraction of the minerals in country peridotites: Ol:Opx:Cpx:Sp= 0.65:0,27:0.07:0.01

- Mantle column: 20 cells and 20 process increments;

- During each process increment peridotite pyroxenes were assimiled: Opx:Cpx=0.8:0.2

-For sake of semplicity, fractional cristalization was not allowed

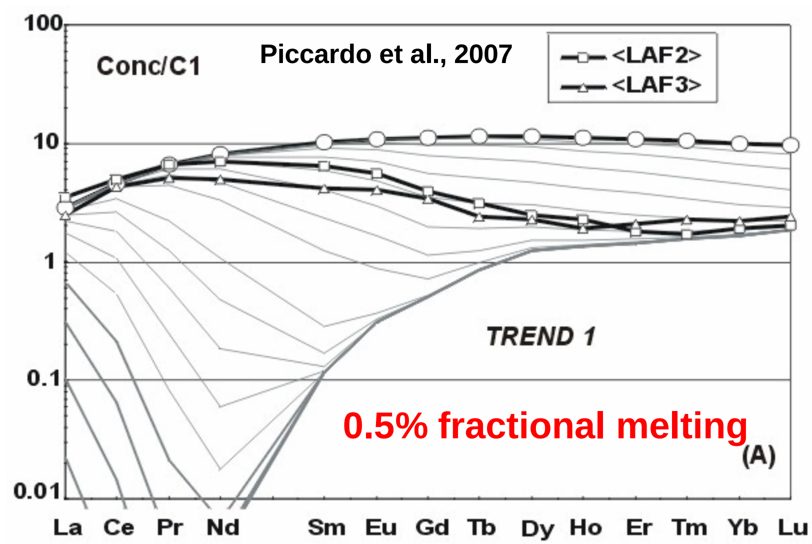
-Porosity: 1%

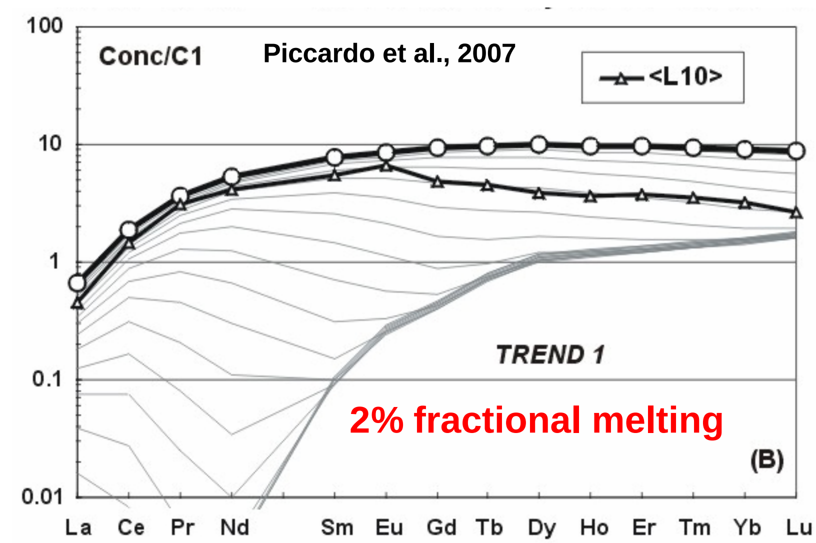
-Melt/rock ratio>0.3

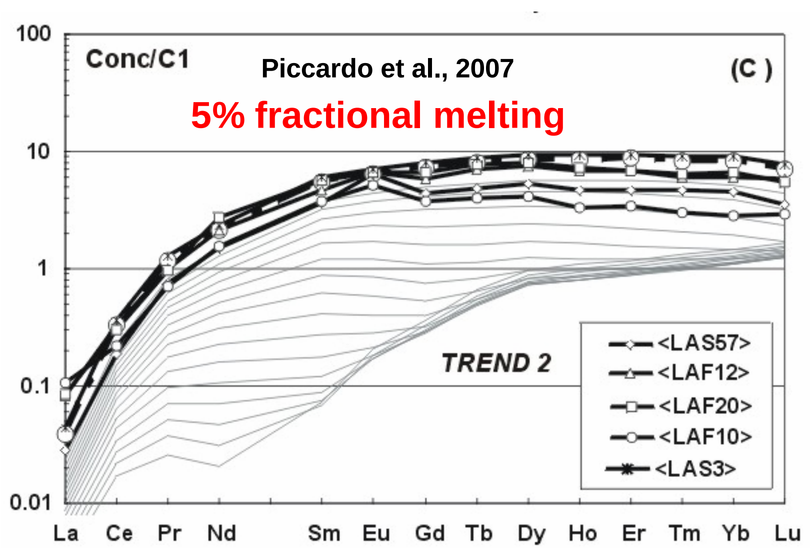
-Solid/melt partition coefficient from Ionov et al. 2002

Numerical simulation (Plate model)

Vernieres et al, 1997



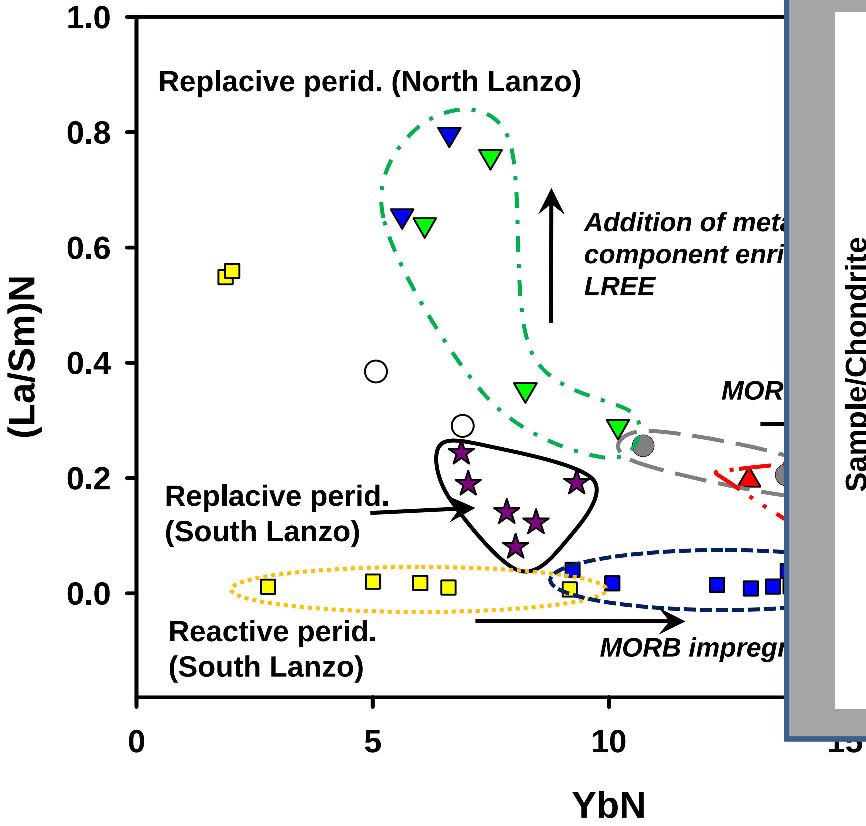


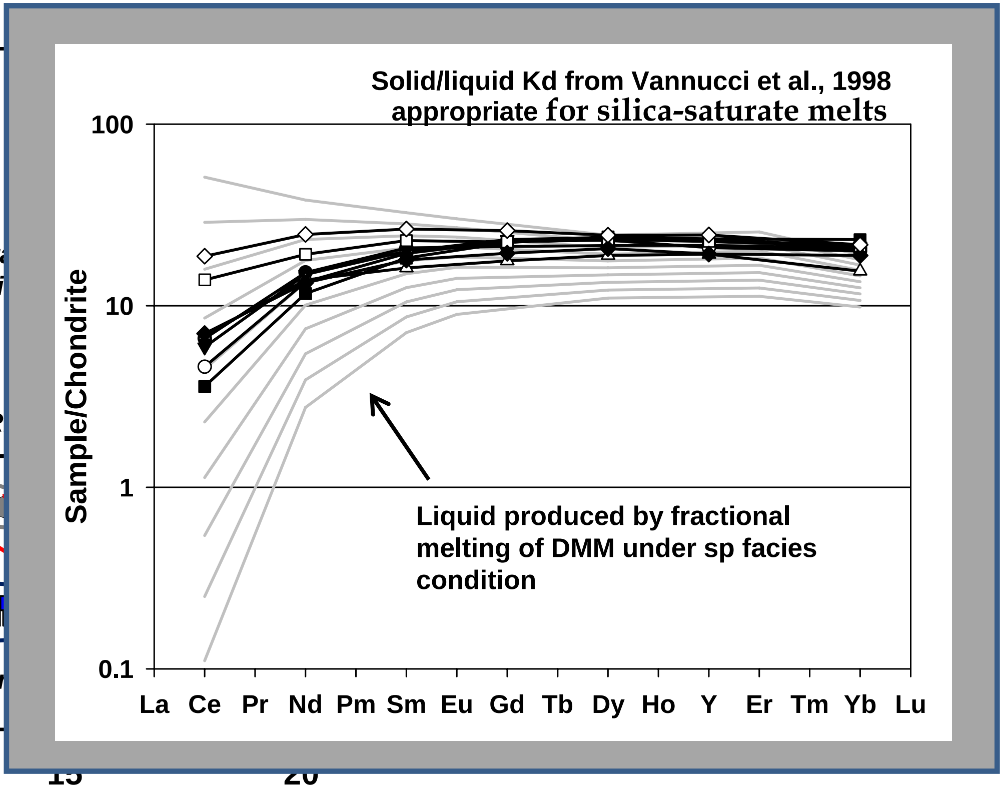


The simulation result show that the REE fractionation of the trends cpx from reactive sp peridotites can be interpreted as transient geochemical gradients induced by reactive migration of different melt increment;

In particular, melt increments by 0.5, 0.2- and 5% fractional melting of spinel facies DMM can explain the REE frationation of cpx LAF2-3, L10 and LAS3 respectively

Cpx trace elements: impregnated and replacive peridotites

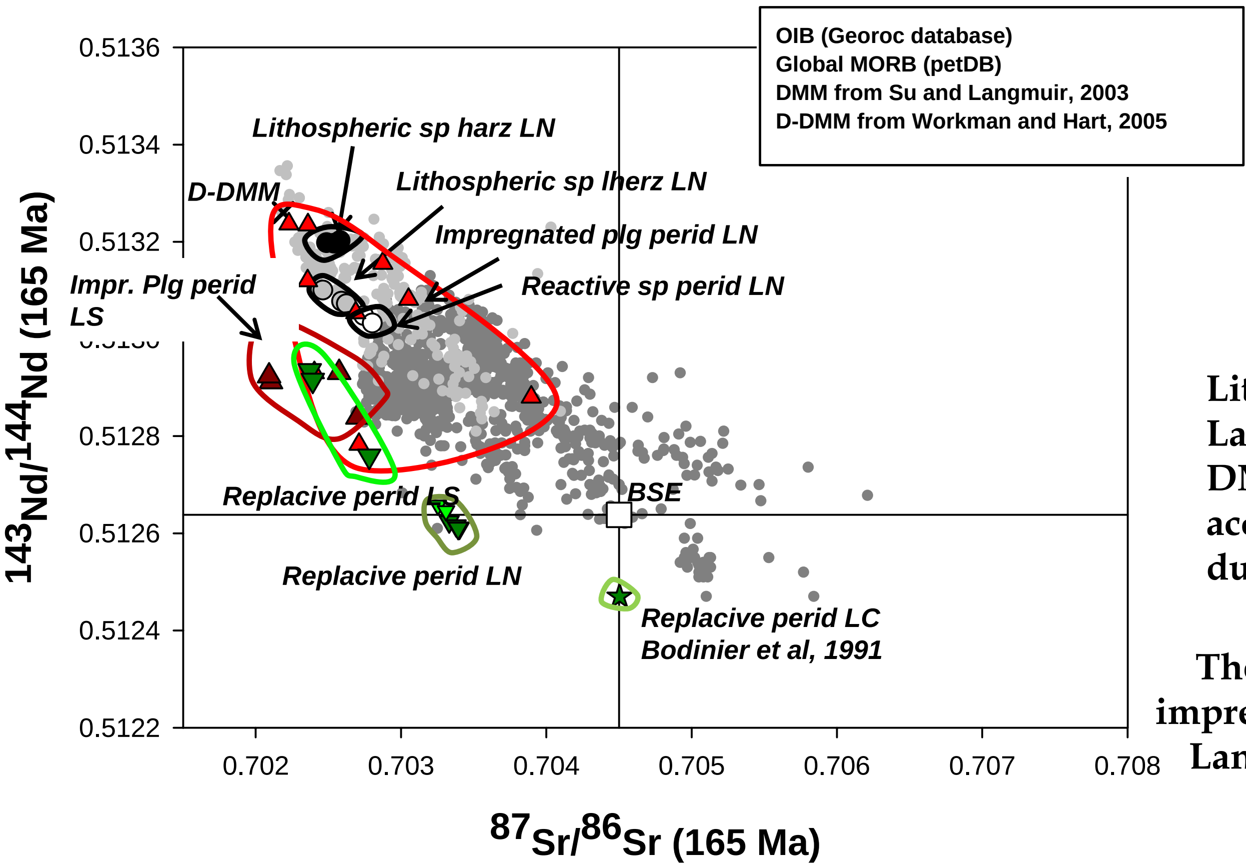


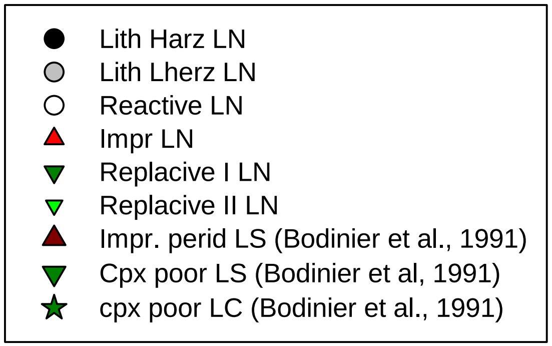


1) Impregnated plg peridotites show relatively low $(La/Sm)_N$ values at increasing Yb_N confirming impregnation by MORB melts;

2) Very high $(La/Sm)_N$ values of replacive peridotites from North Lanzo documents the interaction with strongly LREE enriched melts, possibly alkaline.

The cpx isotopic heterogeneity





Lithospheric peridotites from North Lanzo have high $^{143}Nd/^{144}Nd$ value. DM model ages indicate that they were accreted to the lithospheric mantle during Proterozoic time.

The reactive spinel peridotites and the impregnated plagioclase peridotites (North Lanzo) display a large range in isotopic compositions (from DMM to MORB signatures):

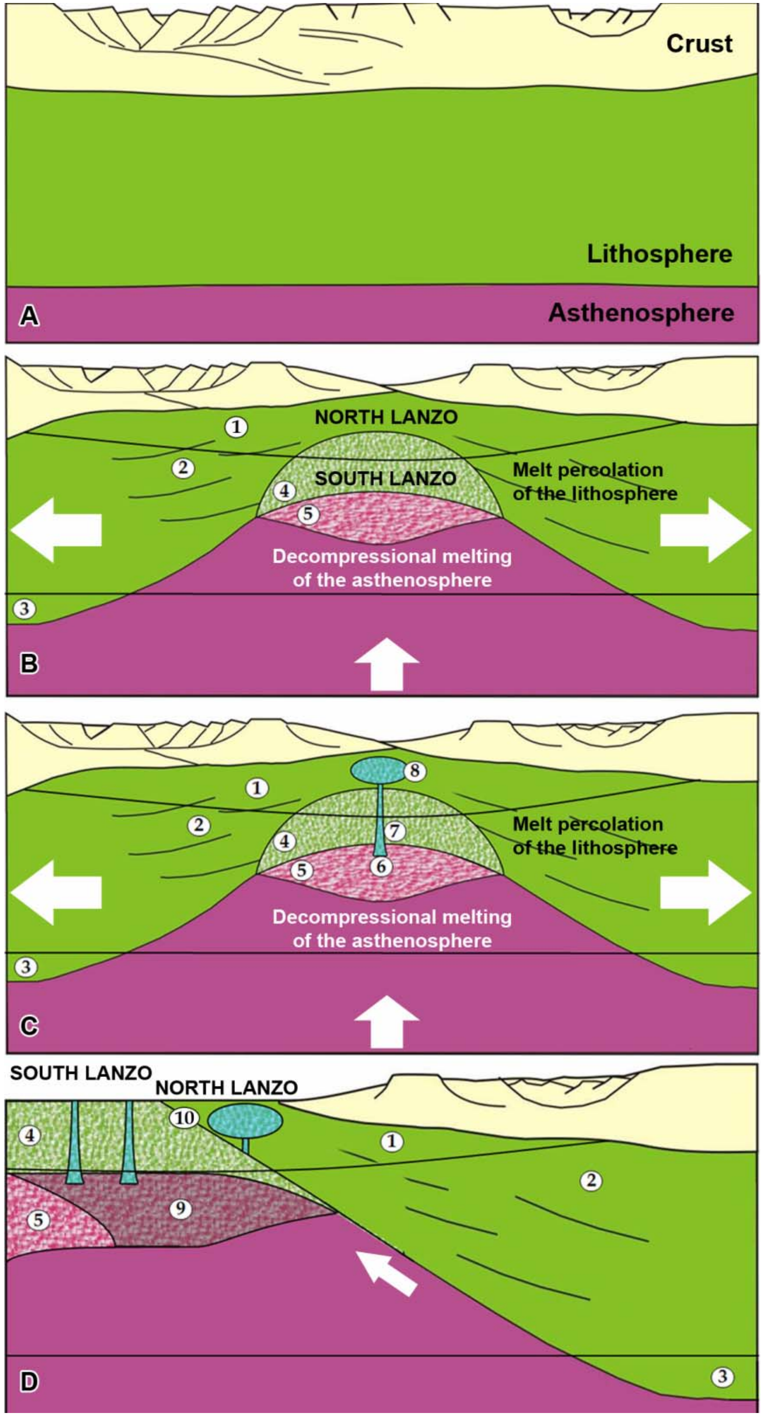
↓

variable interaction of the lithospheric mantle peridotites with MORB type melts.

The replacive peridotites from North Lanzo display OIB signature. OIB signature has been described in cpx from refractory peridotites from the Central Lanzo body (Bodinier et al, 1991).

The replacive peridotites from South Lanzo display MORB signature.

Impregnated peridotites from South Lanzo have MORB signature.



Conclusion

A) The pre-Triassic setting

B) Thinning of the continental lithosphere, causing: (i) exhumation of the shallower lithospheric mantle to plagioclase-facies conditions; (ii) adiabatic upwelling and inception of decompressional melting of the asthenosphere;

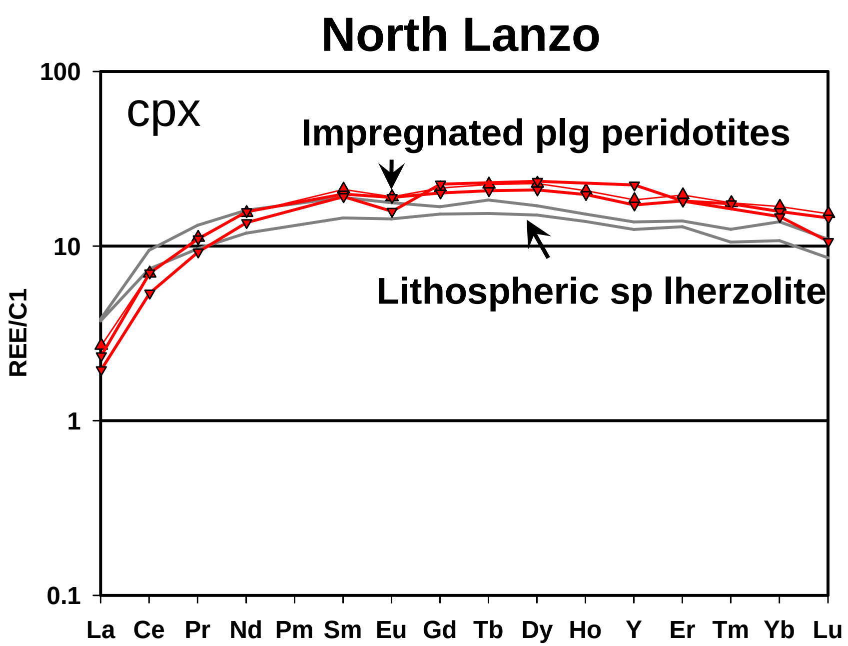
Lithospheric protoliths of the North and South-Central Lanzo peridotites were located at different depths in the sub-continental lithosphere during continental extension ;

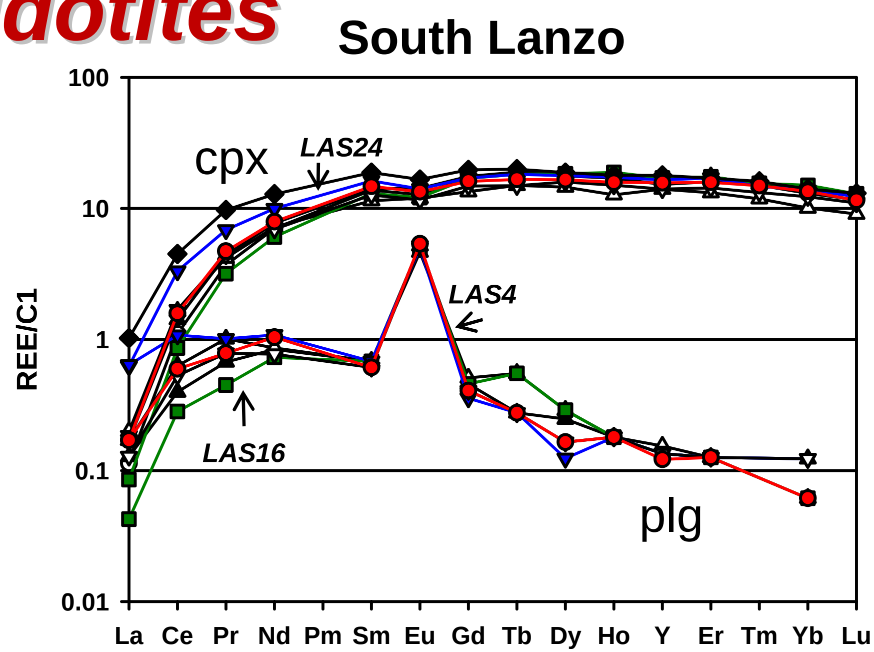
Porous flow percolation through the lower mantle lithosphere of MORB-type fractional melts formed the South Lanzo reactive and impregnated peridotites.

C) Aggregate MORB magmas passed through the South Lanzo peridotites by focused migration within replacive harzburgite-dunite channels, and infiltrated the North Lanzo peridotites forming North Lanzo impregnated peridotites.

D) Break-up of the continental crust and the sea-floor exposure of the sub-continental lithospheric mantle. The North Lanzo peridotites, deriving from shallower lithospheric mantle levels, were exhumed and exposed at OCT zones. South Lanzo peridotites, deriving from deeper lithospheric mantle levels, were exhumed and exposed at the sea-floor at MIO settings

Cpx trace elements: Impregnated peridotites





The impregnated peridotites from North Lanzo show higher content in HREE and high fractionation in LREE in respect to fertile lithospheric peridotites suggesting cpx equilibration with percolating MORB-type melts

The more fertile lithospheric peridotites are the protoliths of the impregnated peridotites

Cpx REE patterns are humped, with strong to moderate LREE fractionation (LaN/SmN from 0.19 to 0.01) and MREE up to 30xC1 maximum at Sm-Gd).

Plagioclase and clinopyroxene in the same sample show trace element equilibrium

Liquids in equilibrium with cpx, using solid/liquid KD for silica-undersaturated systems have irrealistic REE contents, too high to be formed by a DMM spinel-facies source.

Liquids calculated using solid/liquid KD for silica-saturated systems have more realistic REE contents, consistent with those of liquids formed by low degrees (1-5%) of fractional melting.

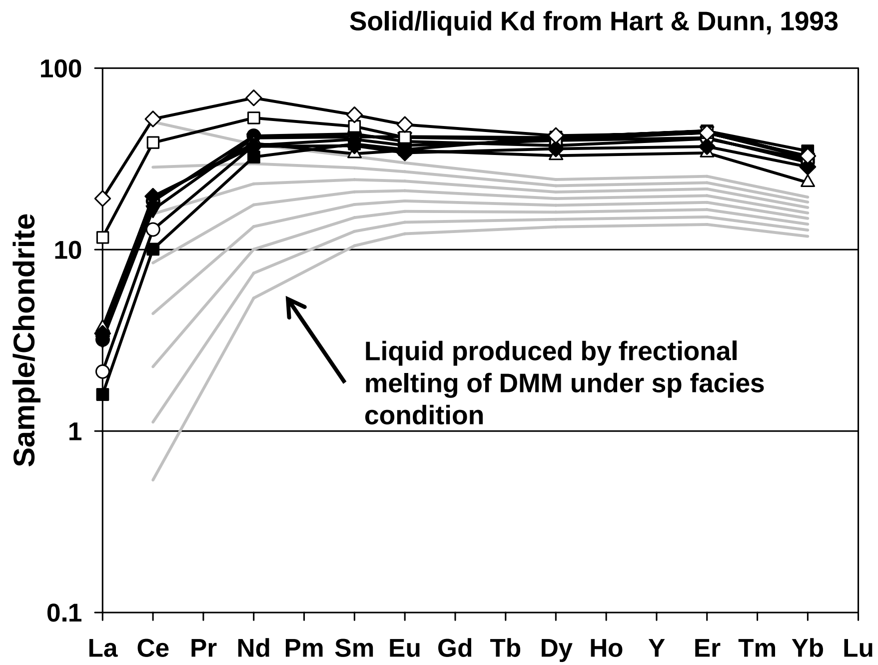
Melt/rock equilibration was assisted by high cpx/liquid KDs, more appropriate for silica-saturate melts: they caused the trace element enrichment of minerals.

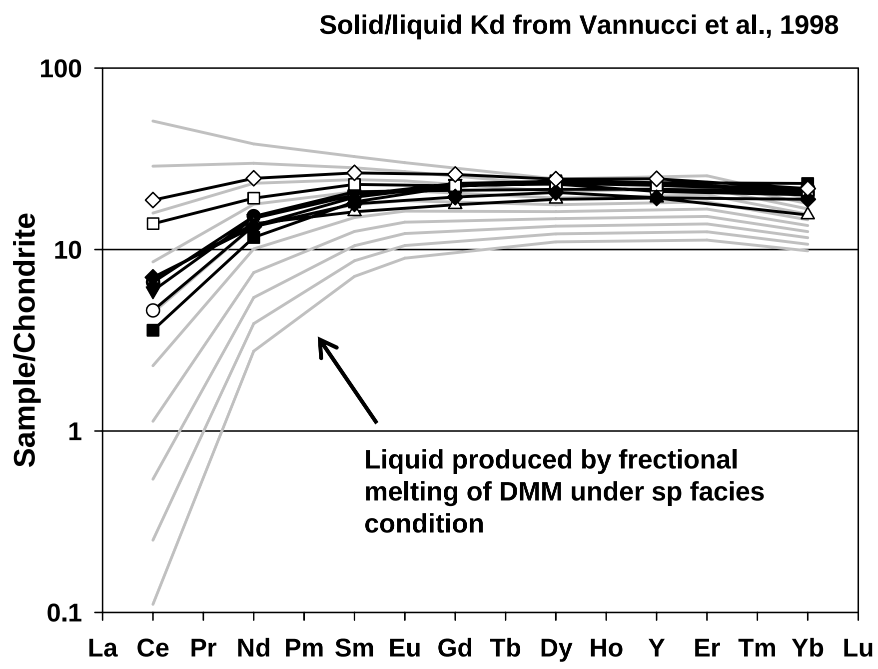
Model details:

C_0 from Johnson et al 1990

Modal proportion: Ol:Opx:Cpx:Sp=0.55:0.25:0.18:0.02

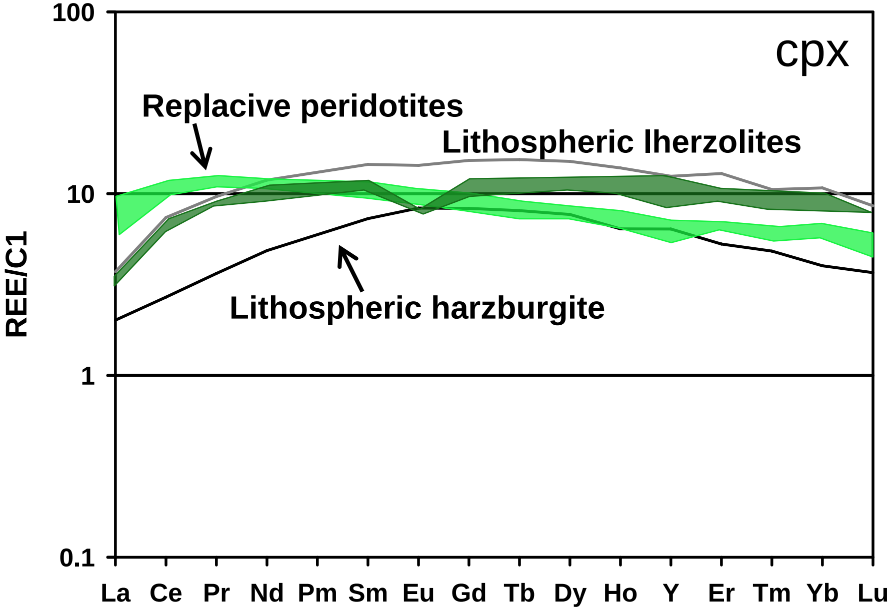
Melting modal composition:
Ol:Opx:Cpx:Sp=0.1:0.2:0.68:0.02



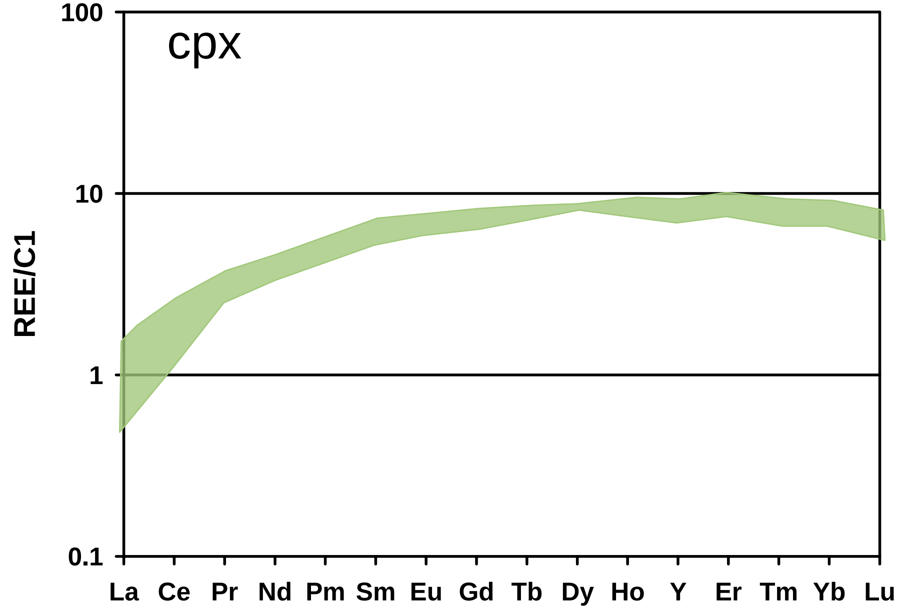


Cpx trace elements: Replacive peridotites

North Lanzo



South Lanzo

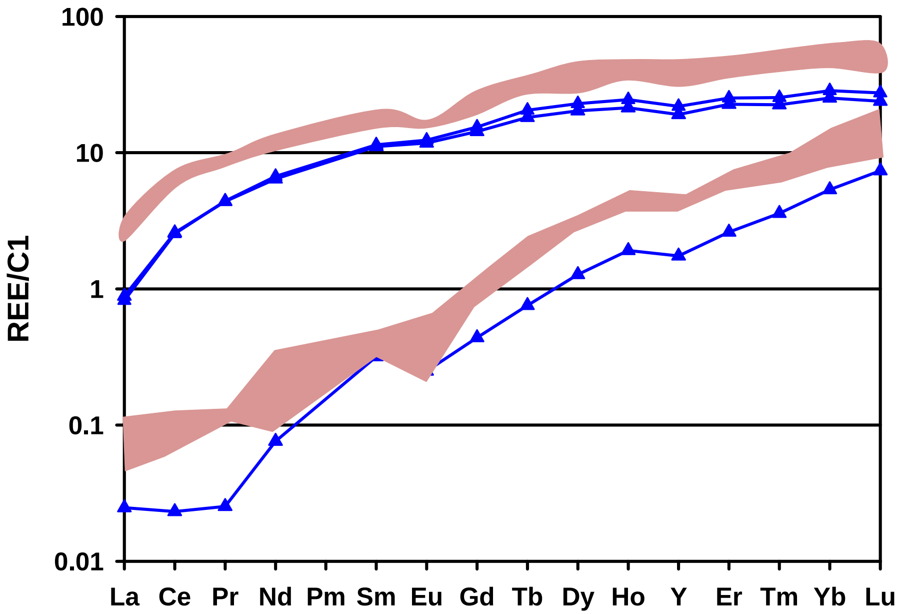


Presence of Cpx showing LREE-enriched and HREE-depleted patterns in the replacive harzburgites indicate that the replacive channels were exploited for upwards migration of enriched melts possibly with alkaline affinity.

Appearance of alkaline melts indicates a drastic change in composition of the melting source for the percolating melts.

Clinopyroxene small interstitial grains in replacive harzburgites and dunites have clear MORB characteristics.

This indicates that MORB melts migrated within these high permeability harzburgite-dunite channels which were formed by reactive demolition (plagioclase+pyroxene dissolution, olivine formation) of the preexisting foliated plagioclase peridotites.



Different types of pyroxenites:

Type 1 **- Cpx and opx show strong fractionated REE patterns, and very high content in HREE**
garnet breakdown processes and trace element re-distribution in pyroxenes.

Type 2 **- Cpx shows fractionated REE patterns, and lower HREE contents with respect to the other pyroxenites : sp-pyroxenites**