Geochemical interaction between slab-derived melts and mantle at high pressure in subduction zones

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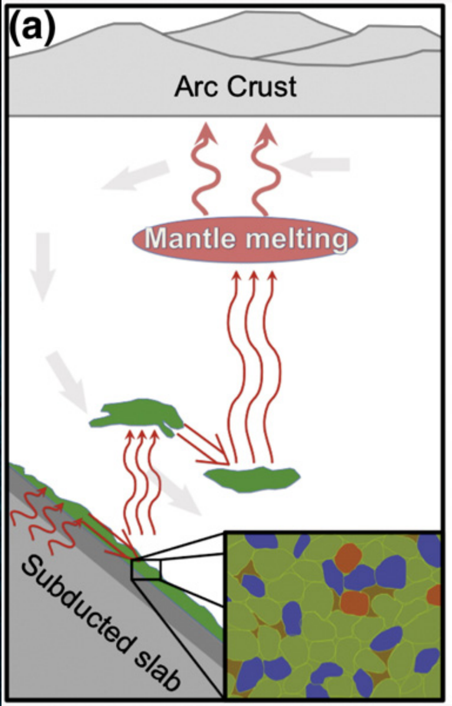
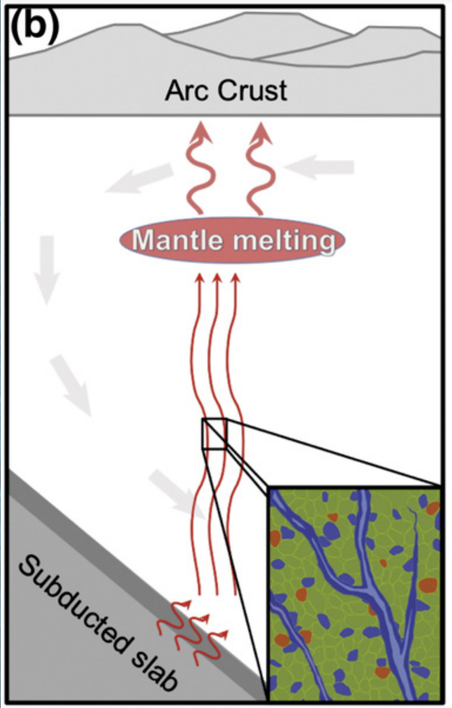
MELT-PERIDOTITE INTERACTIONS AT SUBDUCTION ZONES



Porous flow
instant reaction



Focussed flow
network of veins

Spandler and Pirard 2013 (Lithos)

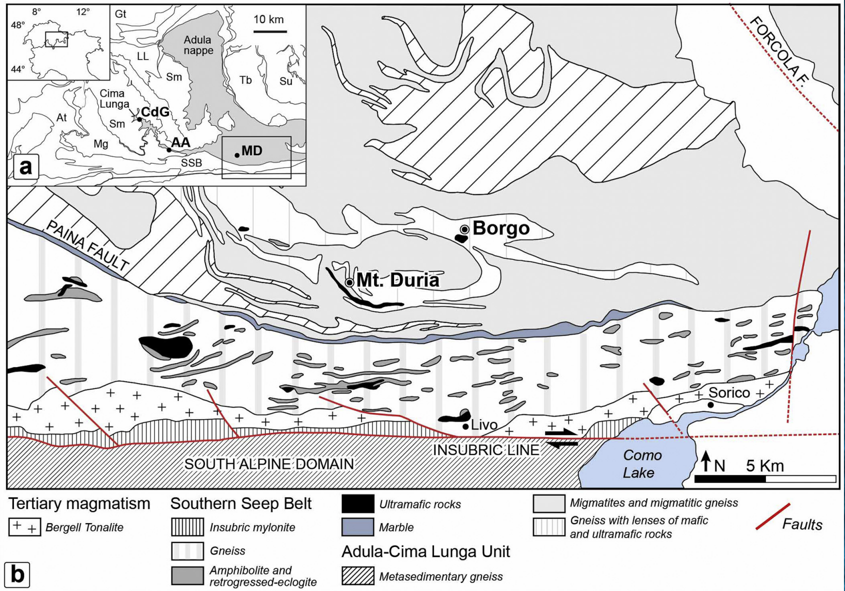
The fate of crust-derived melts at warm subduction zones and the transport mechanism of slab-derived components to the supra-subduction mantle is still a matter of debate.

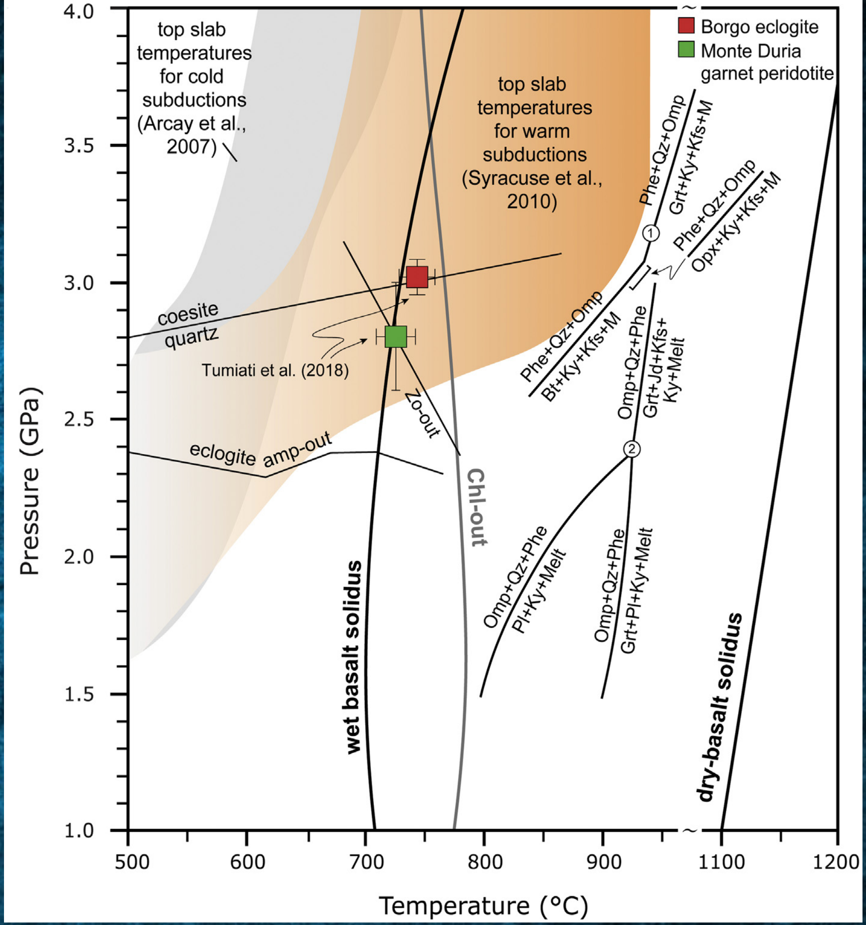
Migration of crust-derived melts into the mantle by porous flow is limited by instant reaction with the peridotites and the consequent production of metasomatic orthopyroxene (±clinopyroxene) and phlogopite hybrid rocks at the slab-mantle interface.

Alternatively, the occurrence of a network of pyroxenite veins in metasomatised mantle xenoliths from arc lavas indicates that metasomatic melts may percolate the mantle by a mechanism of focused flow.

Melt-peridotite interaction via reactive porous flow has been largely studied in mantle samples from oceanic and subcontinental settings. We know little about the role of these interactions at the slab interface.

THE CASE STUDY OF BORGO (CENTRAL ALPS)

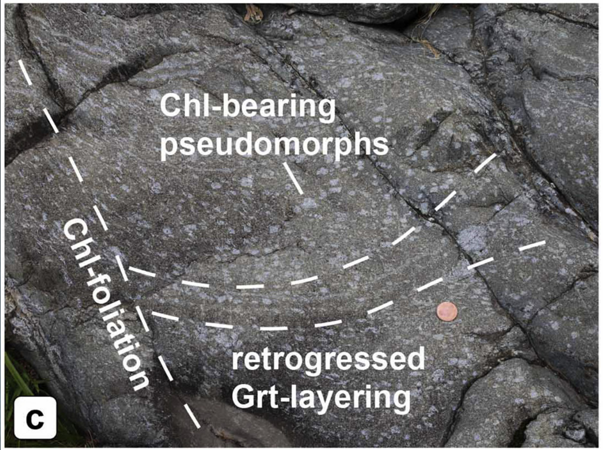


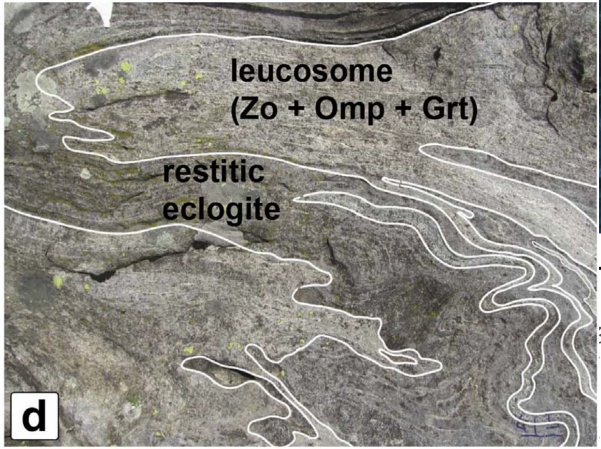


Tumiati et al. 2018 (J Pet); Pellegrino et al. 2020 (Lithos)

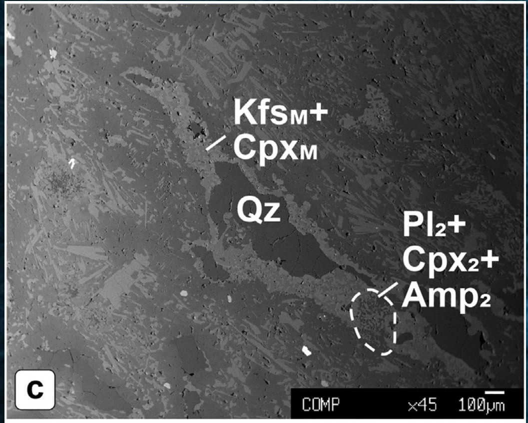
The Borgo outcrop of the Monte Duria area (Adula-Cima Lunga unit, Central Alps, Italy) is an ideal example of melt-peridotite interaction which occurred under a deformation regime at HP. Grt-peridotites occur in direct contact with migmatised orthogneiss and eclogites that record a common HP peak at 2.8 GPa and 750 ° C

THE CASE STUDY OF BORGO (CENTRAL ALPS)

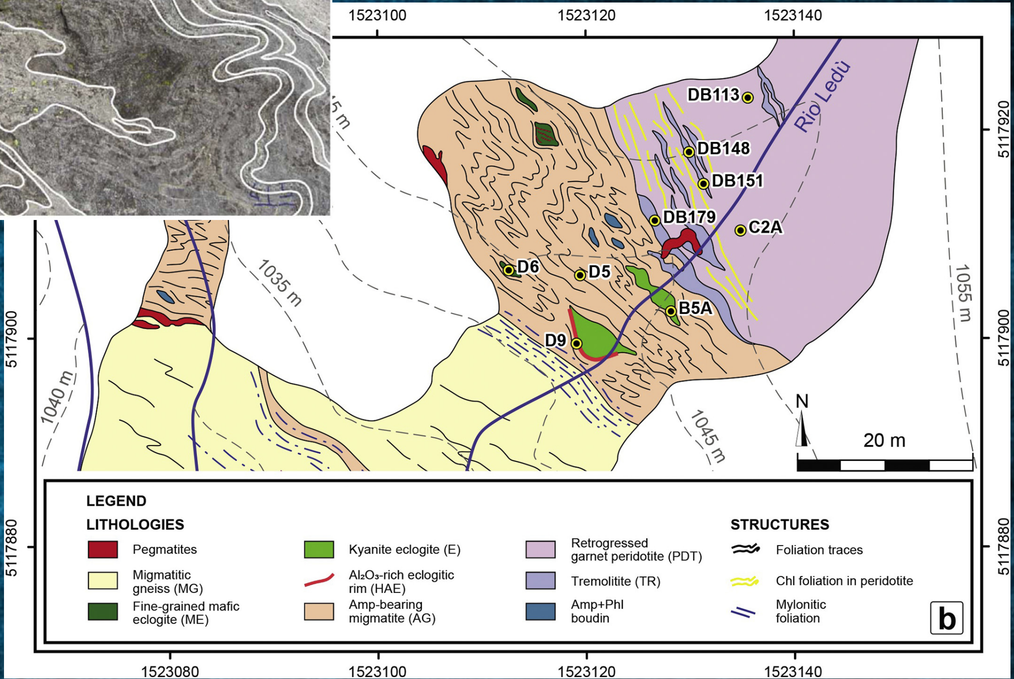




At Borgo, migmatised eclogites are in direct contact with retrogressed Grt-peridotites showing a Grt compositional layering, crosscut by a subsequent LP Chl foliation.

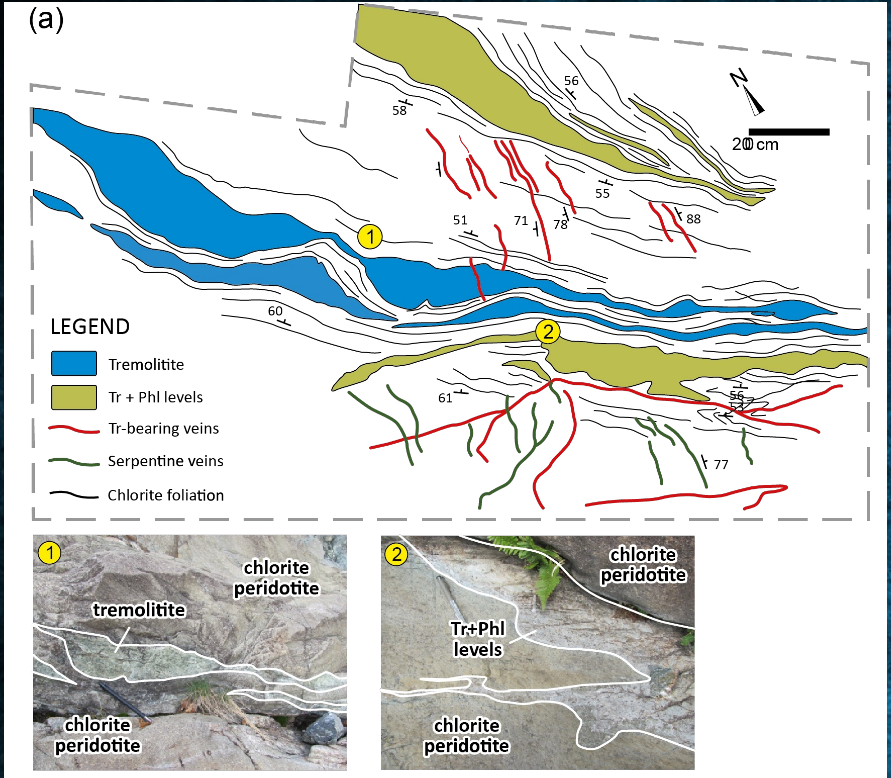


Eclogite boudins in migmatites show thin films and interstitial pockets of crystallised melts parallel to the eclogite foliation (partial melting of eclogites at HP conditions)

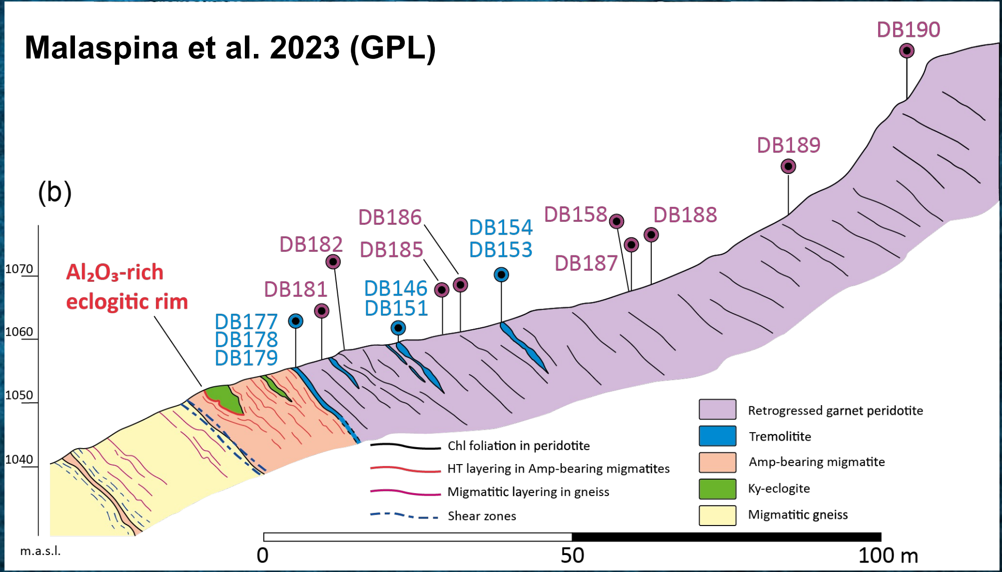


Pellegrino et al. 2020 (Lithos)

THE CASE STUDY OF BORGO (CENTRAL ALPS)



Tremolitites occur both at the peridotite/eclogite contact and within the peridotite body and derived from the retrogression of previous Grt-websterites formed after the interaction at HP between eclogite-sourced melts and peridotites. The peridotite Grt-layering flows into the necks of the boudins, indicating that the stretching of the tremolitites (previous Grt-websterite) occurred when the peridotites were still in the Grt stability field.



We analysed the composition of 16 samples collected along a profile, from the eclogite-peridotite contact to the inner part of the peridotite lens

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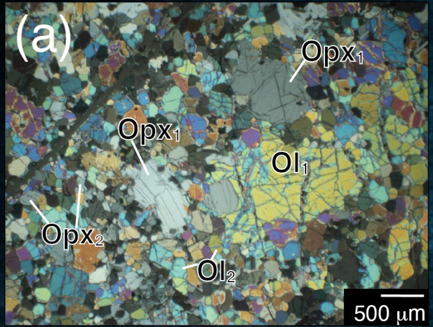
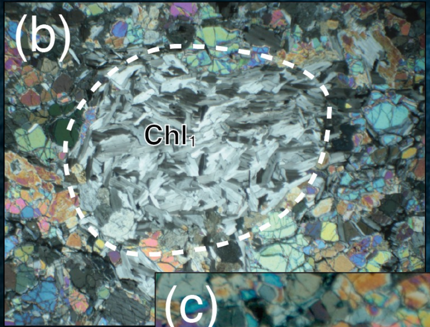
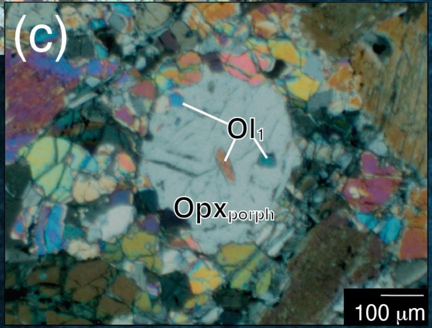
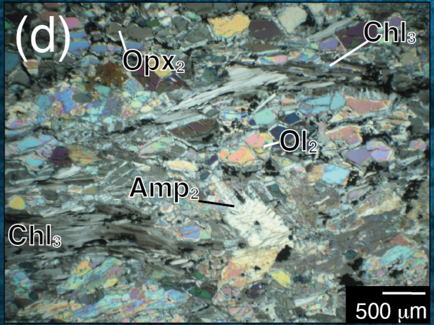
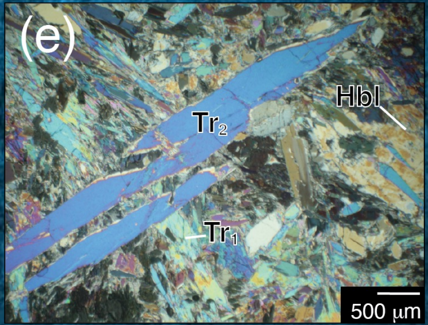


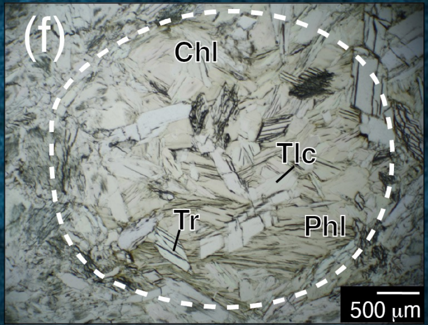


Metamorphic stage	HP peak	HP hydration	HP melt/rock reaction	Decompression	LP-(U)HT	LP-LT hydration and Chl foliation	Retrogression
				Chlorite peridotite			
Olivine	Ol_1			Ol_2			
Orthopyroxene	Opx_1		Opx_{porph}	Opx_2	*Opx_{sym}		
Clinopyroxene	Cpx_1				*Cpx_{sym}		
Garnet							
Amphibole		Amp_1	Amp_{porph}	Amp_2	*Amp_{sym}	Amp_3	
Chlorite		Chl_1				Chl_3	
Phlogopite			Phl_{porph}			Phl_3	
Spinel				Spl_2	*Spl_{sym}		
Serpentine							
				Tremolitite			
Orthopyroxene							
Clinopyroxene							
Garnet							
Amphibole			Hbl	Hbl		Tr_1	Tr_2
Phlogopite							
Talc							
Chlorite							

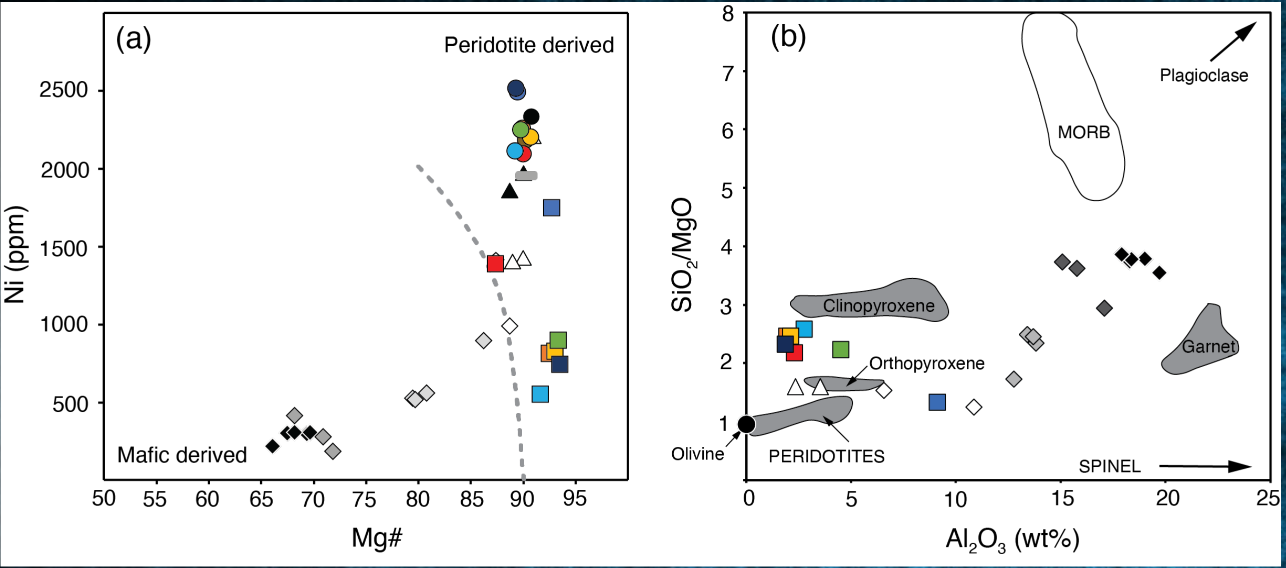








BULK ROCK GEOCHEMISTRY



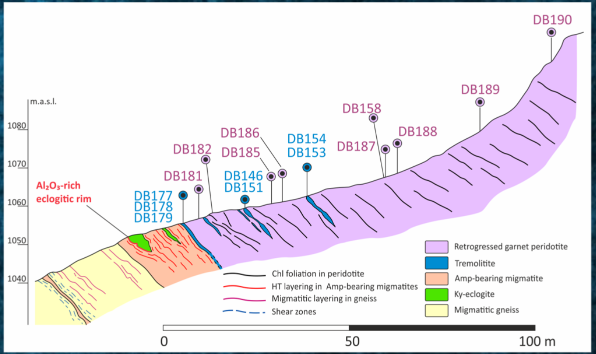
Chl-peridotite

Tremolitite

Grt-peridotites (Duria)
Pellegrino et al. 2020 (Lithos)

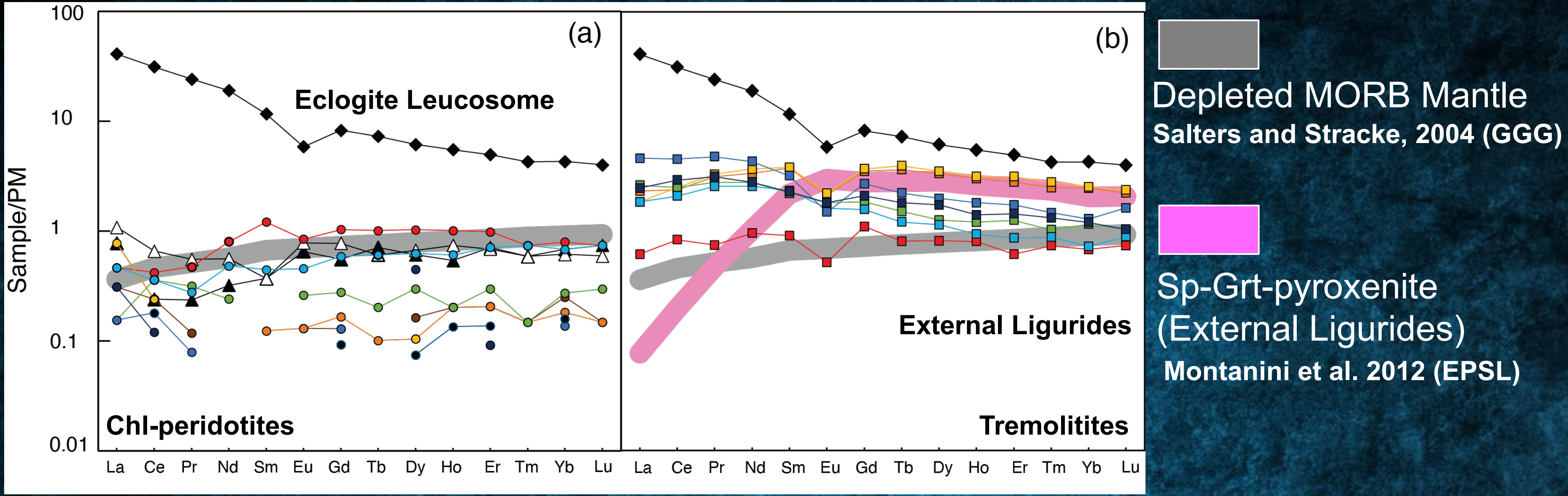
Grt-orthopy. and websterite (Dabie-Shan)
Malaspina et al. 2006 (EPSL)

Sp-Grt-pyroxenite (External Ligurides)
Montanini et al. 2012 (EPSL)



Chl-peridotites: Mg# (90), high Ni, and low Al_2O_3 + CaO.
Tremolitites: Mg# (0.91) and Ni up to 1390 µg/g plotting into the field of the ultramafic compositions (marked difference with respect to Grt- and Spl-pyroxenites of subcontinental ophiolites). They show high SiO_2, high CaO and Al_2O_3 vs SiO_2/MgO close to the composition of metasomatic Grt-orthopyroxenites and websterites from Dabie-Shan, which were formed after the interaction of Grt- harzburgites with Si-rich crust-derived melts at UHP

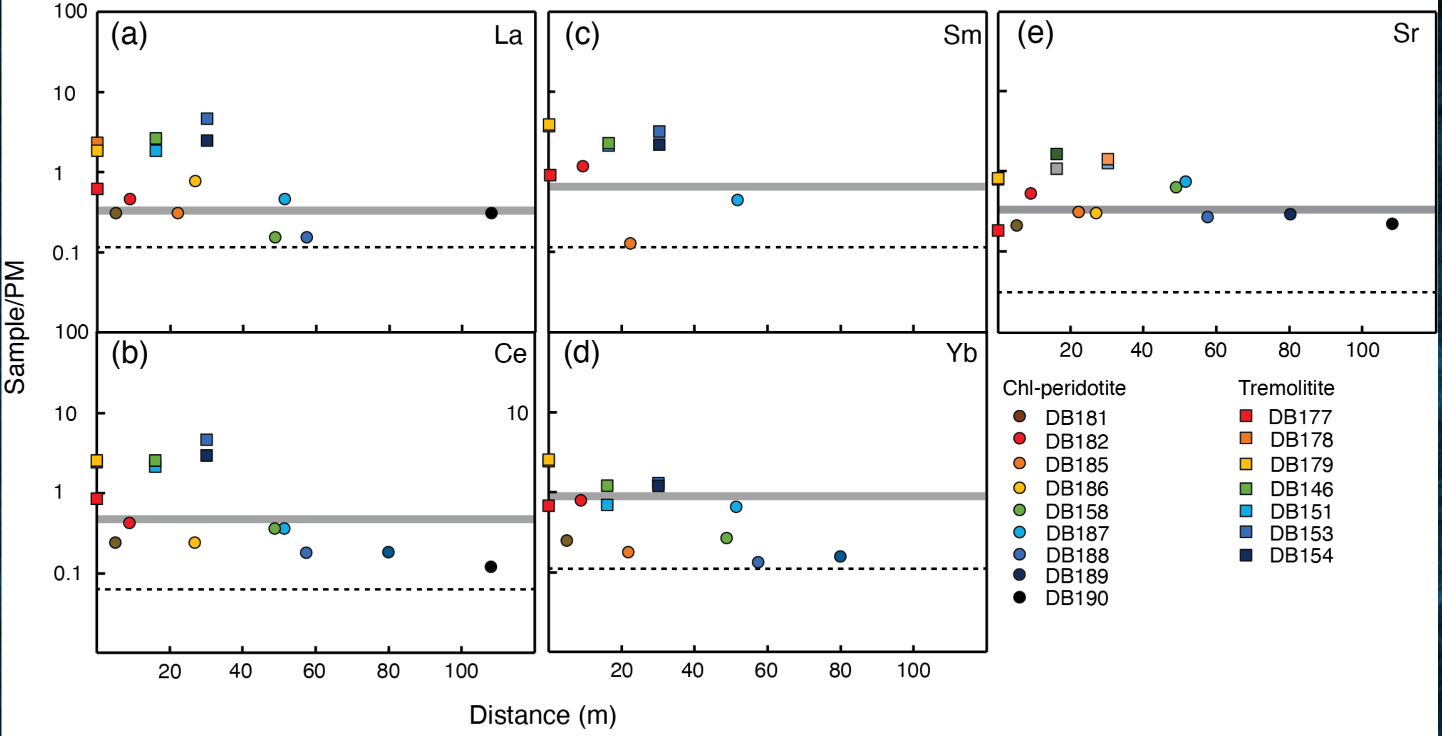
BULK ROCK GEOCHEMISTRY



Peridotites: REE close to or slightly lower than the DMM, with fractionated patterns enriched in LREE relative to the MREE and HREE.

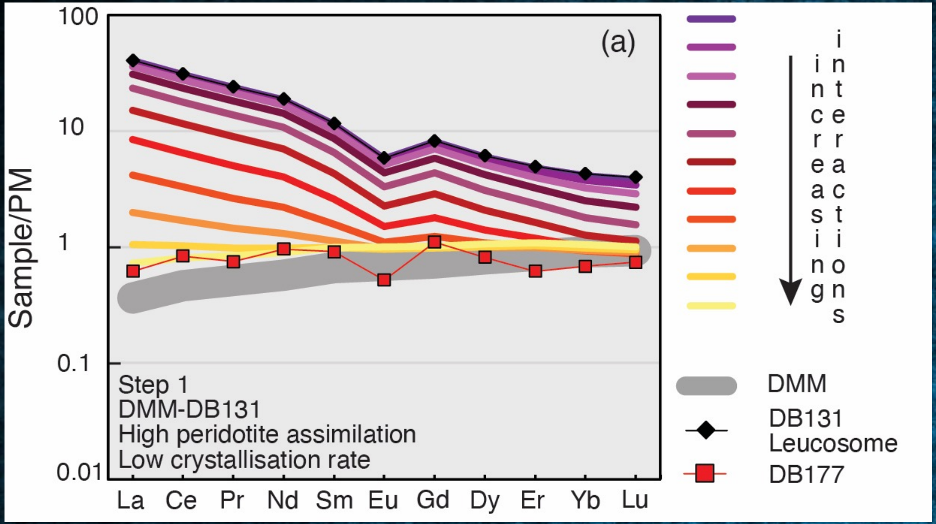
Tremolitites: REE up to 4.63 × PM with enrichments in MREE and LREE/HREE two orders of magnitude higher than subcontinental pyroxenites from External Ligurides. Both peridotites close to the contact with the migmatised eclogites, and tremolitites display a negative Eu anomaly, resembling that of eclogite leucosome produced from a Pl-bearing source.

REE GEOCHEMICAL EVOLUTION IN GRT-WEBSTERITES AND PERIDOTITES AT HP



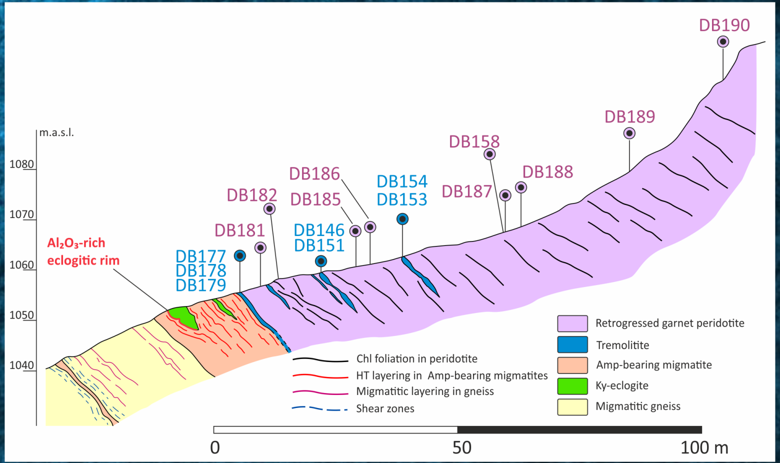
Tremolitites show a progressive increase in LREE from the contact up to about 30 m within the adjacent peridotite. Among the fluid mobile elements, both tremolitites and peridotites show a progressive depletion in Pb from the contact to 80 m within the peridotite body, whereas Sr is almost constant .

REE GEOCHEMICAL EVOLUTION IN GRT-WEBSTERITES AND PERIDOTITES AT HP

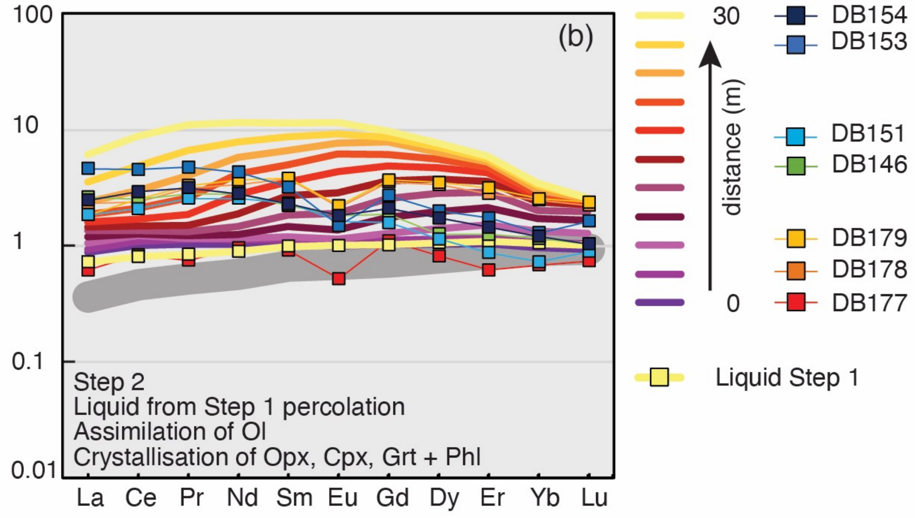


To test this hypothesis, we have numerically simulated the REE gradient applying the Plate Model of Vernieres et al. (1997) using the REE composition of the eclogite leucosome of Pellegrino et al. (2020) as starting melt and the DMM as peridotite matrix.

In the first step, the crustal melt derived from partial melting of eclogites reacts with the peridotite at the eclogite-peridotite interface. The liquids resulting from increasing interactions are assumed to form veins of websterites that are supposed to be the protoliths of tremolitites preserving their original REE composition. After several interactions, the final reacted melt crystallised at the eclogite-peridotite contact likely forms the first websterite DB177, showing a diffusive contact with retrogressed Grt-peridotite .

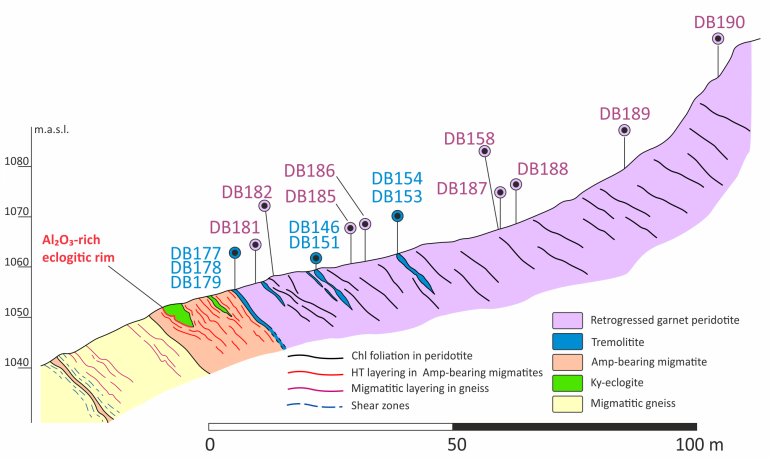


REE GEOCHEMICAL EVOLUTION IN GRT-WEBSTERITES AND PERIDOTITES AT HP



After the interaction at the eclogite-peridotite contact, the reacted melt infiltrates the peridotite producing the REE gradient observed in the tremolitites profile.

We assume an initial peridotite porosity of 20 % that reflects a high perido- tite assimilation coupled with the progressive melt consumption through melt-peridotite reaction during the percolation (i.e. a high extent of transient melt crystallisation), simulated by the progressive increase in crystallisation rate of 50 % Opx, 20 % Cpx, 20 % Grt, 10 % Phl



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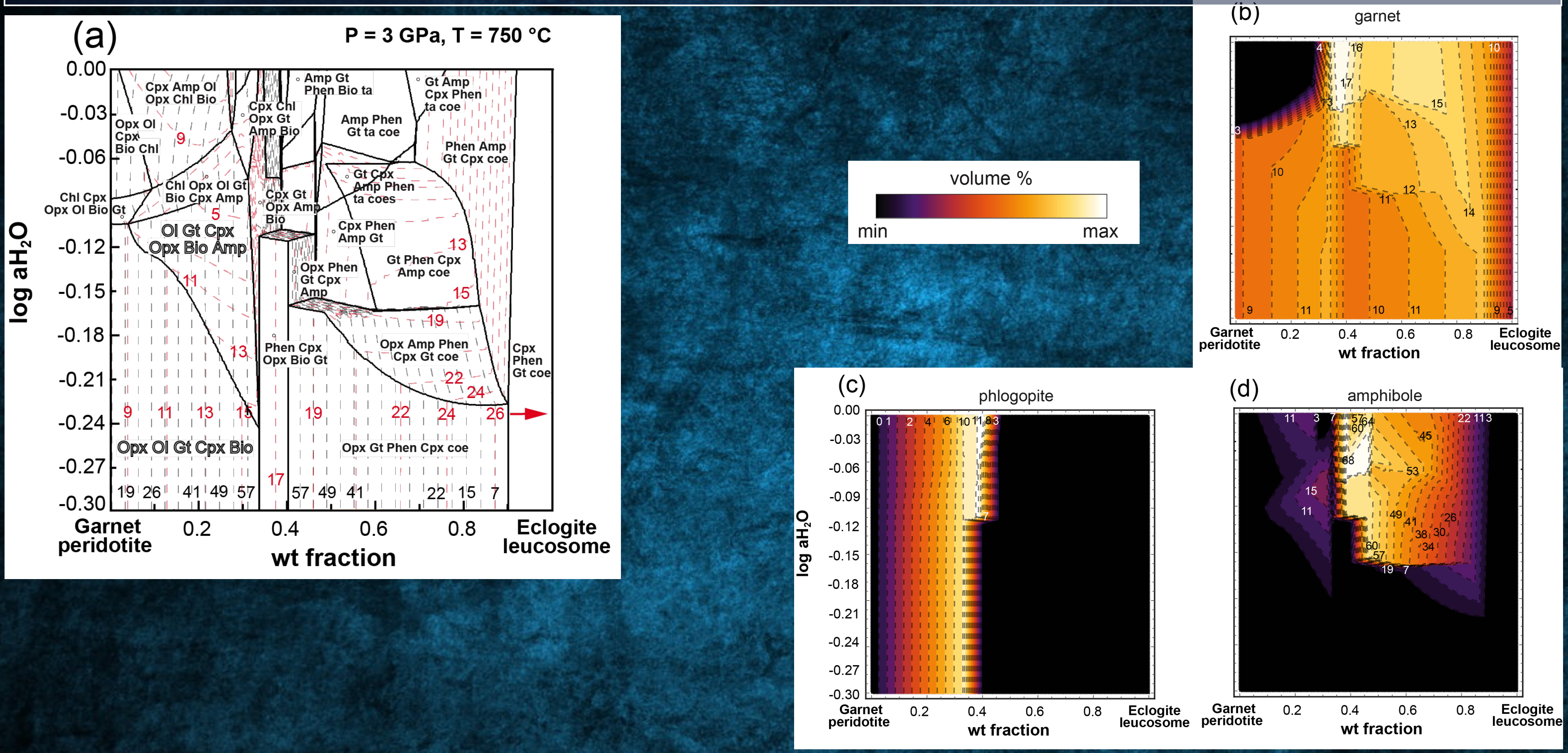
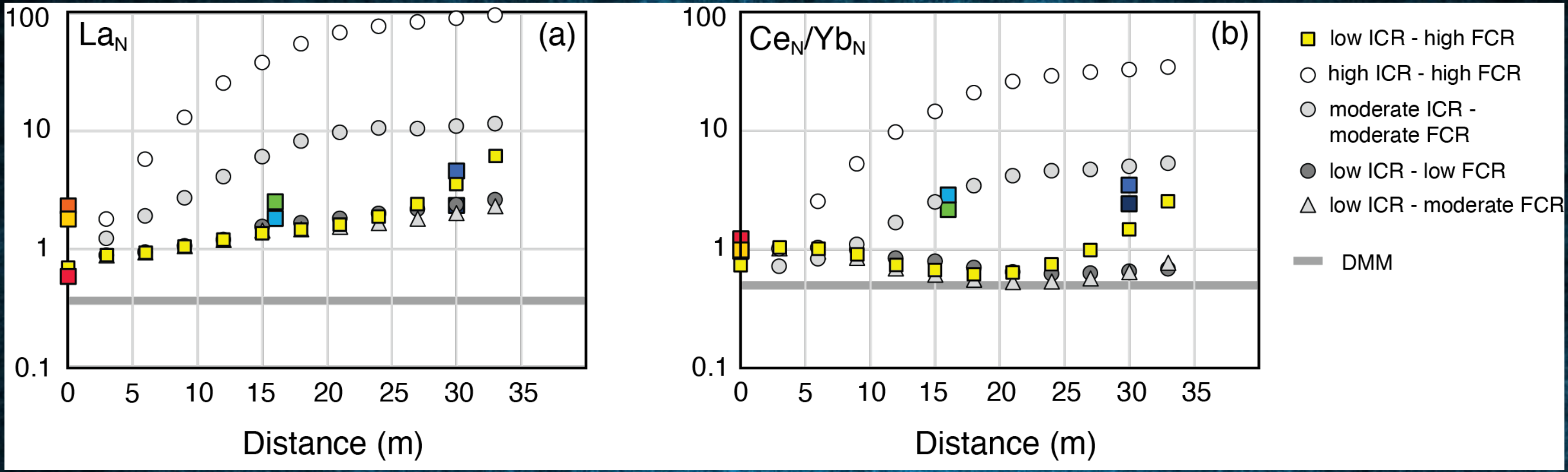


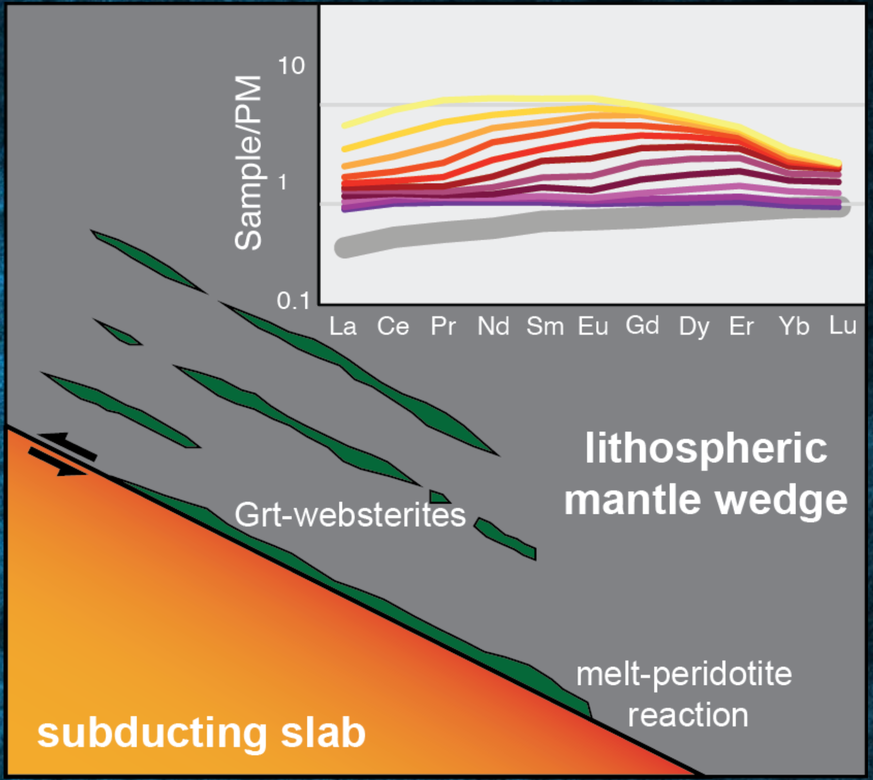
REE GEOCHEMICAL EVOLUTION IN GRT-WEBSTERITES AND PERIDOTITES AT HP



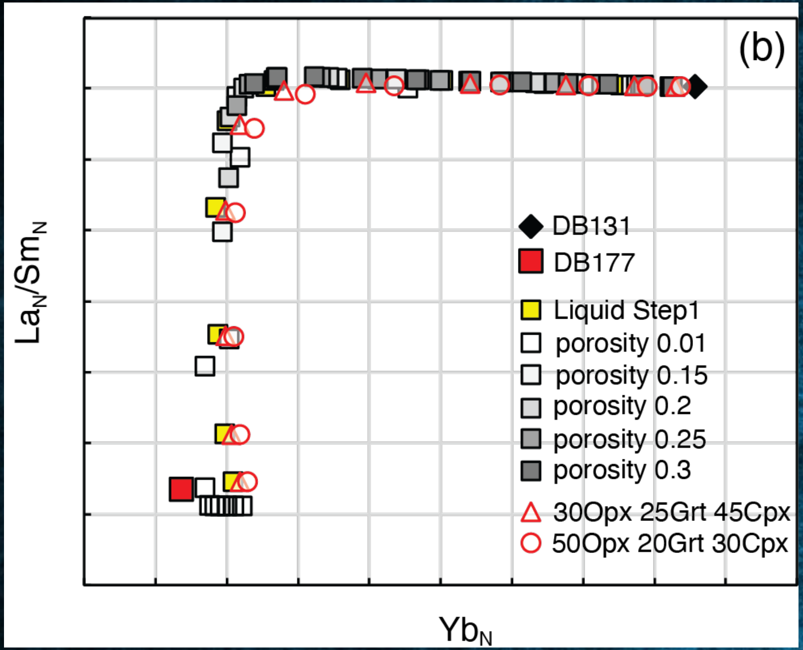
LaN and CeN/YbN resulting from Step 2 calculations (yellow squares) compared with those measured in our tremolitite (coloured squares) along the first 30 m from the eclogite-peridotite contact. Grey scale symbols show the sensitivity of the model to the different extents of initial and final crystallisation rate of the percolating melts in the fractionation of LREE/HREE

POSSIBLE PERSPECTIVES

The numerical simulation aims to model the effect of interaction between crust-derived melts produced by partial melting of mafic components of the slab with the supra-subduction mantle peridotite at sub-arc depths. This includes a first step of crustal magma stagnation and melt-peridotite reaction at the slab-mantle interface and the following metre-scale percolation of reacted melt within the overlying peridotite that buffers the composition of the infiltrating melt.
Reactive melt infiltration at HP is a plausible mechanism to modify the REE budged of mantle peridotites that lie on top of the subducting crustal slab. Samples from those settings tend to show peculiar LREE “spoon-like” fractionations.



SENSITIVITY OF THE MODEL



PM-normalised Yb vs La/Sm of melt resulting from the percolation of the liquid after Step1 at variable porosity (squares) and 30% or 50% of orthopyroxene (triangles and circles) in the crystallizing assemblage.

The model shows that at high Ma/Mc ratio the addition of variable amount (30 or 50%) of orthopyroxene (having rather low Kd for the REEs) in the crystallizing assemblage does not impact significantly on the melt REE composition resulting from the reaction. We also evaluated the role of variable extent of initial porosity: Figure S-6b shows that porosity higher than 0.1 fails to reproduce the low LaN/SmN of melt that generated the retrogressed Grt-websterite (DB177) close to the contact with the peridotite-eclogite interface. On contrary, assuming porosity lower than 0.1 the model results in too fast melt LaN/SmN lowering.