Transmission electron microscopy (TEM) investigations of (hydrous) chain silicates from the lithospheric mantle beneath the Carpathian Pannonian region (CPR)

Pargasite, as a hydrous chain silicate plays a **key role in water storage in the mantle** and its presence causes the **rheologic contrast** between the lithosphere and the asthenosphere (Green et al., 2010; Kovács et al., 2017). **CPR mantle xenoliths** contain interstitial and micro lamellar pargasitic **amphibole.**

OBJECTIVE:

To find the micro and nano-lamellae of **pargasite** in CPR mantle xenoliths, and constrain their formation via **TEM.**

ZSÓFIA PÁLOS[1,3*], PÉTER PEKKER[4], MIHÁLY PÓSFAI[4], THOMAS P. LANGE[1,2], NÓRA LIPTAI[1,2], MÁRTA BERKESI[1,2], CSABA SZABÓ[1,3], ISTVÁN KOVÁCS[2,3]

[1]Lithosphere Fluid Research Lab (LRG), Eötvös Loránd University, Budapest, Hungary

[2]MTA CSFK Lendület Pannon LitH$_2$Oscope Research Group

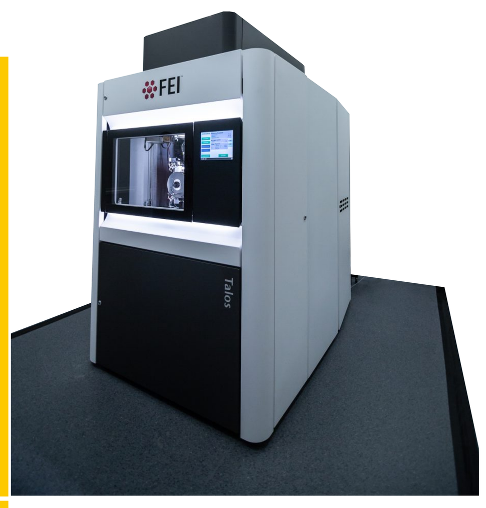
[3]MTA CSFK Geodetic and Geophysical Institute, Sopron, Hungary

[4]Nanolab, University of Pannonia, Veszprém, Hungary

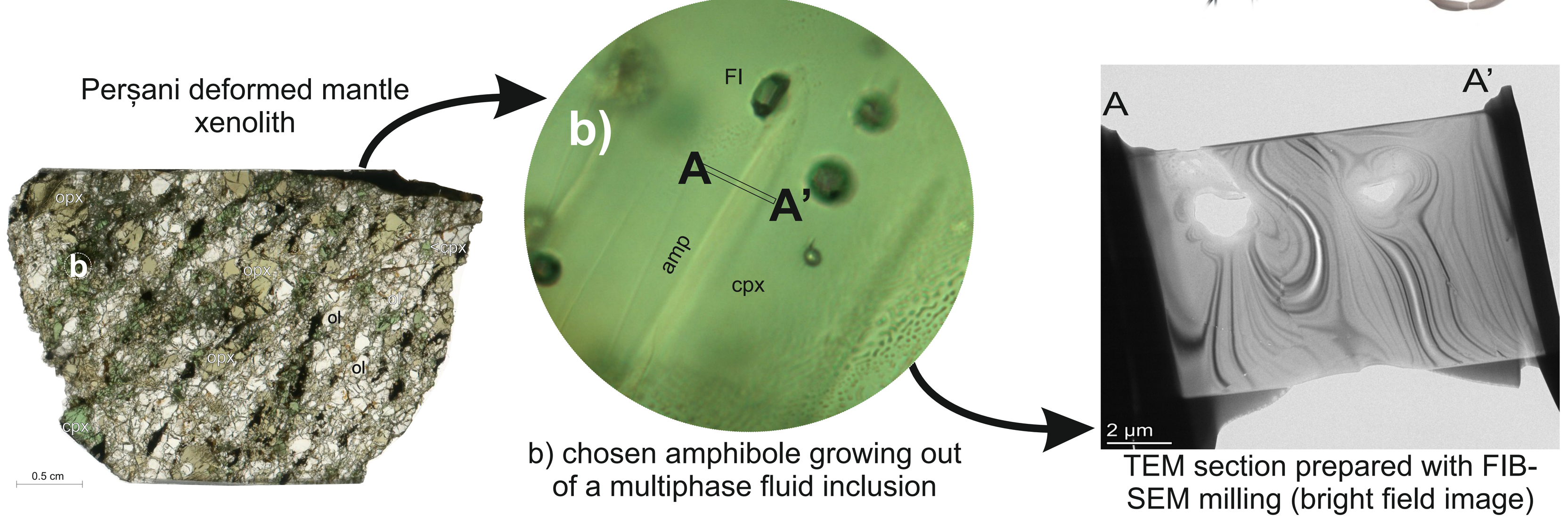
(*correspondence: paloszsofia@gmail.com)

Methodology

TEM investigations provide us with new aspects on the behaviour of mantle minerals. TEM has not been used to study pyroxenes from lithospheric mantle xenoliths in the past decades.

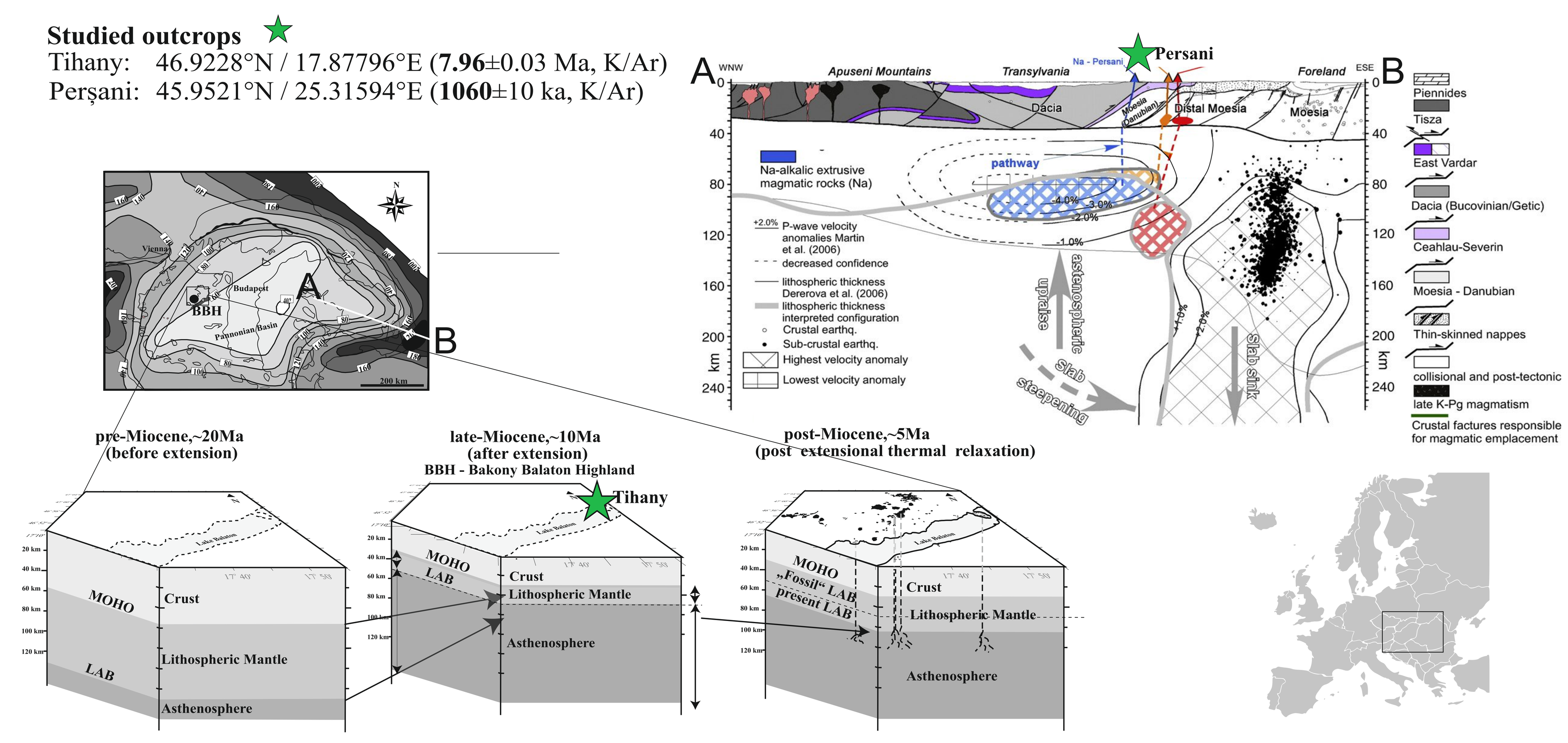


Through focused ion beam (FIB-SEM) micro sampling, a well defined TEM lamella could be prepared, which fulfills the challenges of orientation (perpendicular to the *c* axis) the pyroxene and finding the interface with the amphibole.



Geological background

The studied mantle xenoliths were brought to surface in the Carpathian Pannonian region (CPR) by the plio-pleistocene alkaline basalt volcanism.

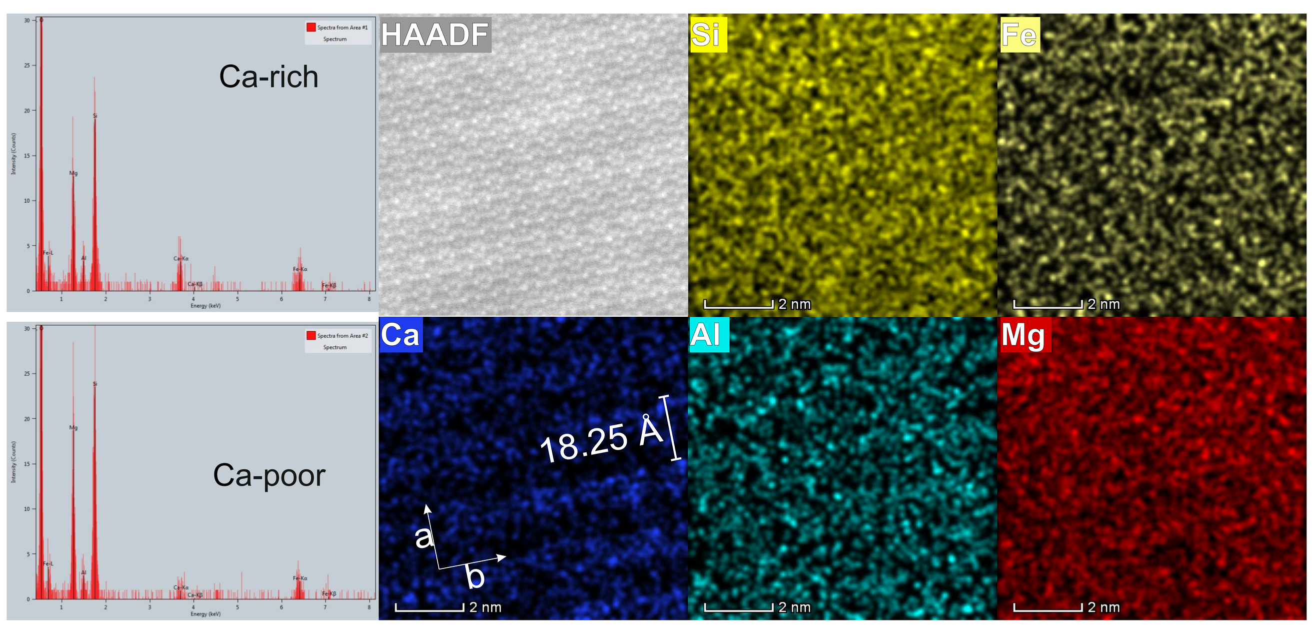


Carpathian-Pannonian region sample location and neogene evolution modified after Seghedi et al., (2011) and Kovács et al., (2012). Geochronological data displayed by Wijbrans et al., (2007) and Seghedi et al., (2016)

The **central** CPR sample (**Tihany**), is of **lithospherized** astenospheric origin, the **marginal** CPR (**Perșani**) is from a **metasomatised** mantle domain by a downgoing, torn off slab.

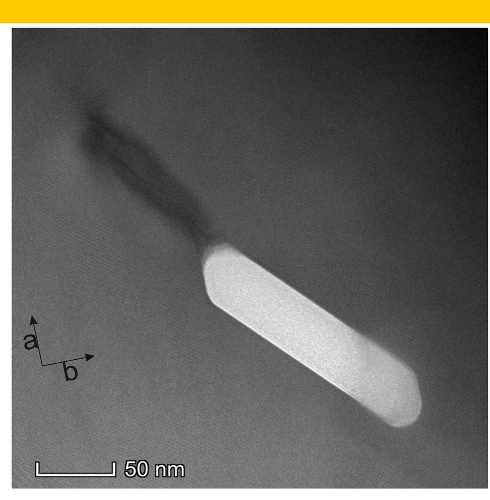
Tihany samples

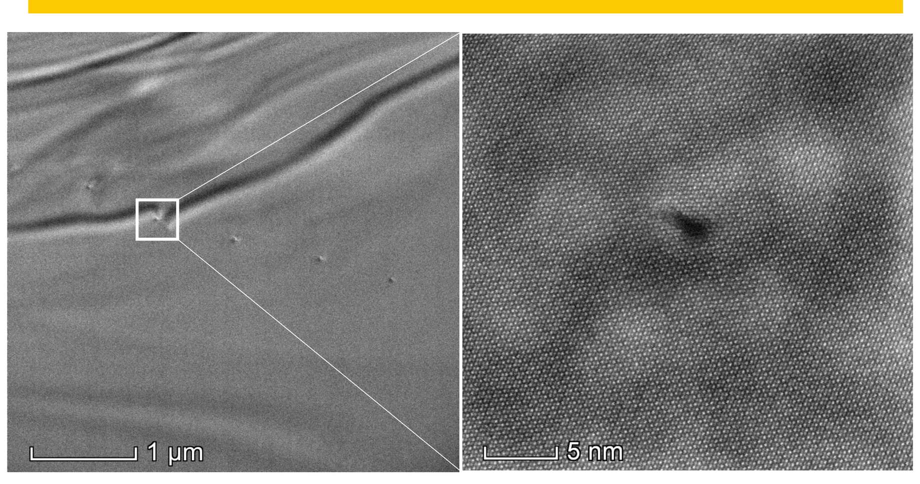
Amphibole lamellae were not found in the central CPR (Tihany) pyroxenes. The nano inclusions and dislocations may indicate the preceding state of the 'freshly formed' lithosphere, where the **single ribbon amphibole lamella exsolution** would take on the scale of **10 million years** (Veblen, 1991).



▲EDS spectra of Ca-ordered and non-ordered Ca-poor domain in the Tih-0509 orthopyroxene, section is perpendicular to *c* axis. STEM HAADF image and elemental maps form the Ca-ordered domain. Ca ordering is unit cell scale (a=18.25 Å). The Ca in orthopyroxene structure controls the substitution of trace elements (Buseck and Veblen, 1978). Ca ordering can indicate slight **Ca enrichment** (Boland, 1972) and/or **exsolution of Ca-rich lamellae** (or clinopyroxene exsolution from orthopyroxene) by **cooling** (Weinbruch et al., 2003).

▼Series of **dislocations** in clinopyroxene, there is a low-angle (<1°, the subtle difference in orientation is visible from low angle) grain boundary, which **could act as a channel for diffusion**, promoting the formation of hydrous chain silicates (pargasite or biopyriboles).



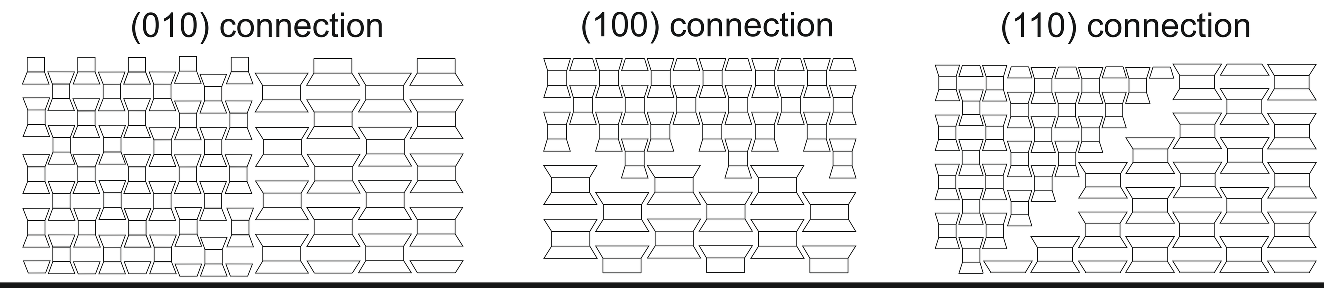


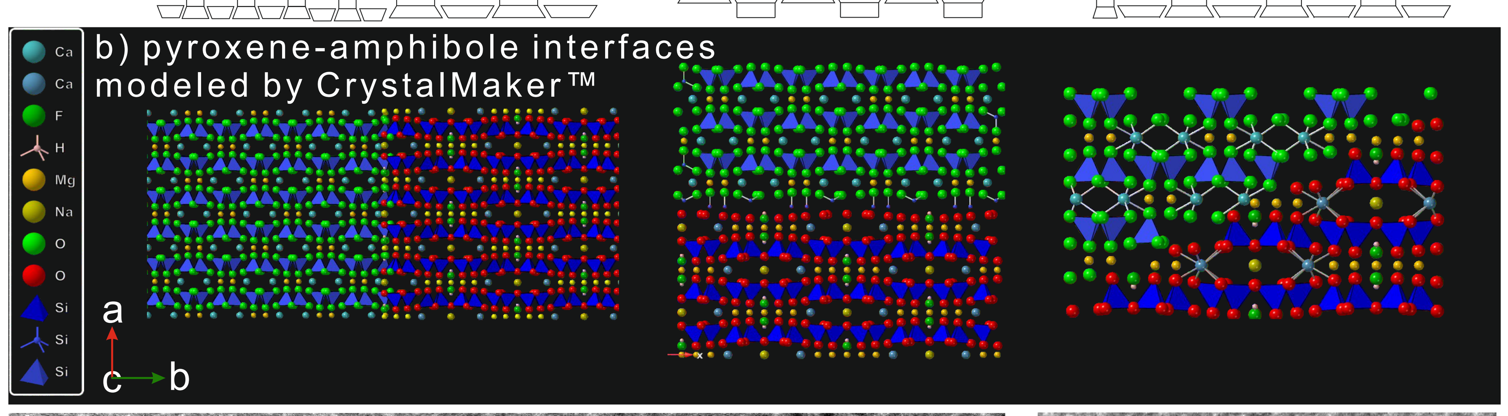
▲Bright field TEM image of a **negative-crystal shaped nano inclusion** in orthopyroxene with a dislocation in the upper left corner. The dislocations can act as diffusion pathways for H_2O and other fluids (Bakker and Jansen, 1994). There are no variations of the crystal chemistry in the crack or in the inclusion as traces of former diffusion.

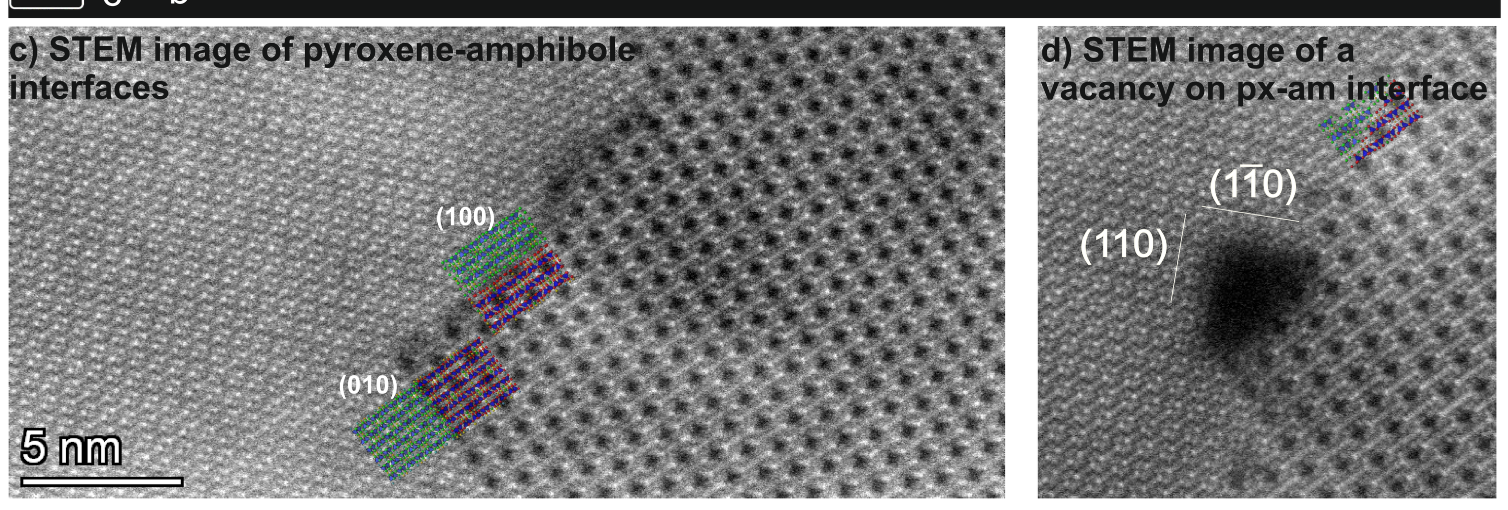
Perșani sample

Formation of the studied amphibole lamella is possible through the **reaction of the trapped fluid and the host** clinopyroxene, through deformation-induced dislocations (Skrotzki, 2001) and **structural channels** on the amphibole-pyroxene interface (Veblen and Buseck, 1981).

a) I beam model of the observed pyroxene-amphibole interfaces







▲On the amphibole-pyroxene interface (modeled on picture (b) amphibole: red O atoms, pyroxene: green O atoms), only the (010) boundary gives perfect fit. The (100) and (110) boundaries are uneven, favor the formation of grain boundary misfit, thus opening structural channels (d) that **result in increased diffusion rate** (Veblen, 1991).

CONCLUSIONS:

- **Central CPR** Tihany mantle pyroxenes show features related to a possible amphibole formation, however either the time frame to exsolve amphiboles was too narrow, either the decreased water activity in the post-extensional setting (Patkó et al., 2019) hindered the process.
- The **marginal CPR** sample Perșani clinopyroxene shows amphibole lamellae, where the entrapment of a metasomatic fluid inclusion and the host-fluid reaction was the possible mechanism of amphibole formation. This is consistent with the findings of Liptai et al., (2019), that the pargasitic amphiboles are more abundant on the marginal localities of CPR.

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