High-Mg amphibole and bulk-rock composition from Ciomadul dacitic pumices suggest rapid eruption trigger by strongly hydrous mafic magma recharge

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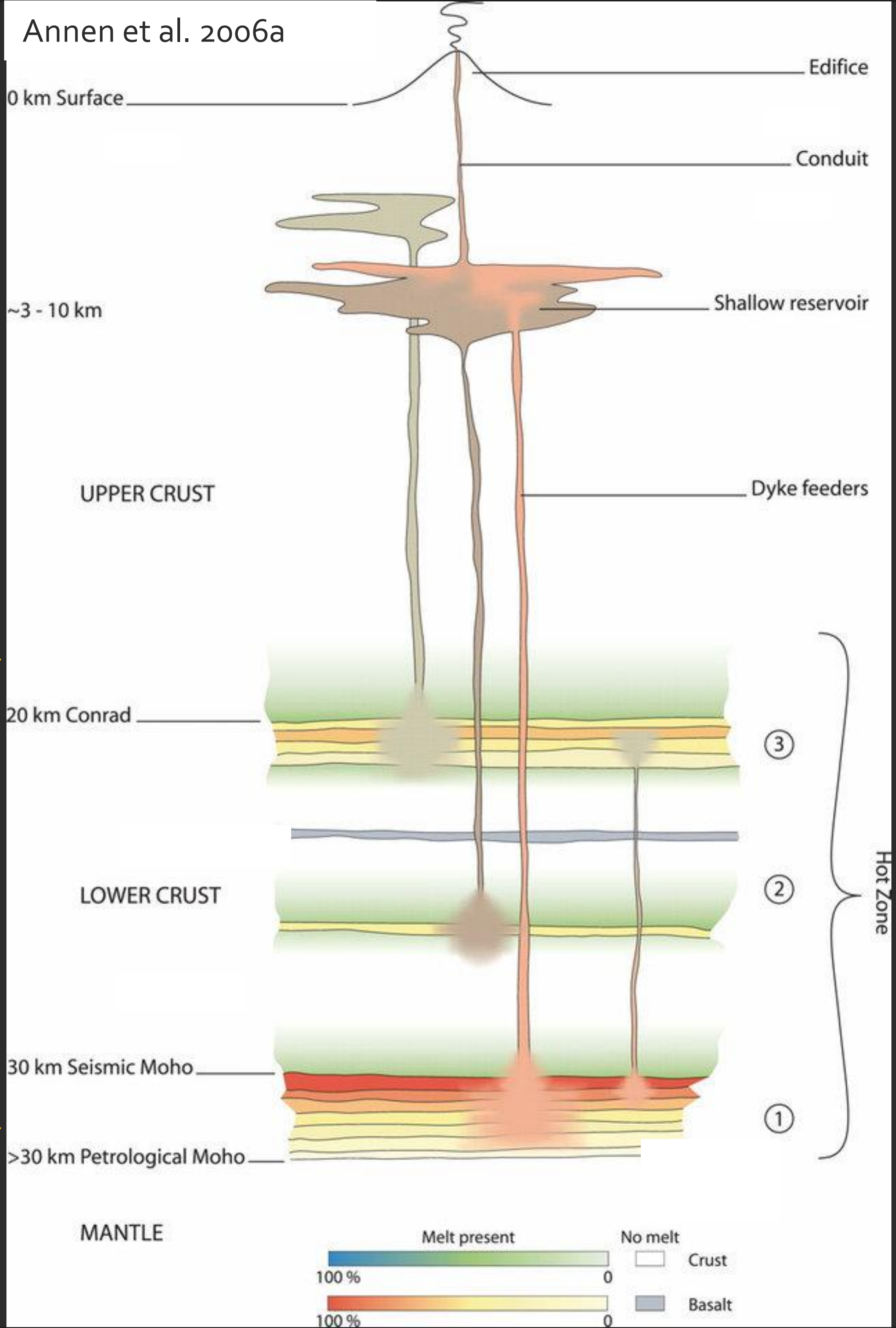
What lies beneath volcanoes?

Shallow crustal storage: abundant direct information from the erupted volcanic products

Deep magma storage: limited direct information mainly from cognate enclaves and mafic crystal clots



MOTIVATION - BACKGROUND PUBLICATIONS

- Vinkler et al. 2007: „High-Mg crystal phases - mantle-derived xenocrysts or early crystallizing product from a primitive mafic magma” → pyroclastic deposits

- Kiss et al. 2014: „remobilization of upper crustal silicic crystal mush body by hot mafic magma” → older lava dome activity

- Laumonier et al. 2019: „This dominantly felsic upper crustal mushy magma storage is underlain by a hot lower crustal zone with mafic magma accumulation.”

- Lukács et al. 2021: „To maintain magma reservoir for such a long time above solidus, continuous magma input by deeper recharge is required.”

METHODOLOGY

Integrated textural and geochemical study of mineral and glass phases – a kind of crystal forensic investigation to reveal magma storage processes

- 1. Polarizing petrographic microscope: ELTE TTK FFI, Department of Petrology and Geochemistry, microscope laboratory
- 2. SEM-EDS: ELTE TTK FFI, Department of Petrology and Geochemistry, Scanning electron microscope laboratory
- 3. Microprobe-WDS: University of Göttingen, GeoZentrum, Germany, electron microprobe laboratory
- 4. LA-ICP-MS, Microprobe-WDS: CNRS-ISTO Orléans, France, LA-ICP-MS and electron microprobe laboratory
- 5. Bulk-rock major and trace element: AcmeLabs Ltd., Vancouver, Canada

Amphibole cation calculation and classification based on Leake et al. (1997) for 23 anions.

CIOMADUL VOLCANO, ROMANIA, EAST CARPATHIANS, EUROPE: FROM 1 MA TO 30 KA ERUPTION HISTORY

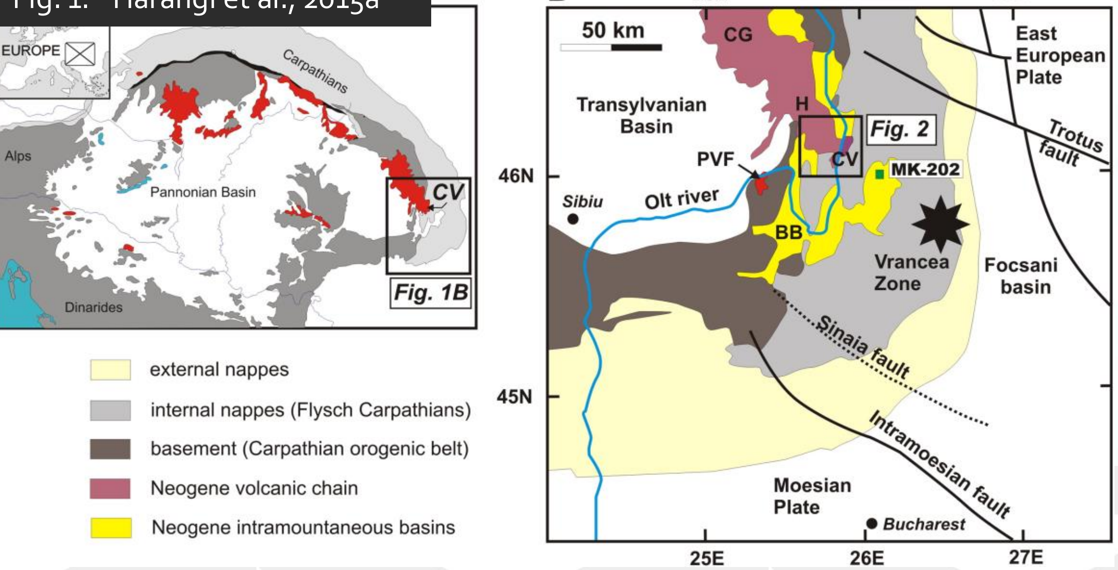
The youngest volcano in Eastern Central Europe!

Old Ciomadul Eruption Period
(1 Ma – 300 ka, 1-3rd Eruption Episode)
and
Young Ciomadul Eruption Period (160–30 ka, 4-5th Eruption Episode)

~ 40 kyr long quiescence

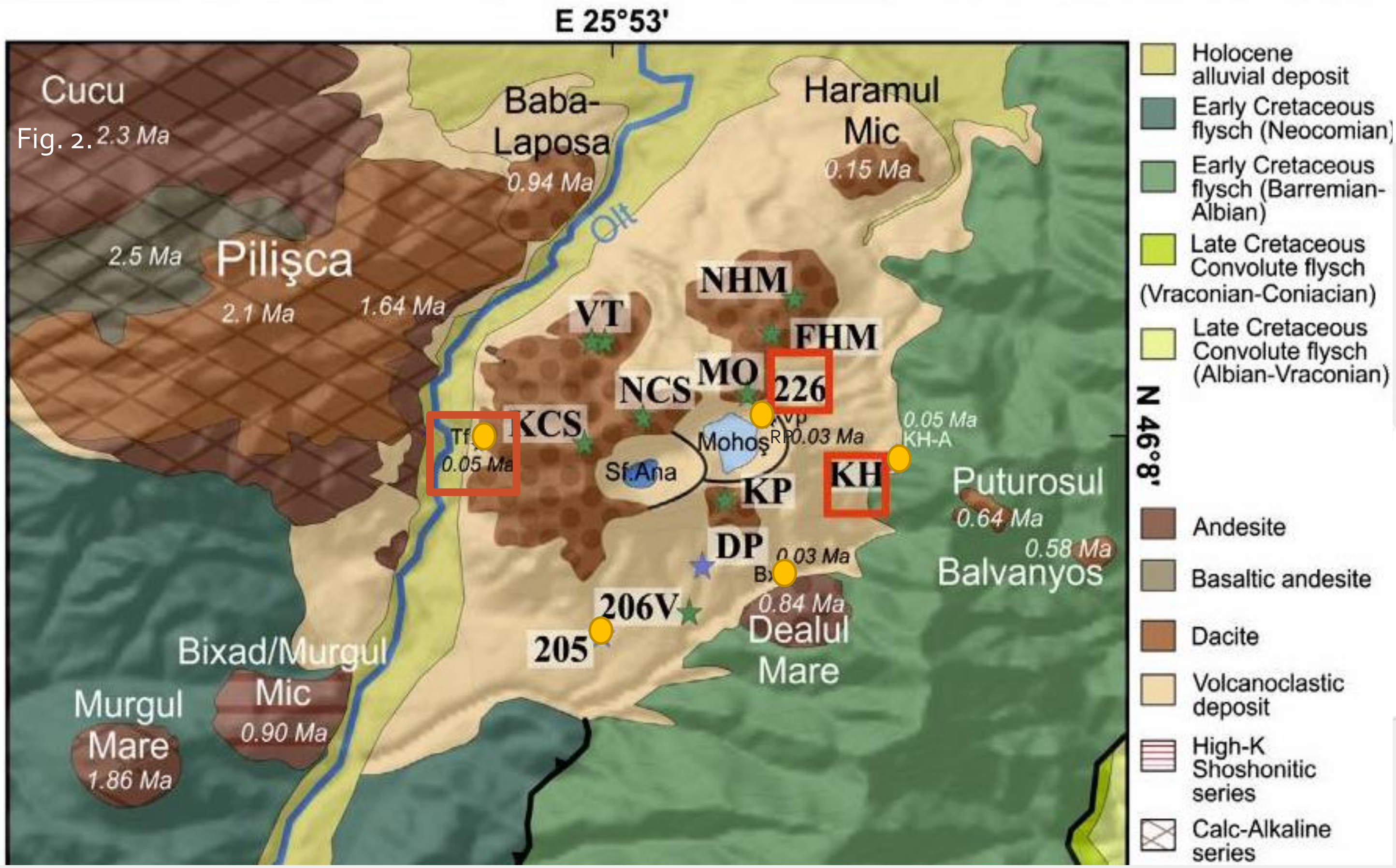
5th Eruption Episode (Ee5): 56-30 ka explosive eruptions

Fig. 1. Harangi et al., 2015a



226+KH: Mohos unit (early 56-45 ka explosive eruption product; Tf: Tuşnadul unit (50 ka explosive eruption product)

● Presence of px within amph/mafic crystal clots



Molnár et al. 2019 after Szakács et al. 2015

STUDIED MATERIAL

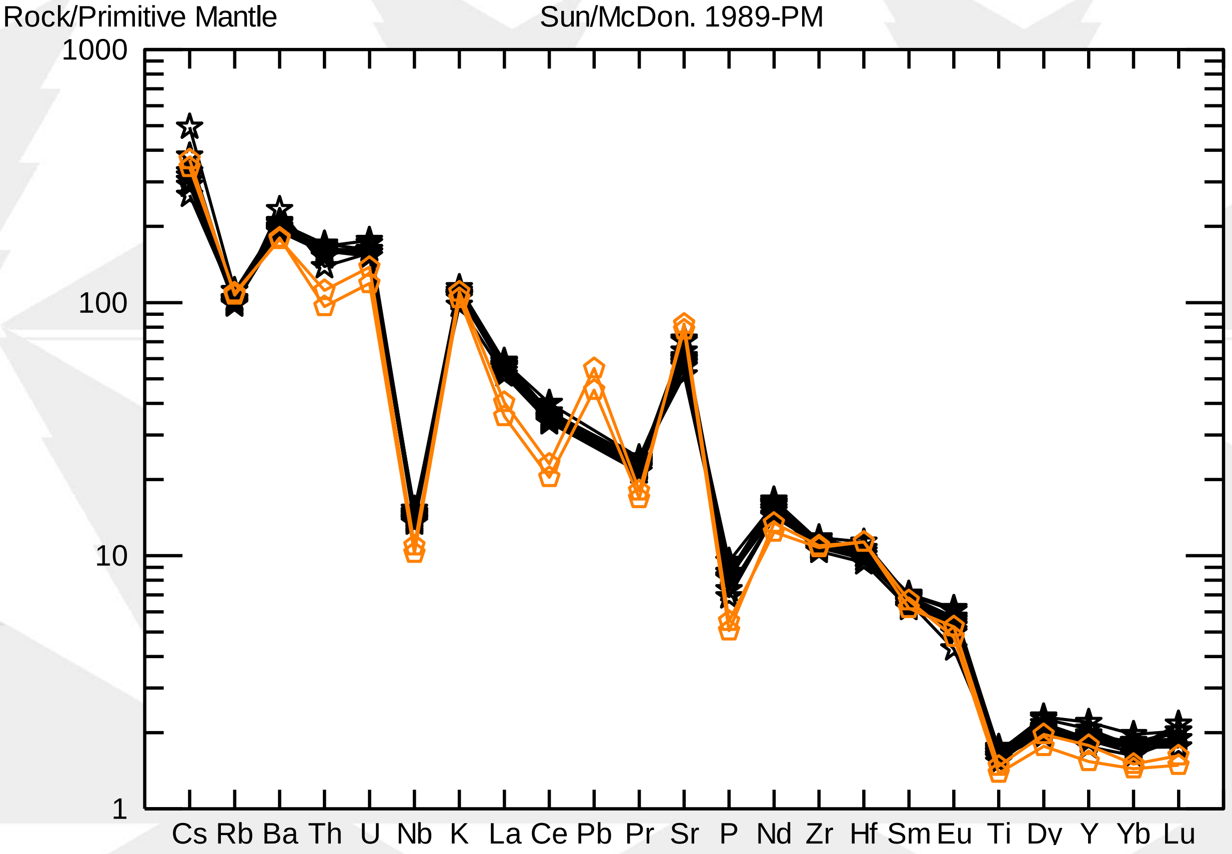
Pumice from explosive eruption

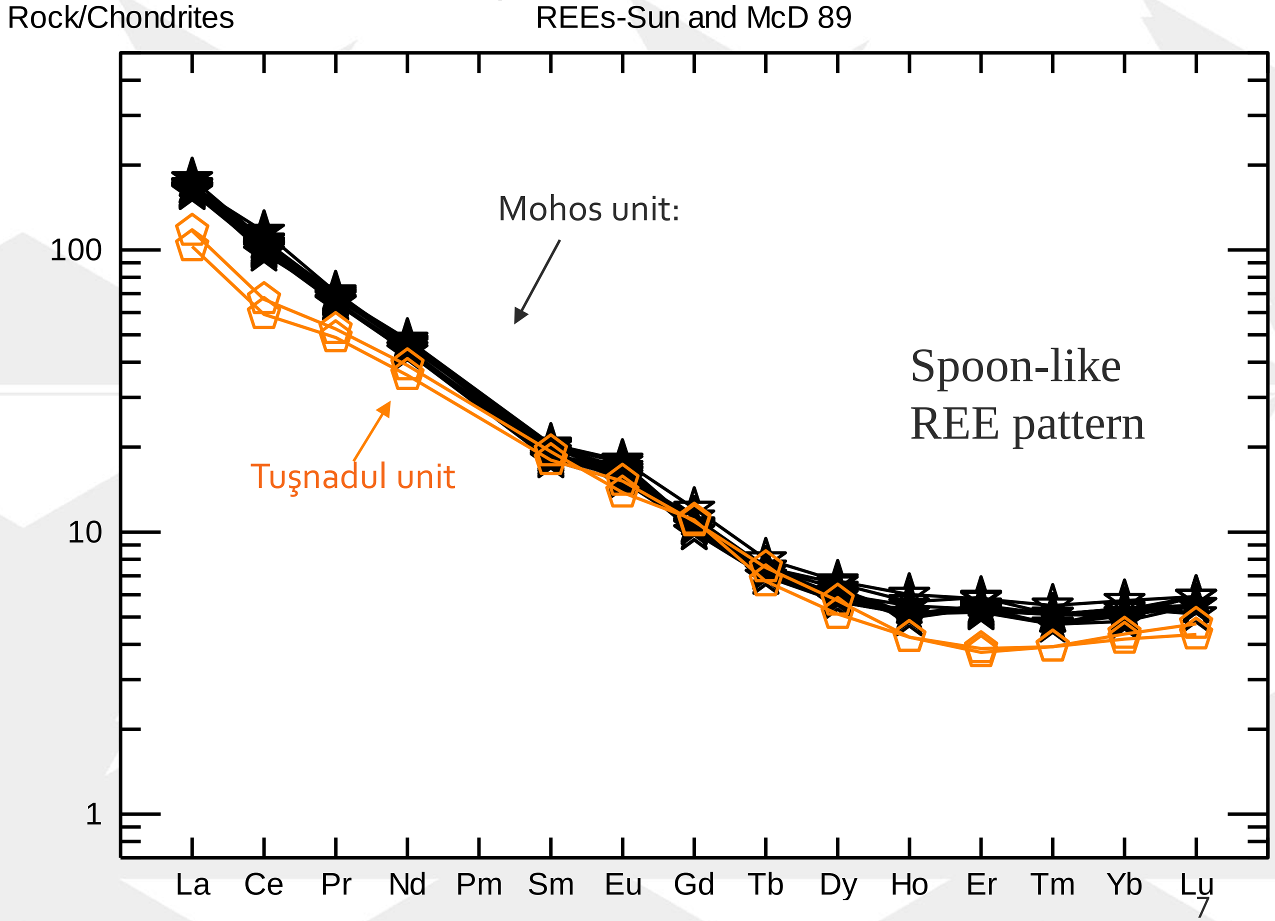
Macrocrysts:

Plagioclase, amphibole, biotite

BULK ROCK DATA

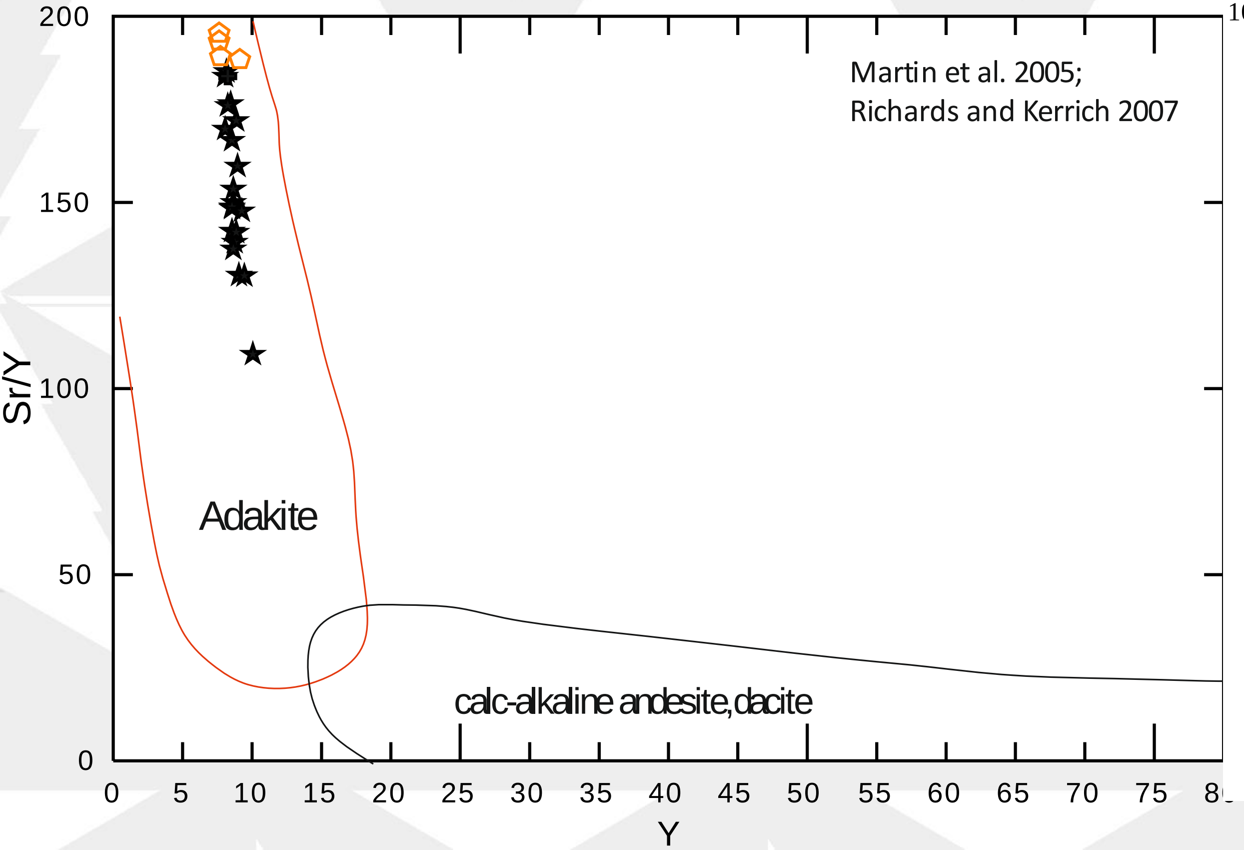
Relatively high-Mg values: Mohos unit (56-45 ka products): 0.48-0.64; 0.54-0.56 in the Tusnadul unit (50 ka pumices))
Sr/Y (Mohos unit (56-45 ka products): 109-185; 188-235 in the Tusnadul unit (50 ka pumices))
Dy/Yb (Mohos unit (56-45 ka products): 1.54-1.92; 1.65-2.13 in the Tusnadul unit (50 ka pumices))

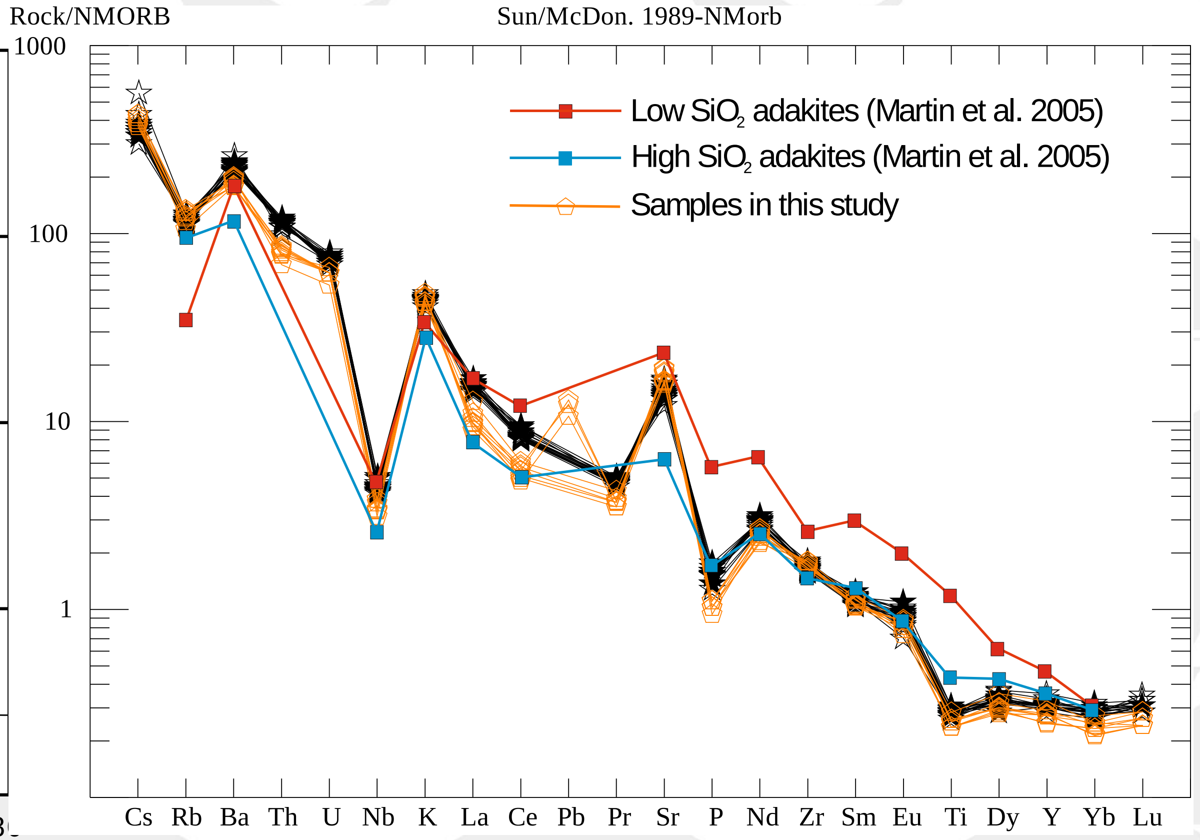




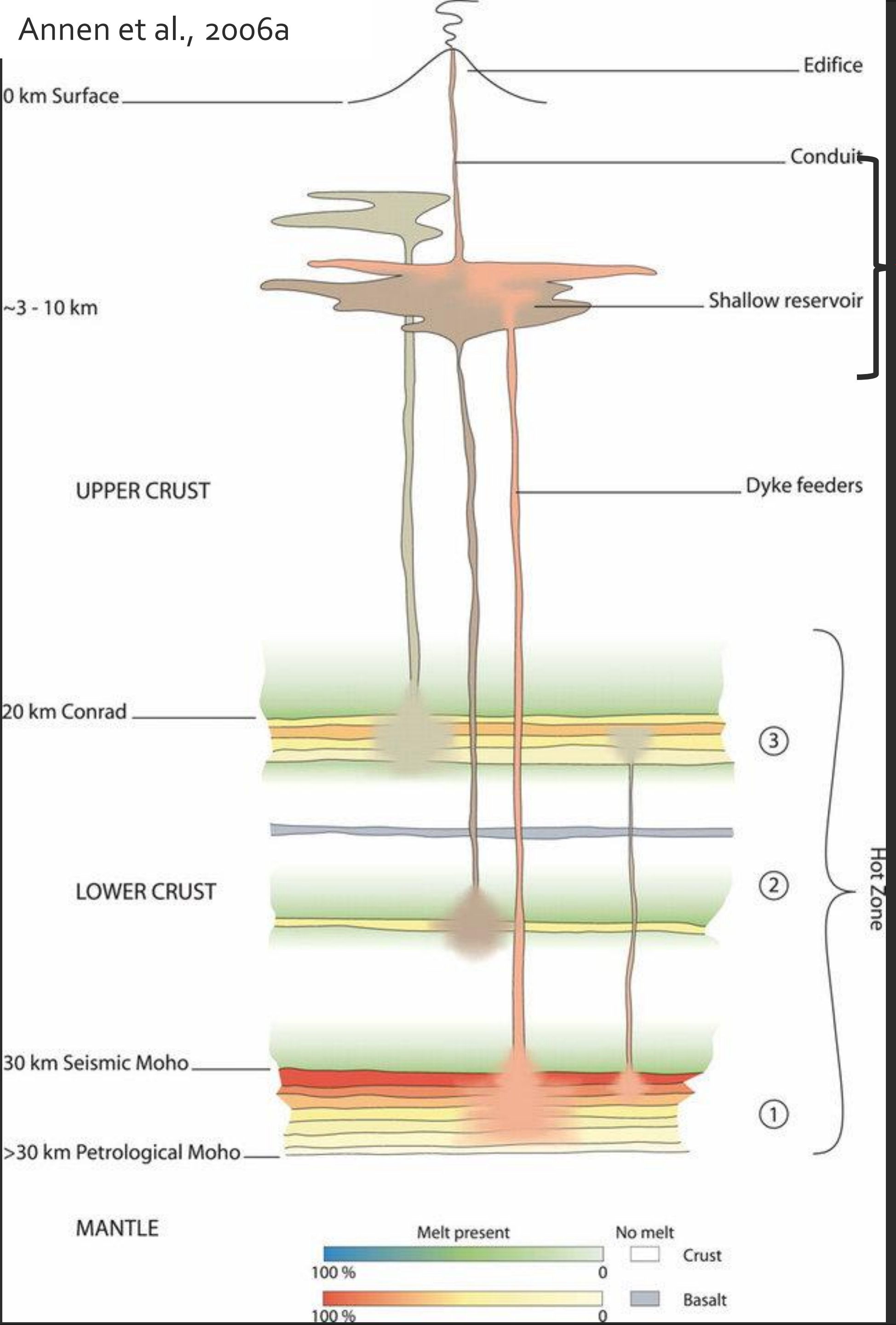
BULK ROCK DATA

Relatively high-Mg values (avg. of 0.56-0.62 mol%)
Sr/Y (Mohos unit (56-48 ka products): 147-157; 225 in the Tusnadul unit (50 ka pumices))
Dy/Yb (Mohos unit (56-48 ka products): 1.71-1.73; 1.89 in the Tusnadul unit (50 ka pumices))
⇨ ~adakite-like rocks.

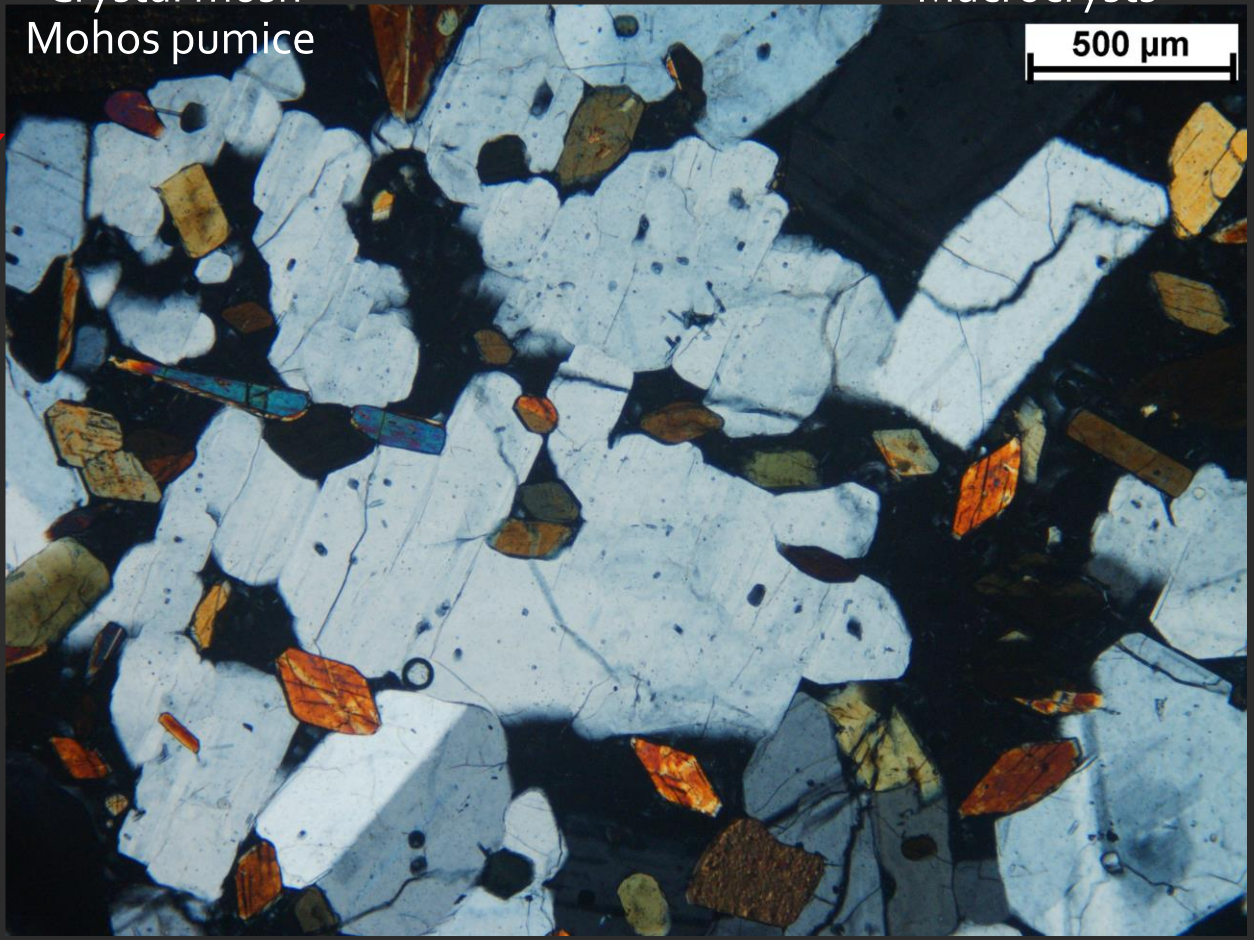




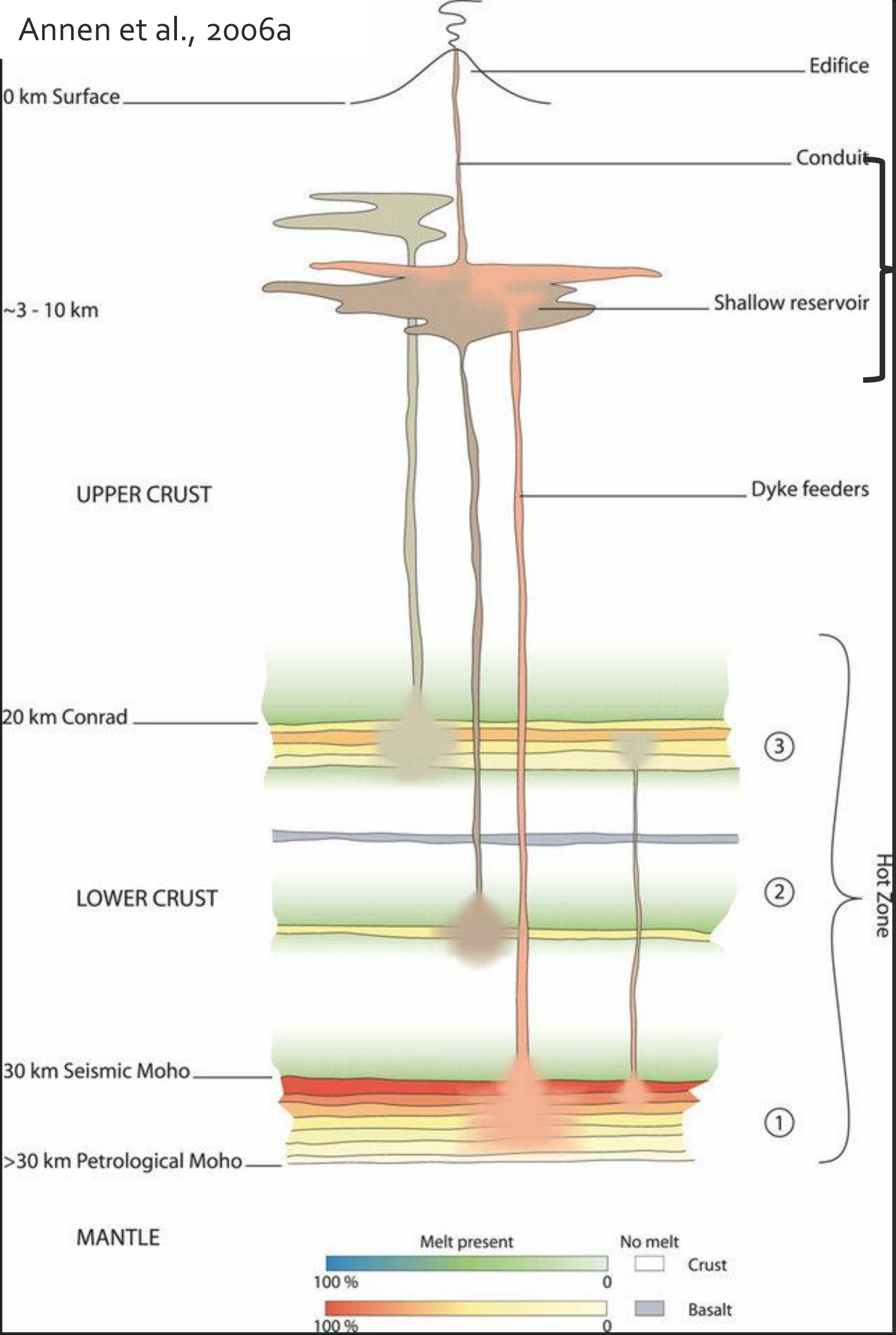
Annen et al., 2006a



Crystal mush
Macrocrysts

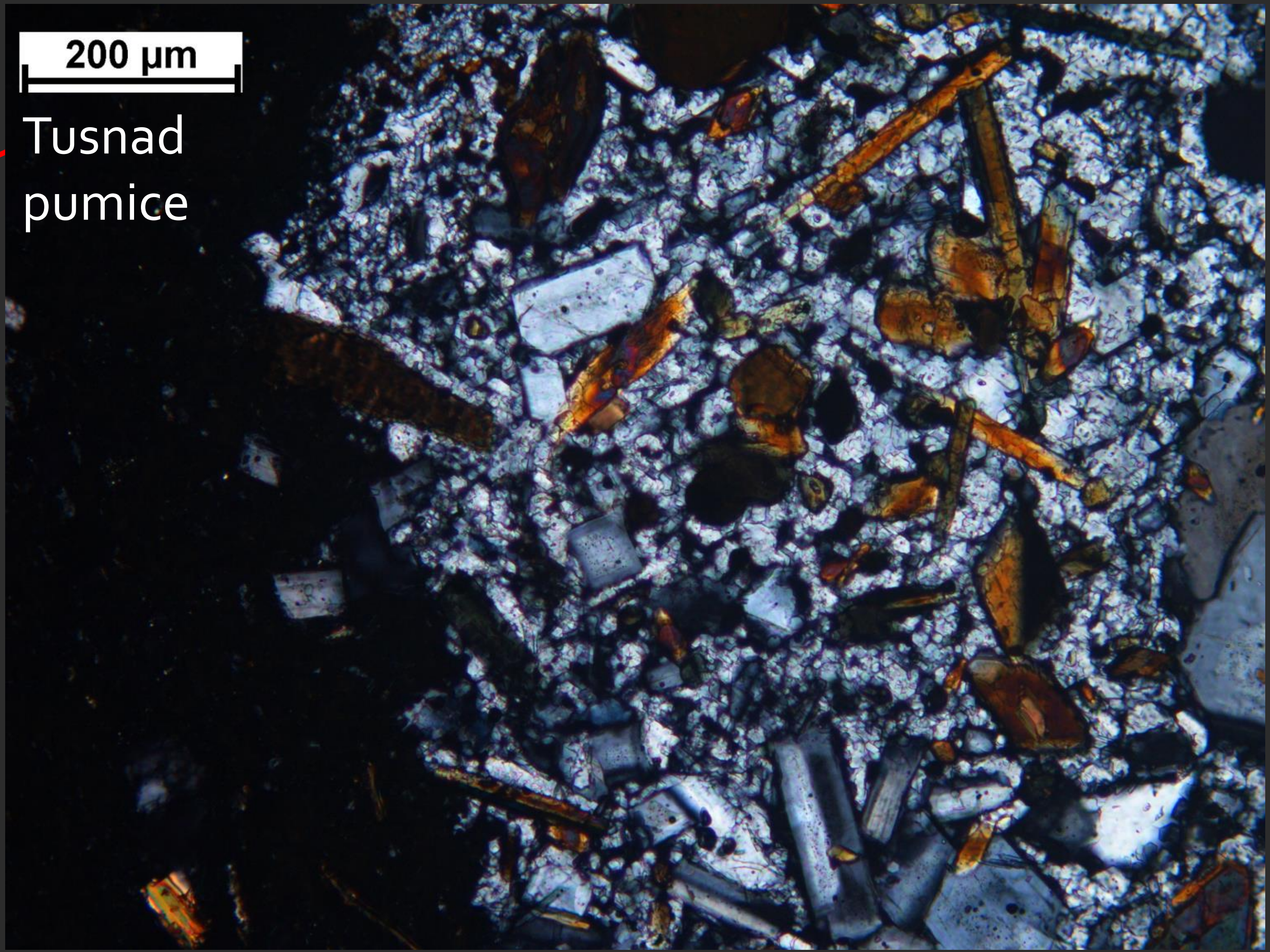


crystal mush – 760 –800 °C (Holland and Blundy 1994)



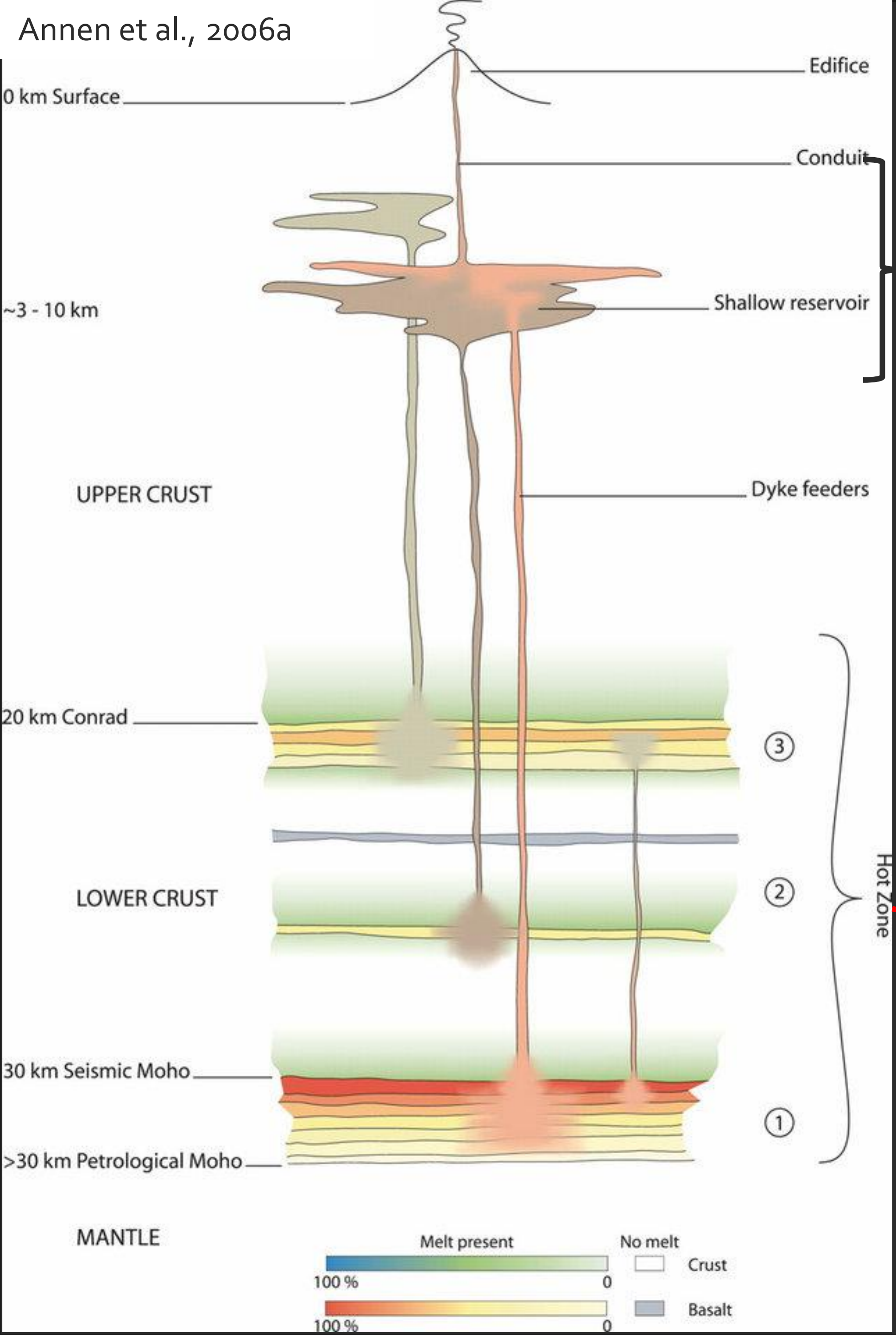
Crystal mush component

Macrocrysts



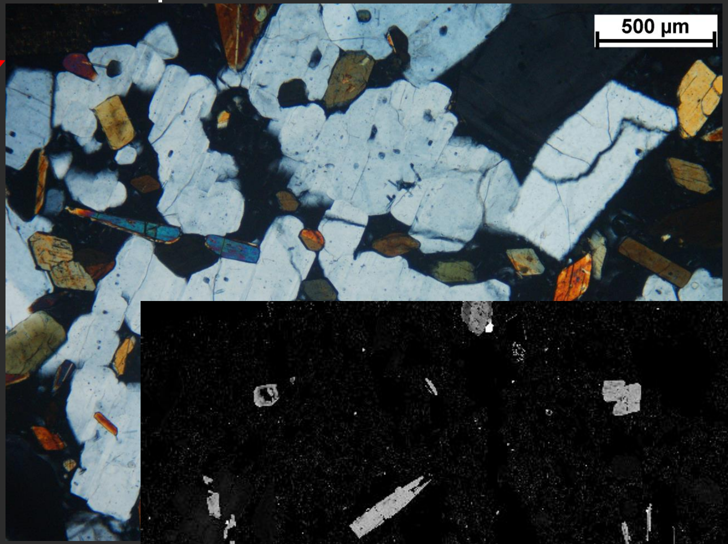
crystal mush – 690 –715 °C (Holland and Blundy 1994)

Annen et al., 2006a



Crystal mush

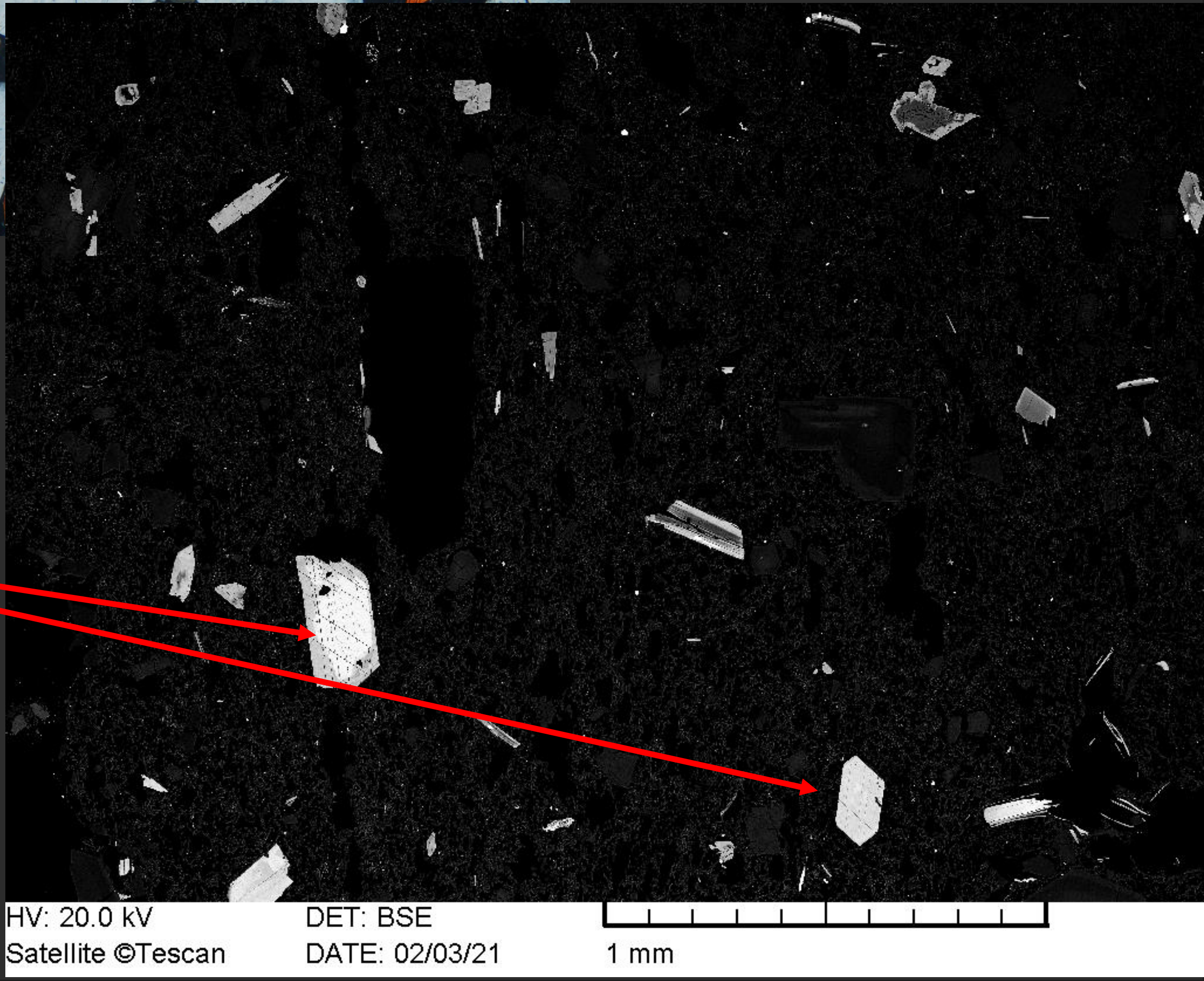
Mohos pumice



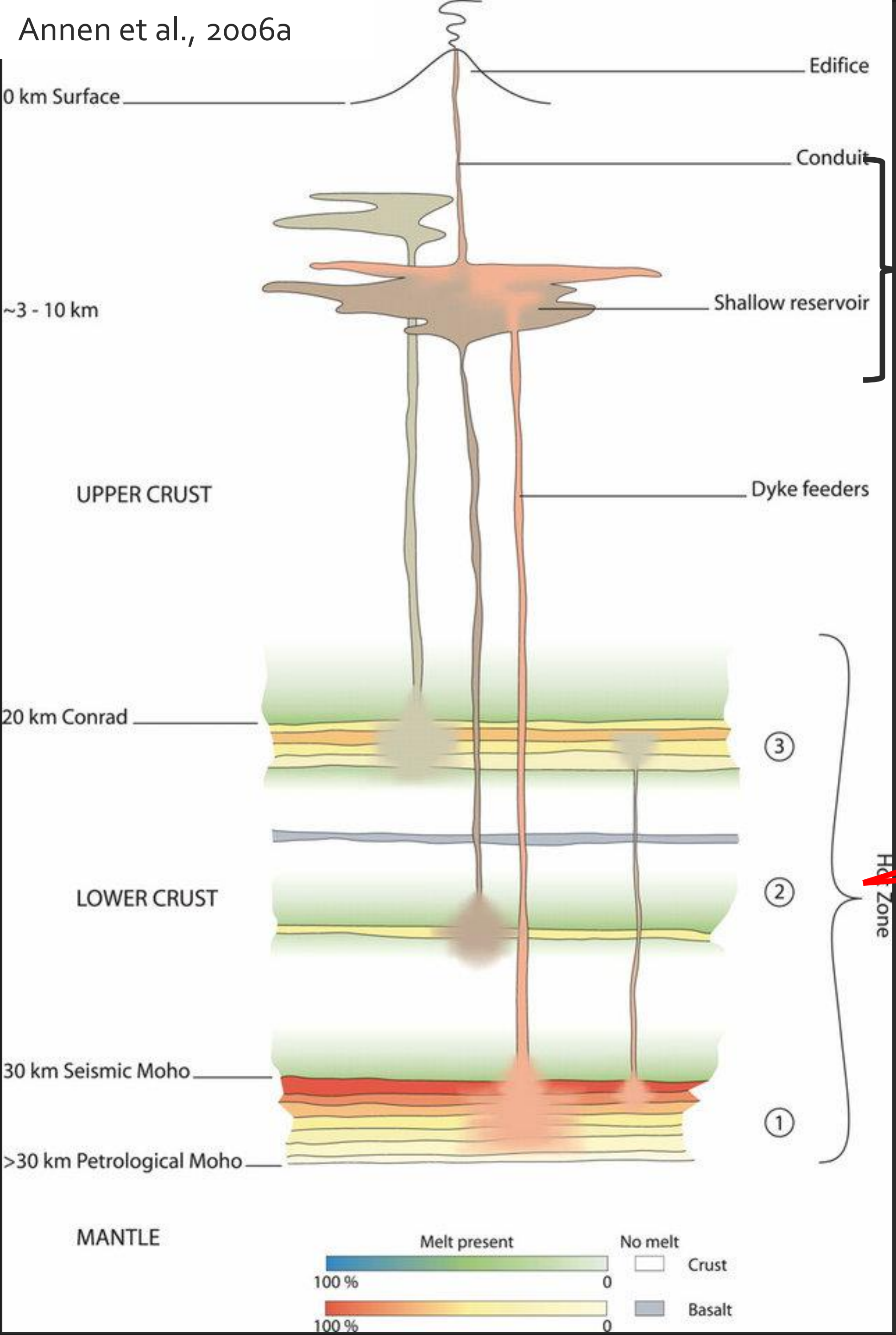
Macrocrysts

Diverse amphibole crystals

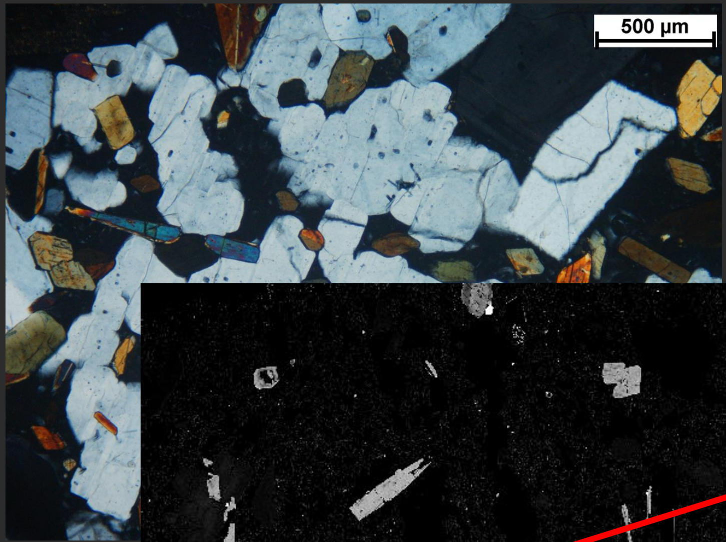
Amphibole crystals with low MgO and low Al_2O_3



Annen et al., 2006a



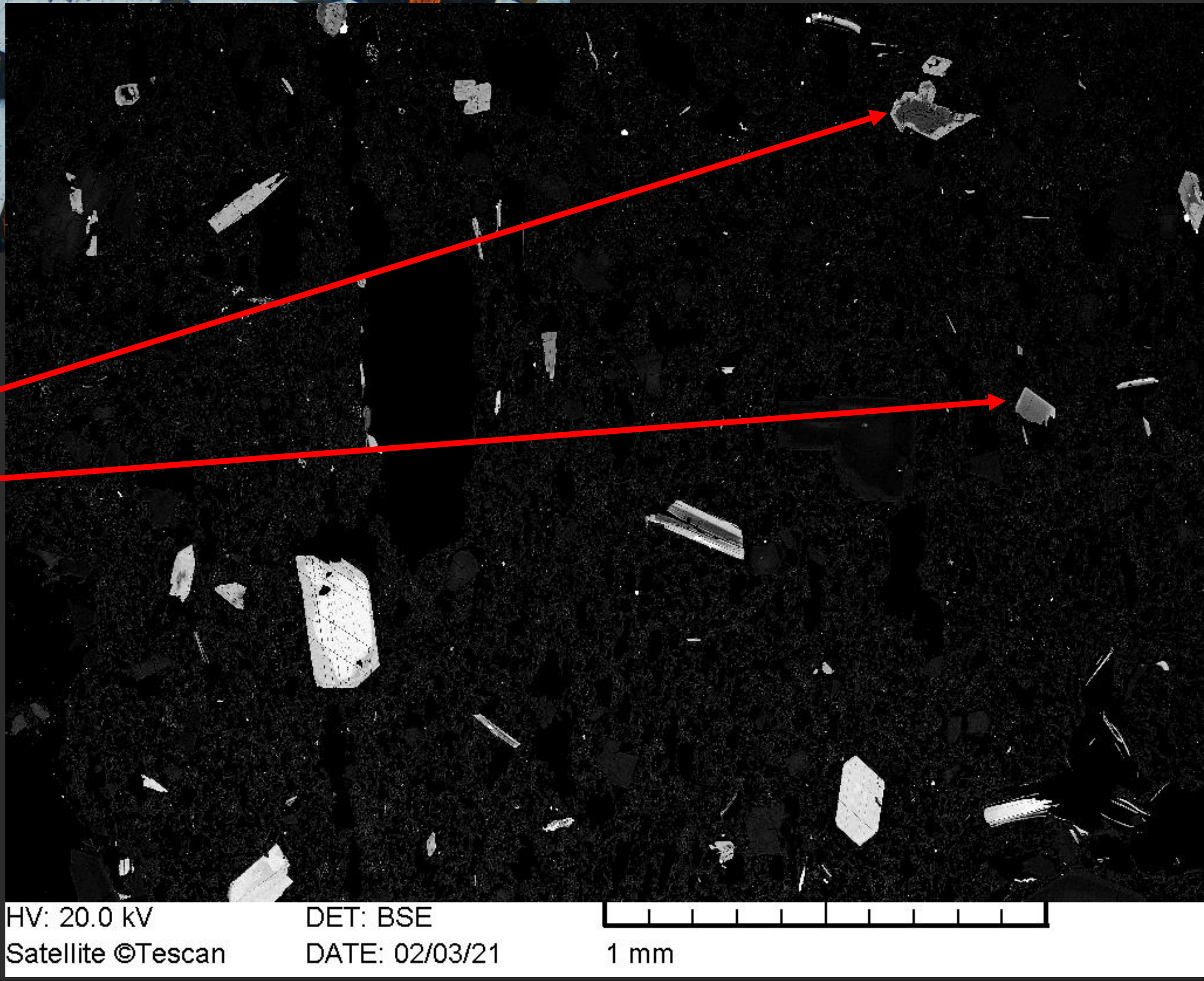
Crystal mush
Mohos pumice



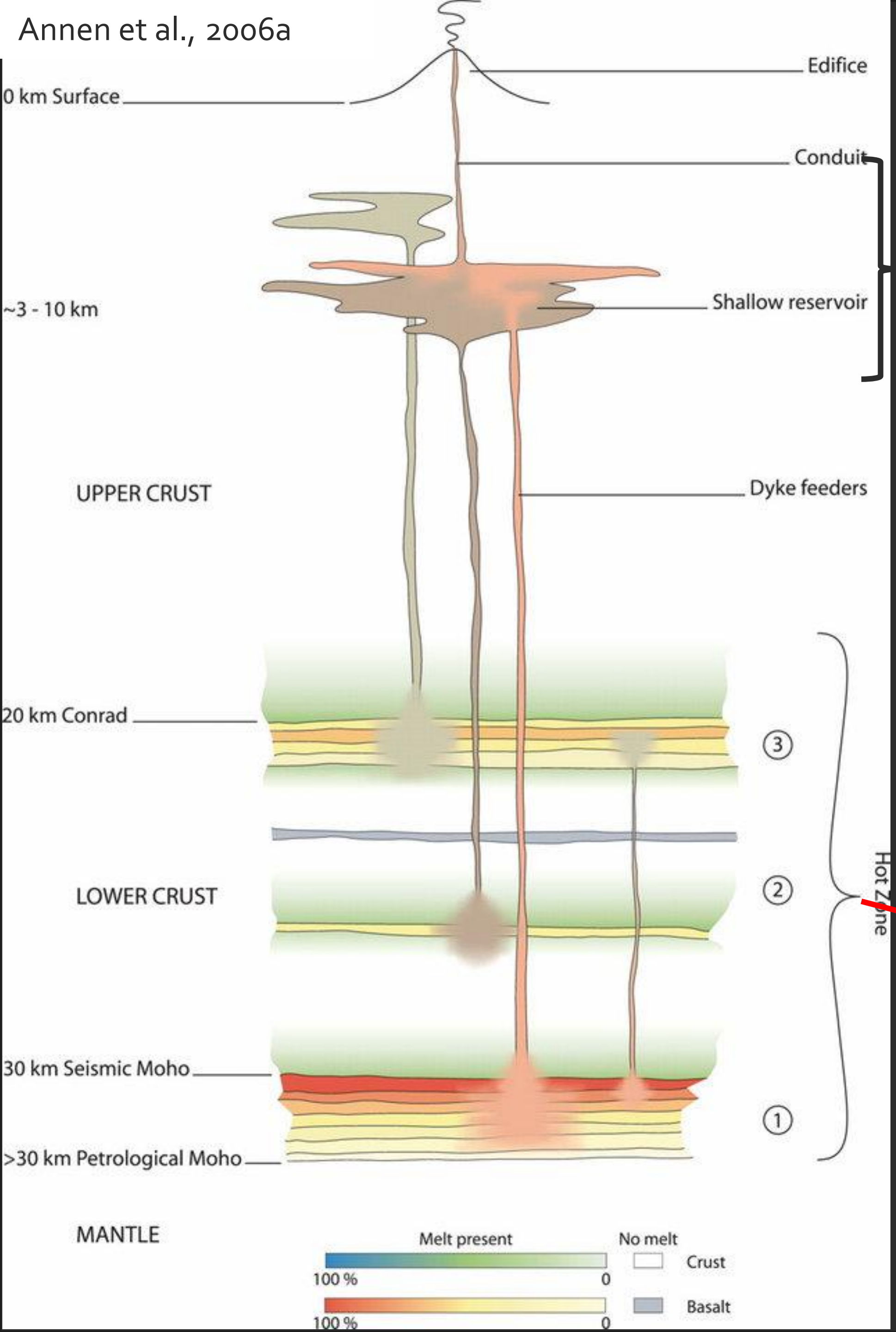
Macrocrysts

Diverse amphibole crystals

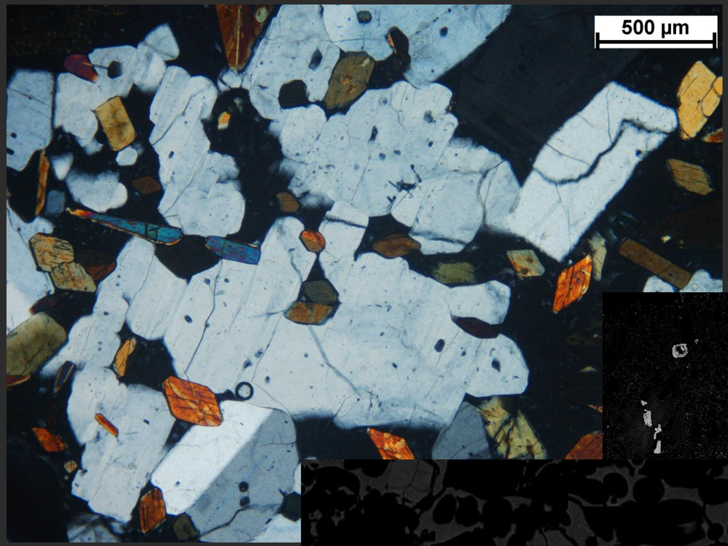
Amphibole crystals with high MgO and low Al_2O_3



Annen et al., 2006a



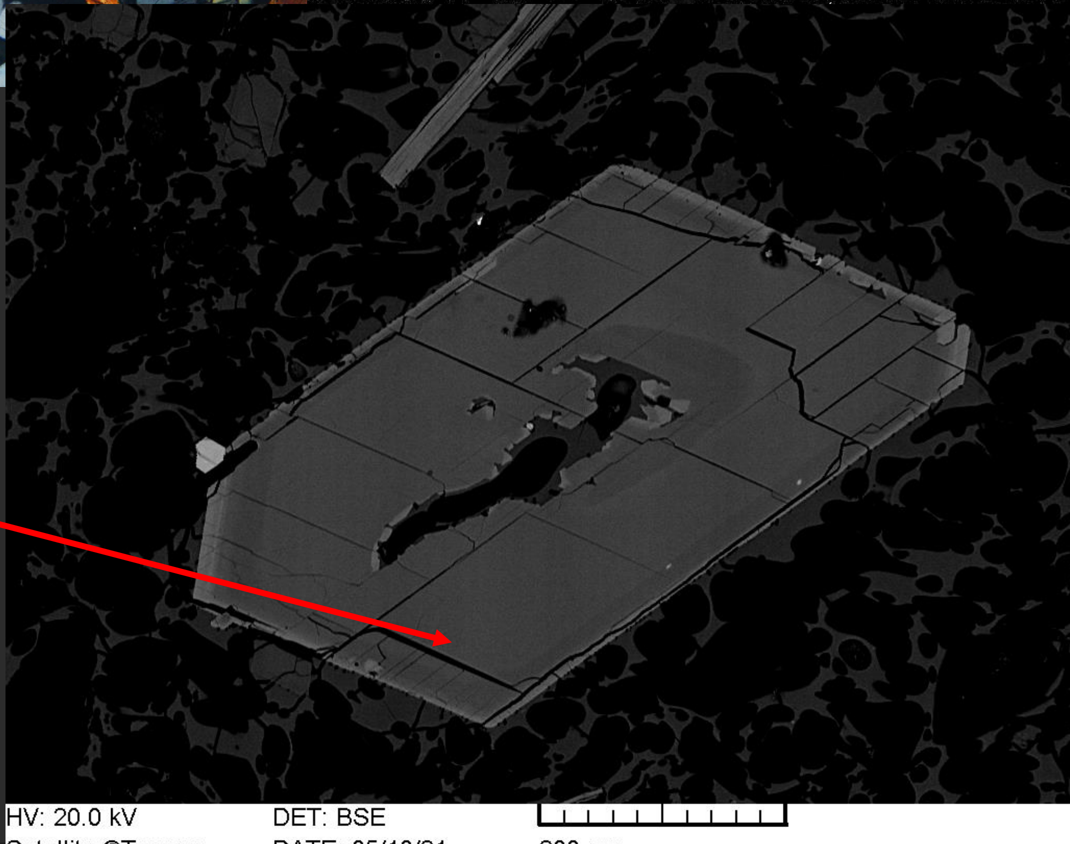
Crystal mush
Mohos pumice



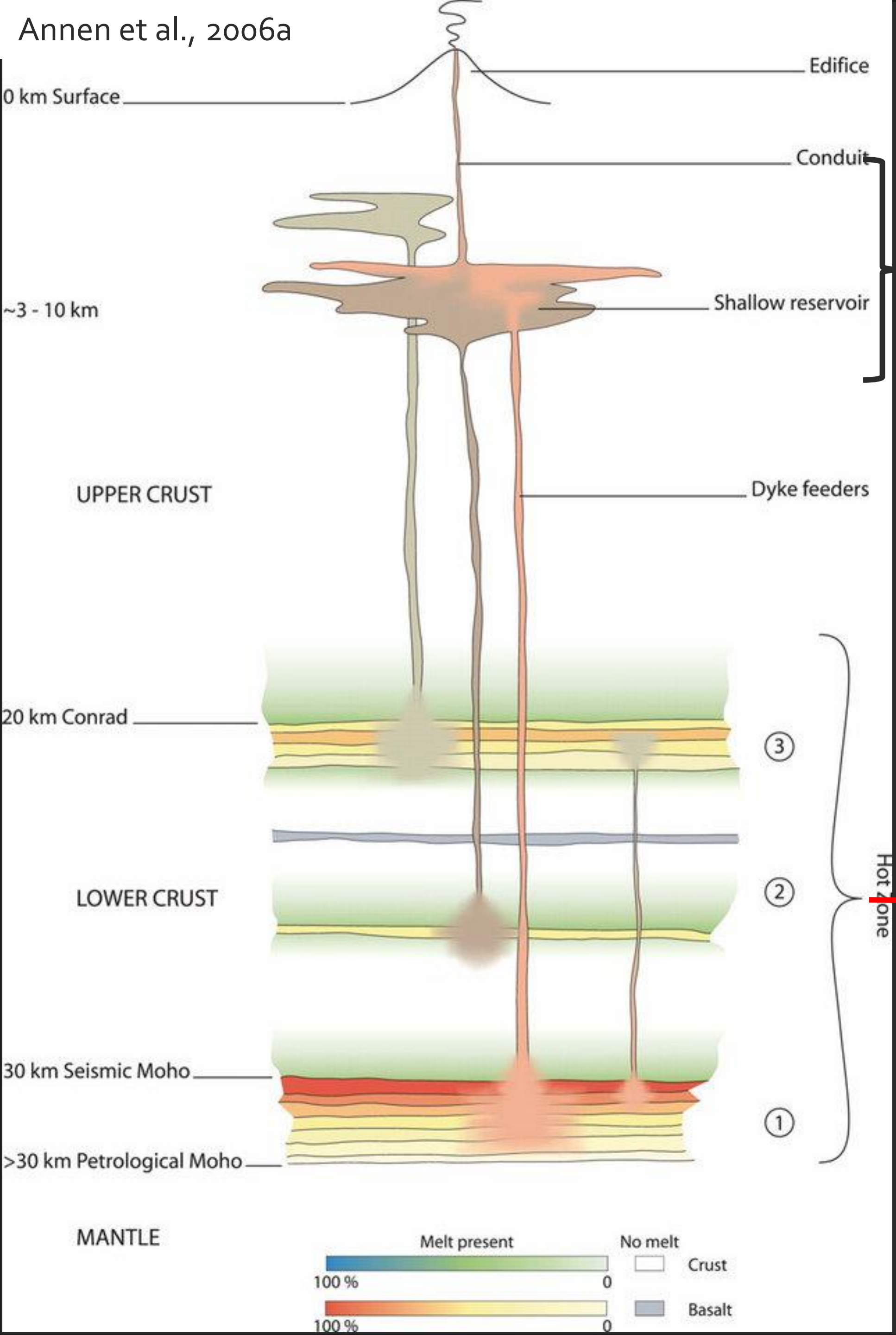
Macrocrysts

High-Mg amphiboles:
Absence of plagioclase intergrowth
→
H_2O-saturated crystalization enviroment (Ulmer et al., 2018)

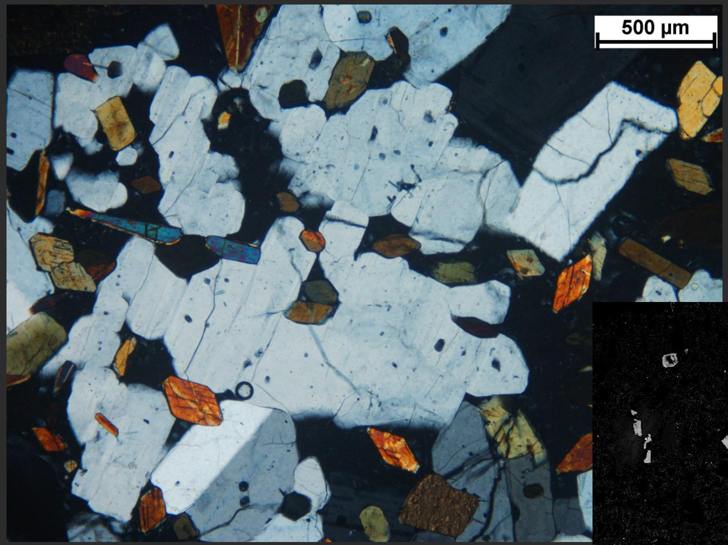
>0,90 Mg#
Cr_2O_3~0,89 wt%
increased Cr, Ni, Co content
Low Nb/Zr in high Mg macrocrysts compared with mafic crystal clot amphiboles



Annen et al., 2006a



Crystal mush
Mohos pumice



Macrocrysts

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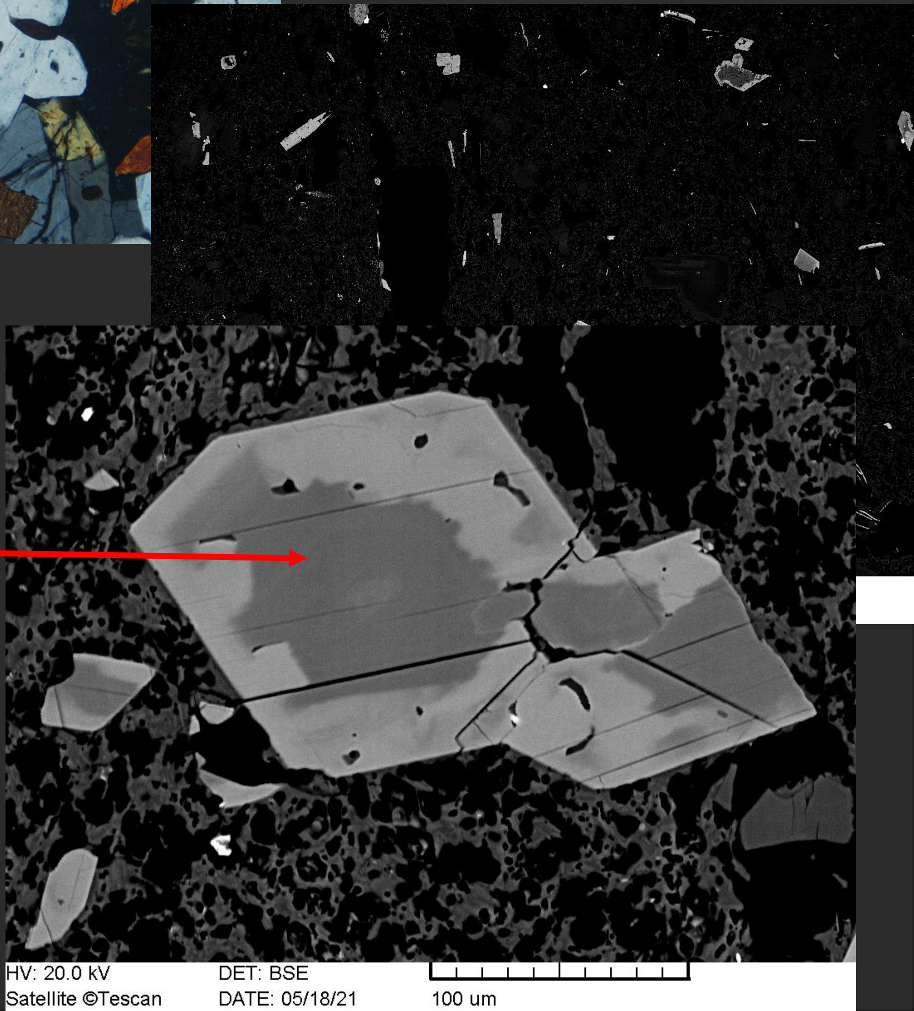
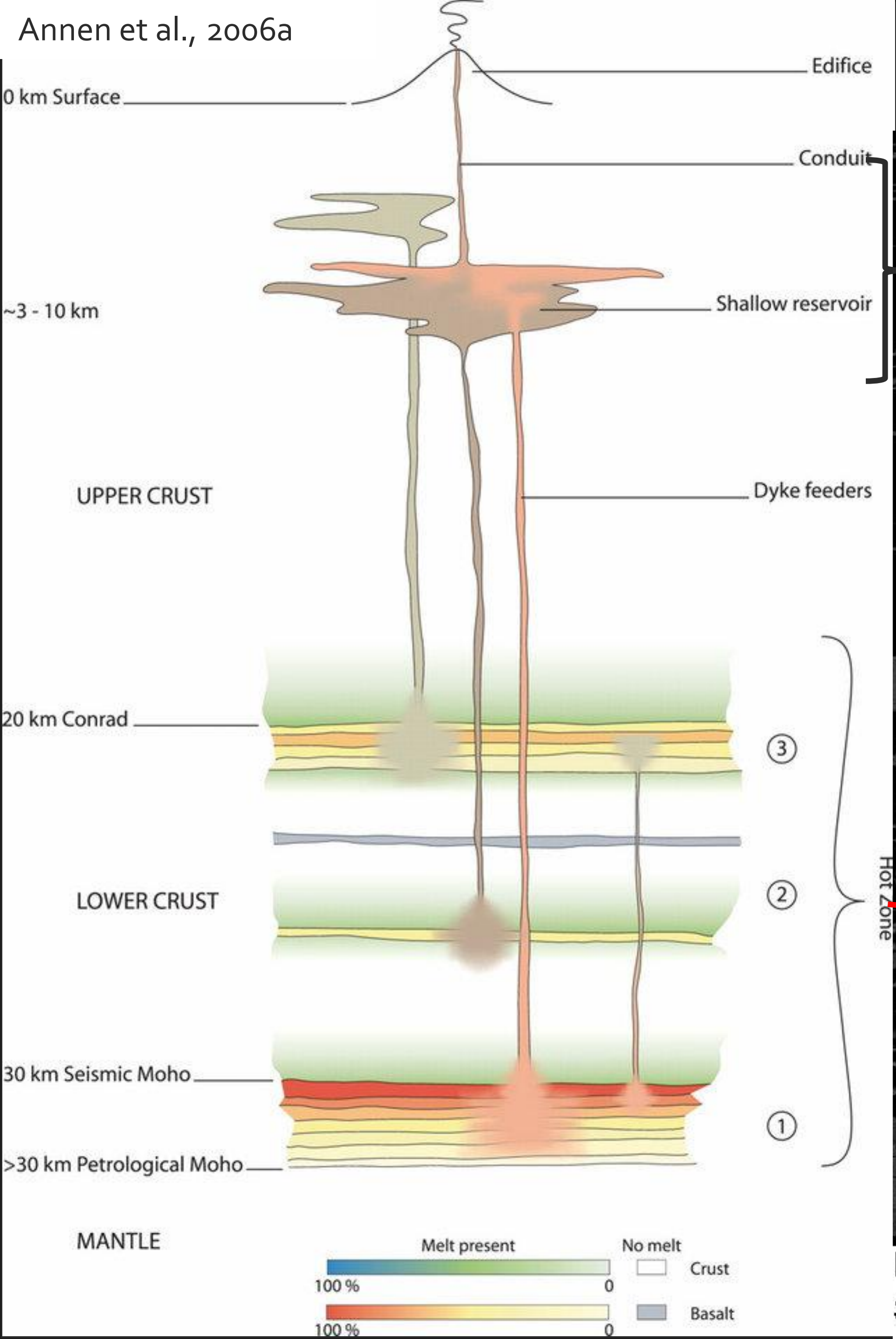
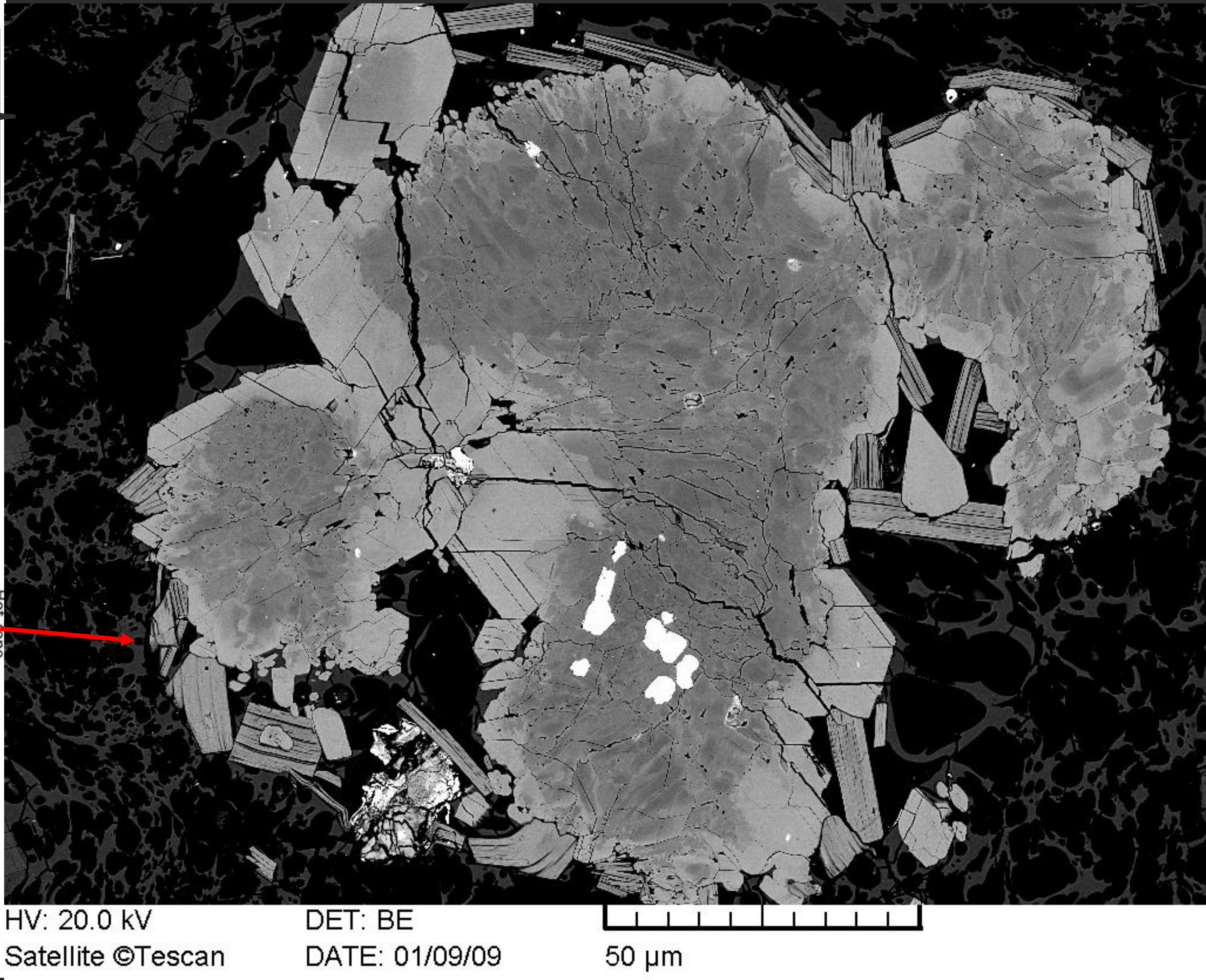


Annen et al., 2006a

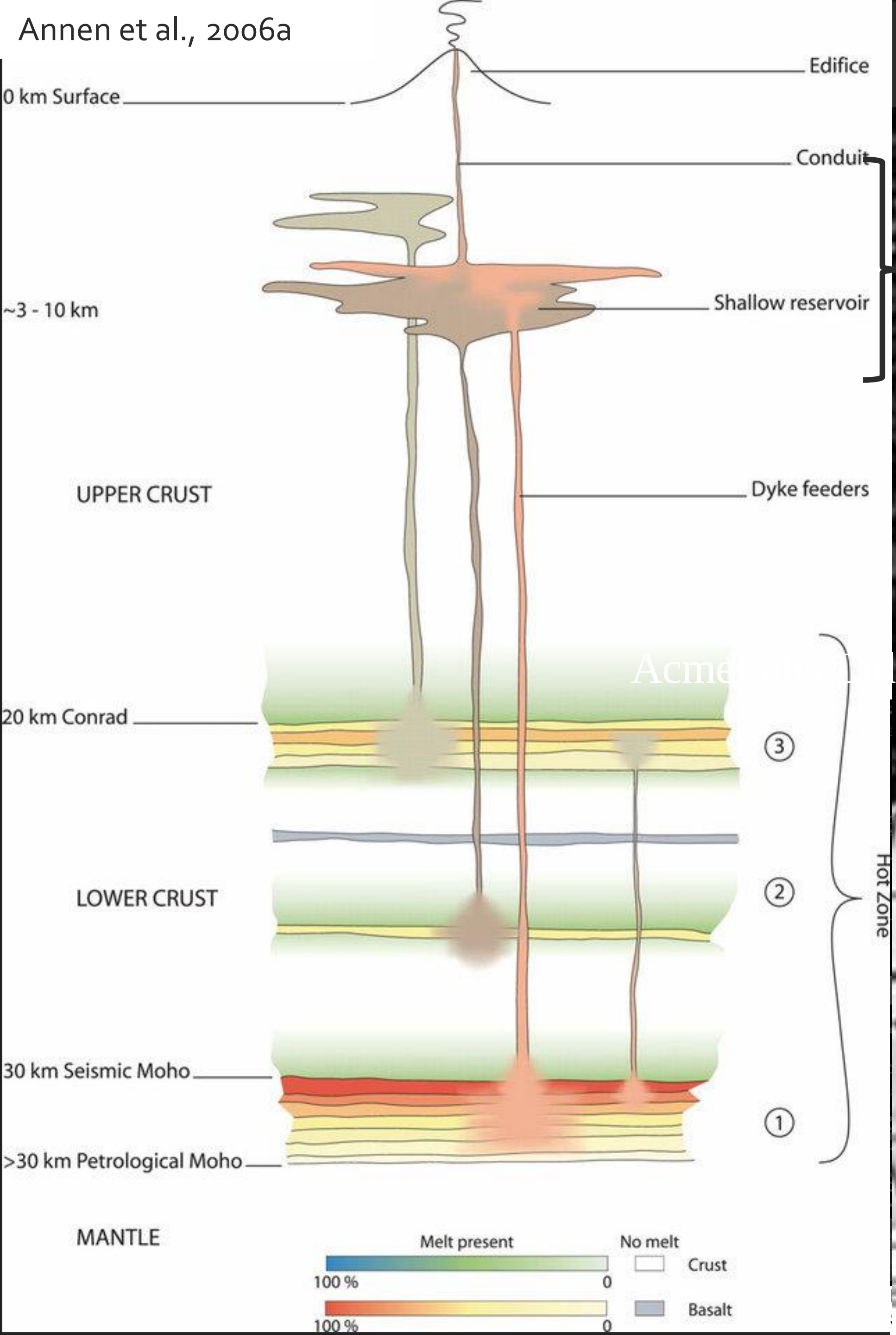


Crystal mush
Mohos pumice – mafic crystal clot

Macrocrysts
CrSp Cr# = 0.73 - 0.79

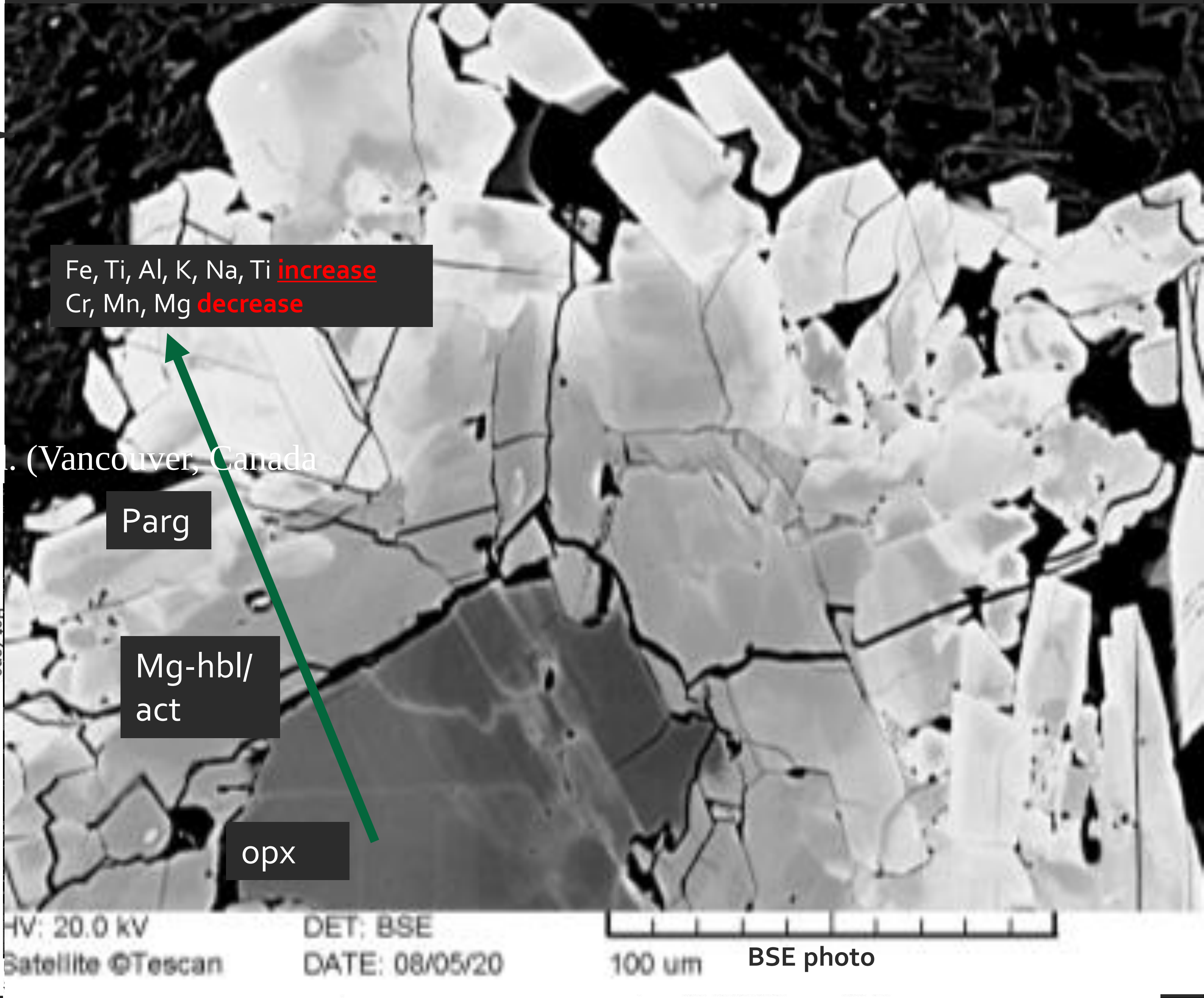


Annen et al., 2006a

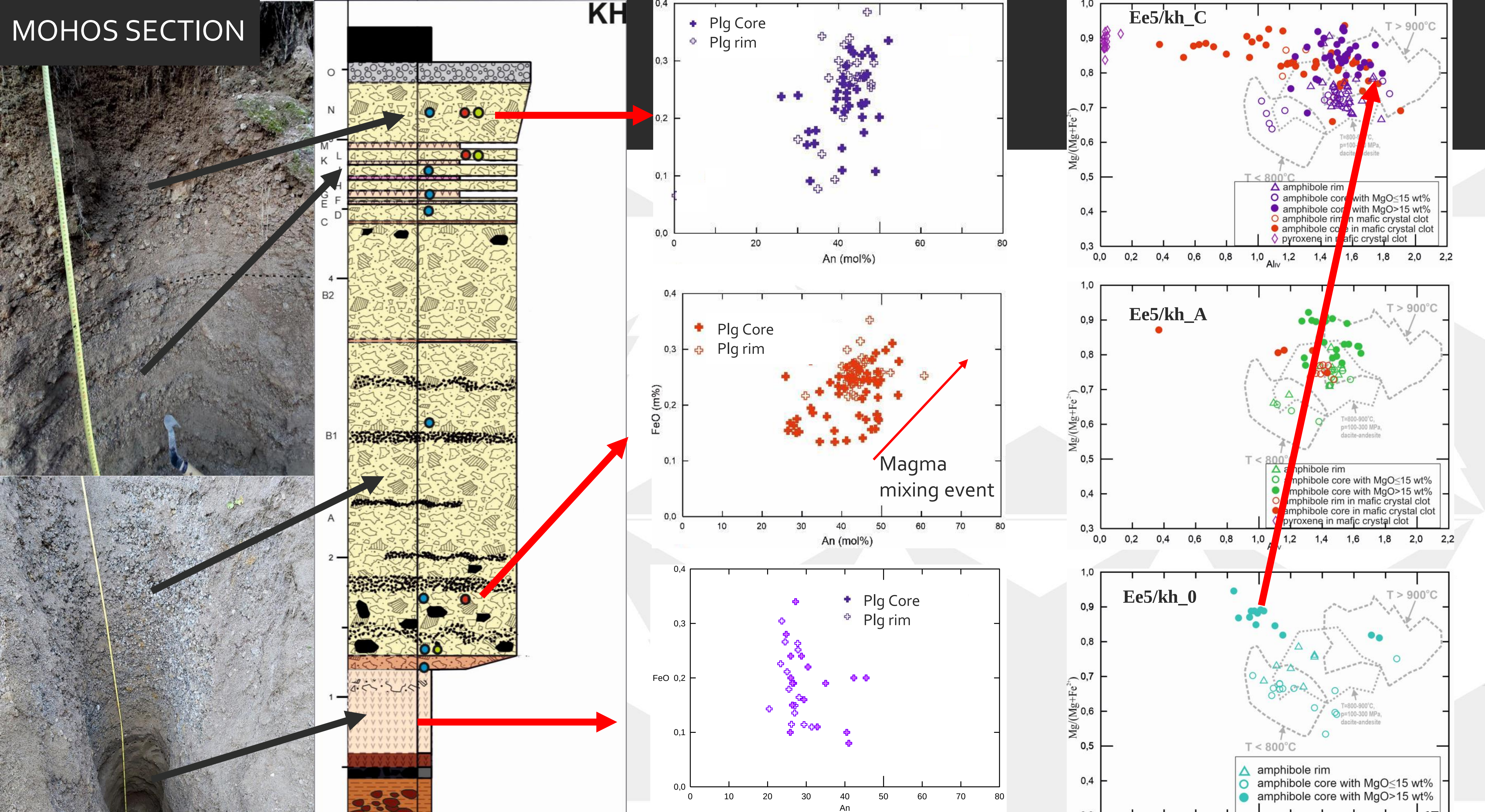


Crystal mush

Macrocrysts

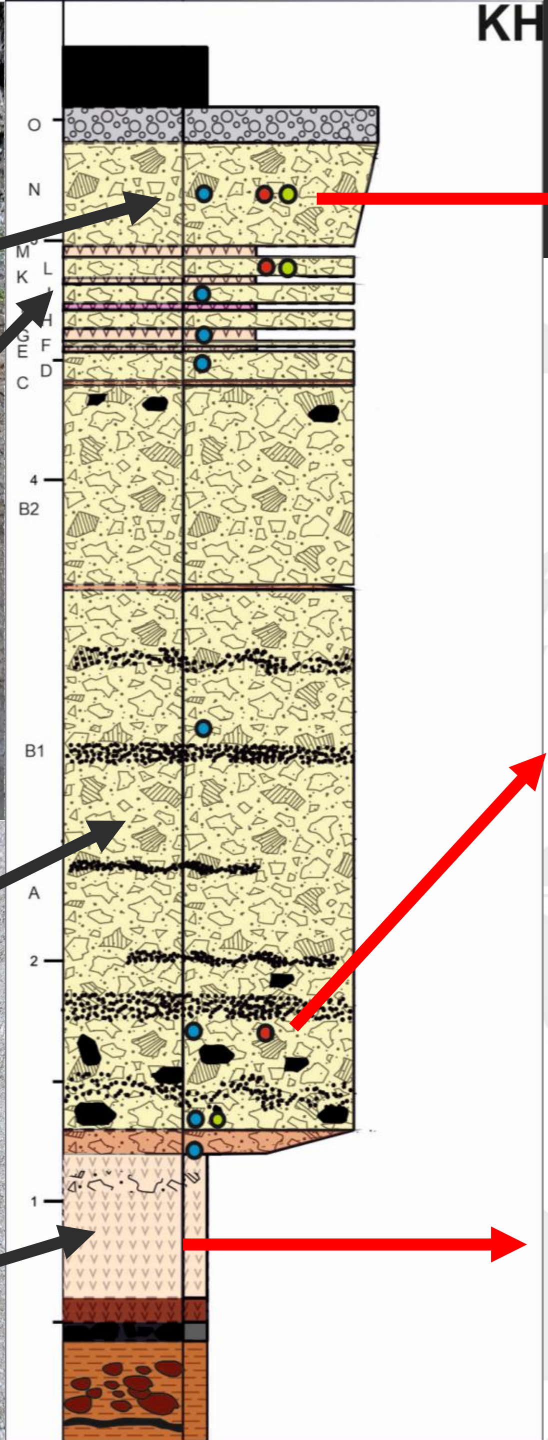


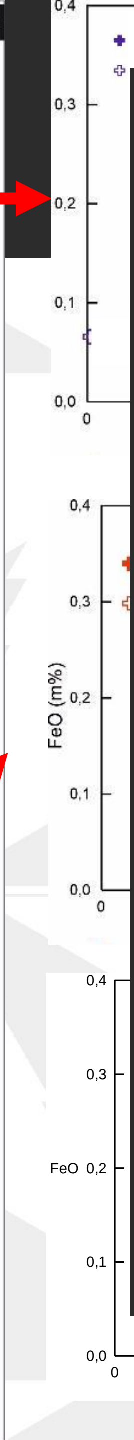
MOHOS SECTION

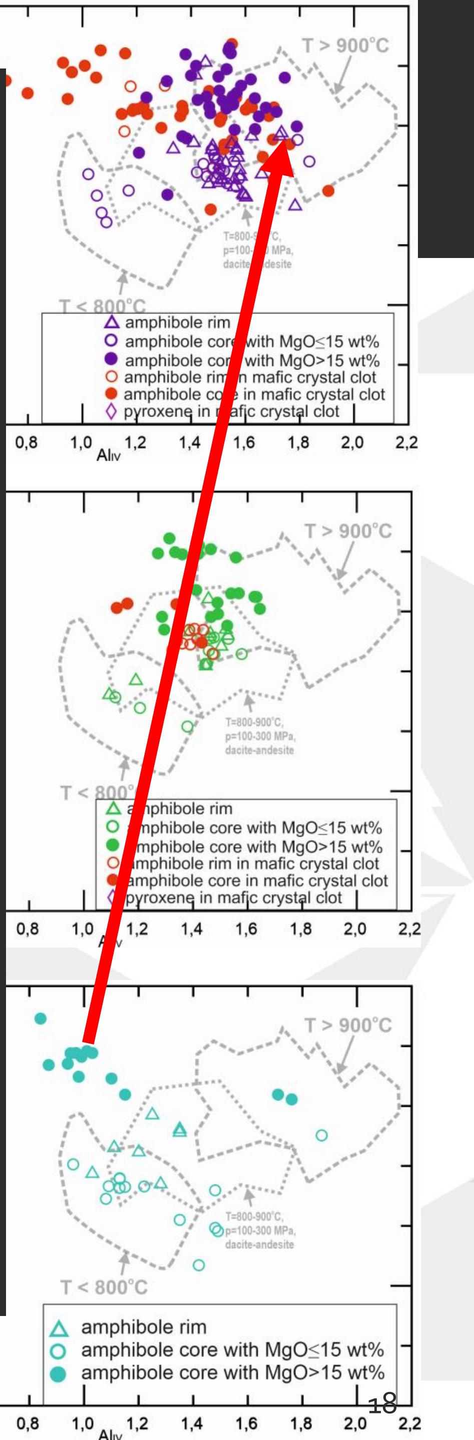


Amphibole fields are from Kiss et al. 2014

MOHOS SECTION



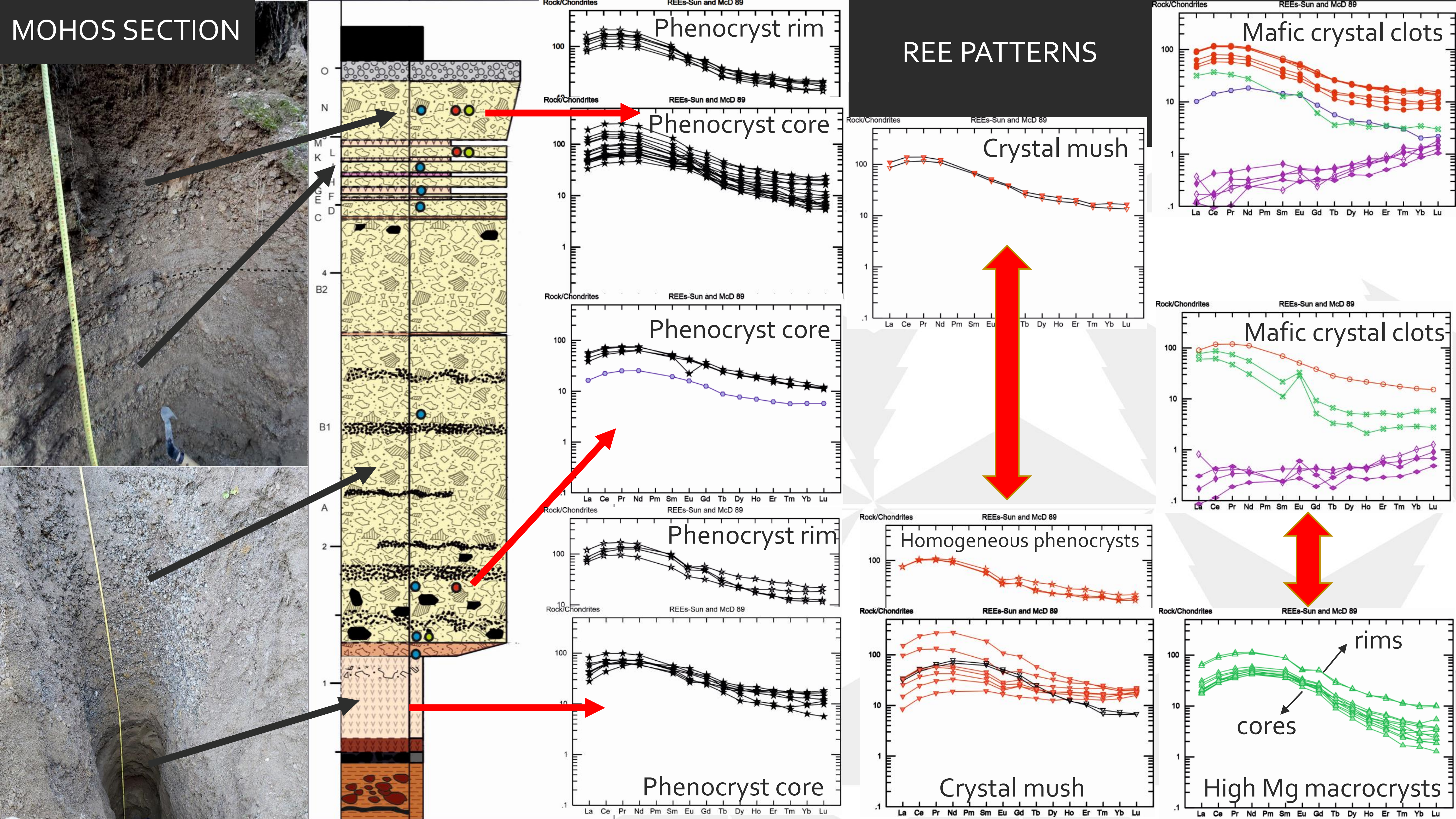




High T amphibole composition shift towards higher Al_{IV} content, plagioclase towards higher An component (more mafic composition) ⇨ magma mixing

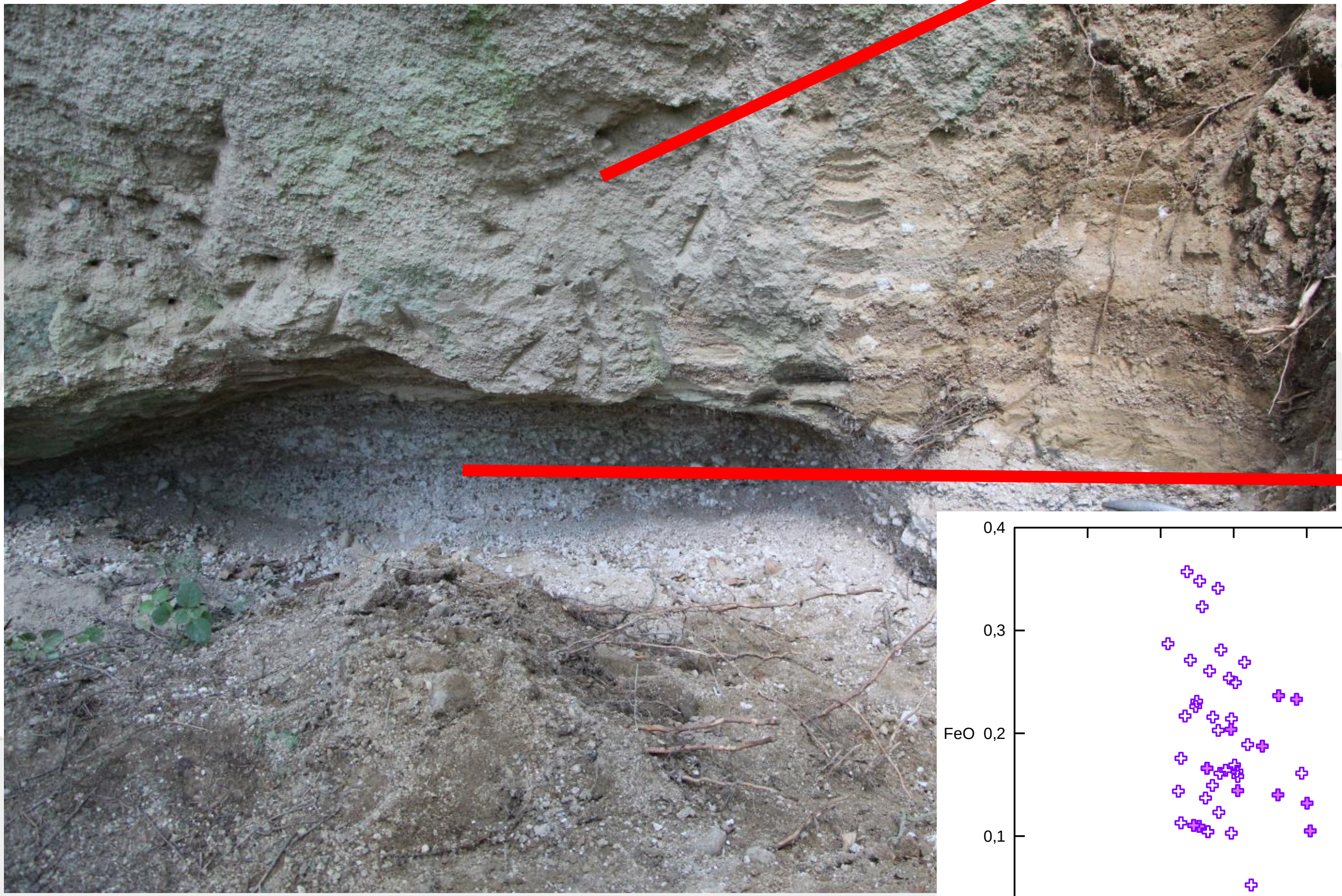
[increasing P_{H_2O} → An-rich feldspar crystallization (e.g., Nelson and Montana 1992; Annen et al. 2006a; Humphreys et al. 2006, Viccaro et al. 2010, 2012, Renjith et al. 2014)

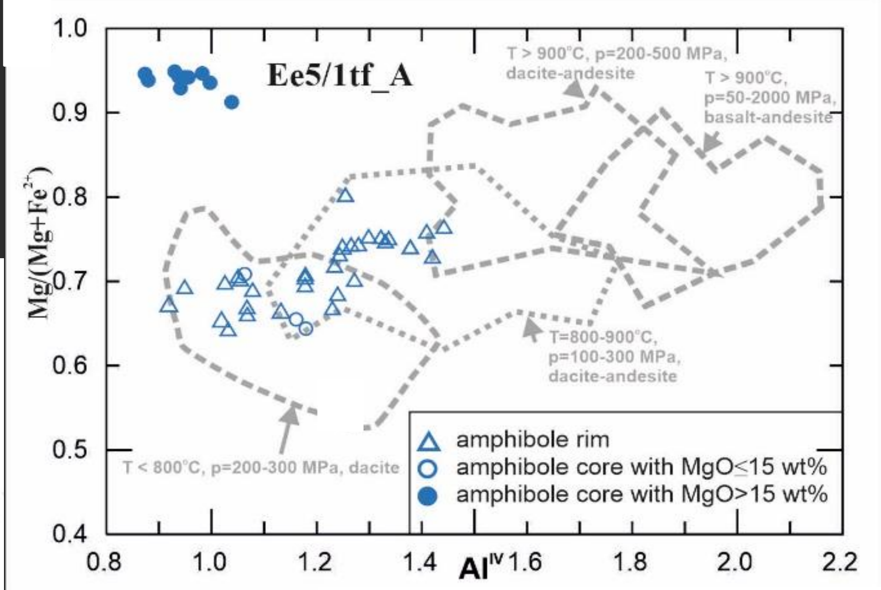
Amphibole fields are from Kiss et al. 2014


MOHOS SECTION
REE PATTERNS
O
N
M
L
K
J
H
G
F
E
D
C
4
B2
B1
A
2
1
Rock/Chondrites
REEs-Sun and McD 89
Phenocryst rim
Phenocryst core
Phenocryst core
Phenocryst rim
Phenocryst core
Crystal mush
Homogeneous phenocrysts
Crystal mush
Mafic crystal clots
Mafic crystal clots
High Mg macrocrysts
rims
cores
100
10
1
.1
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu

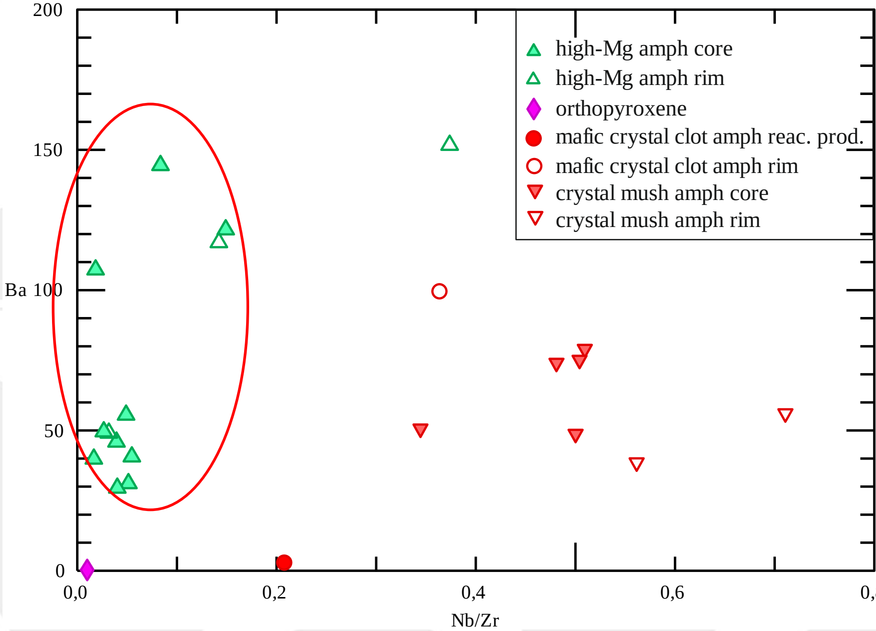
TUSNAD SECTION

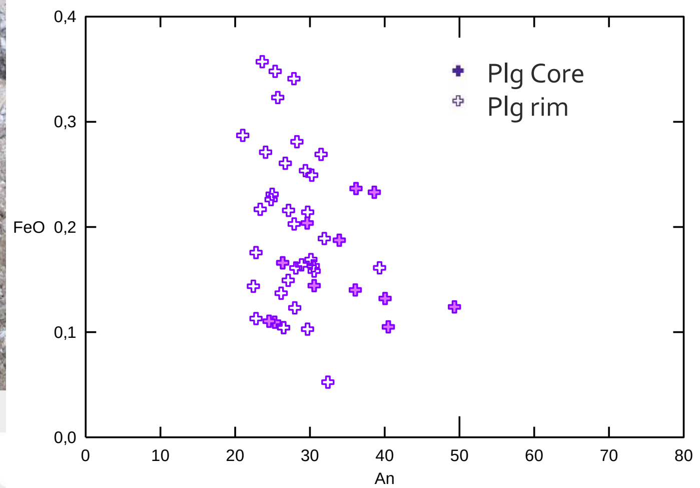
There are no mafic crystal clots or/and high Mg amph





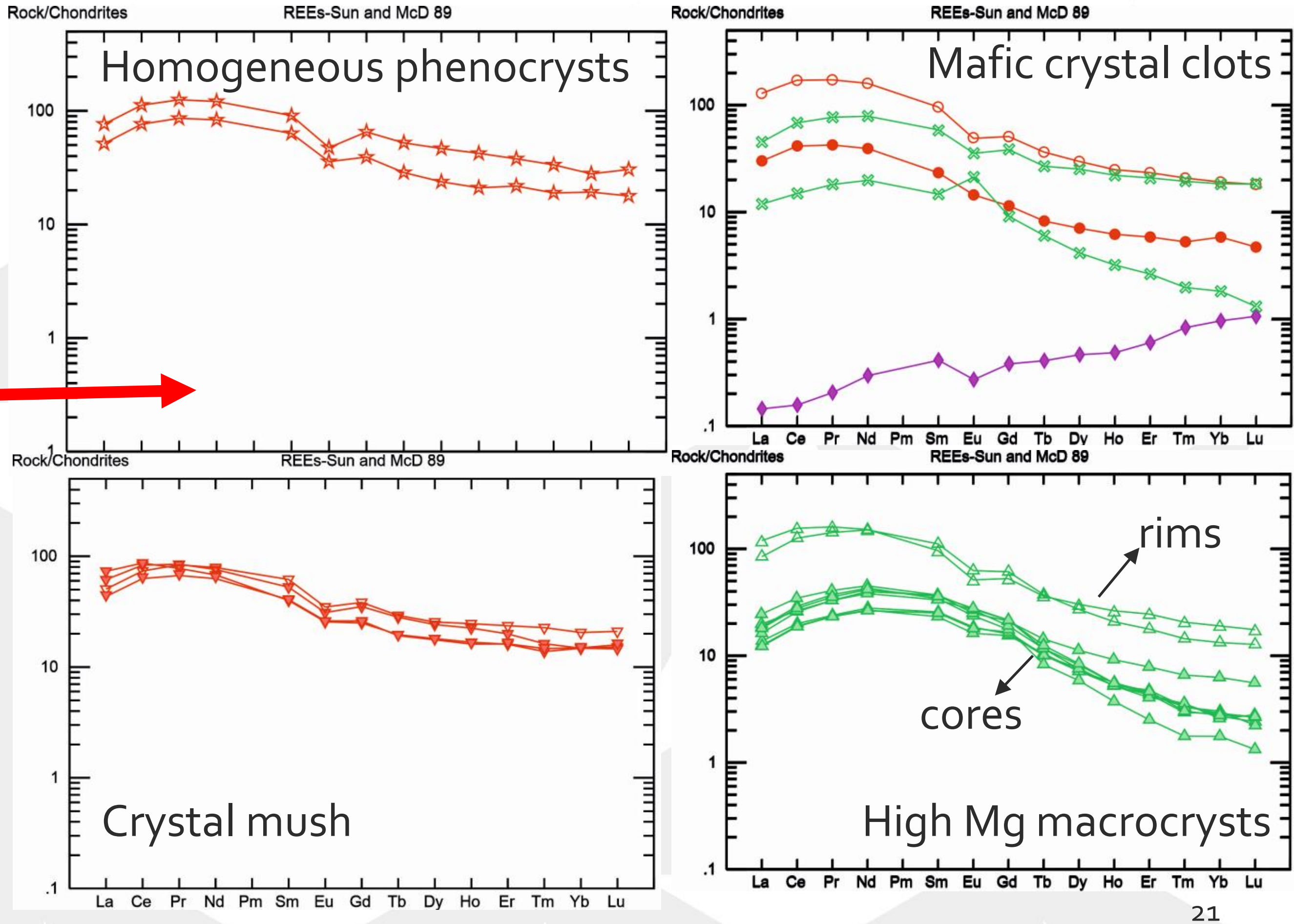
Amphibole fields are from Kiss et al. 2014



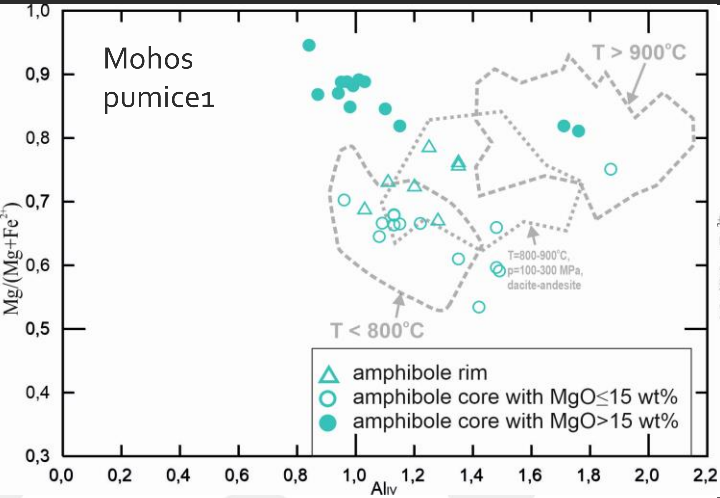


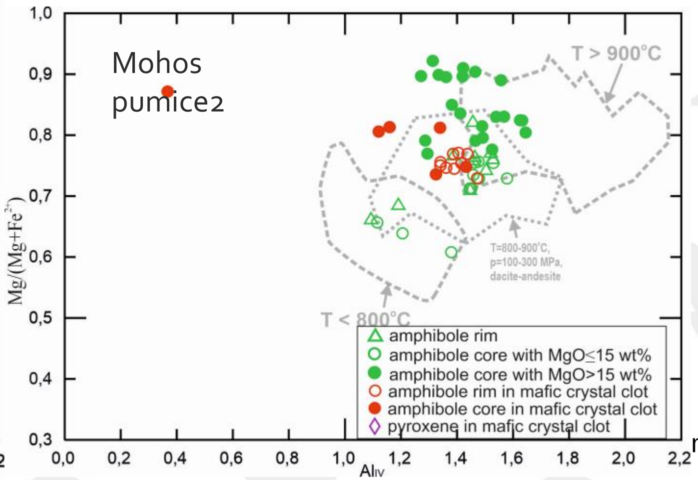
TUSNAD SECTION

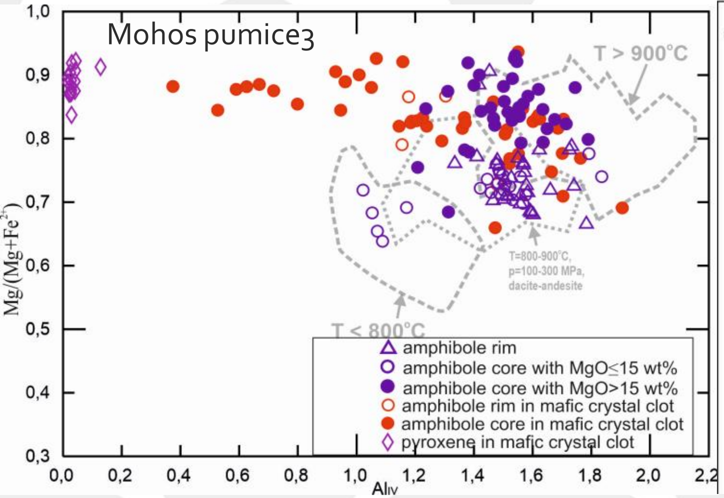
There are no mafic crystal clots or/and high Mg amph

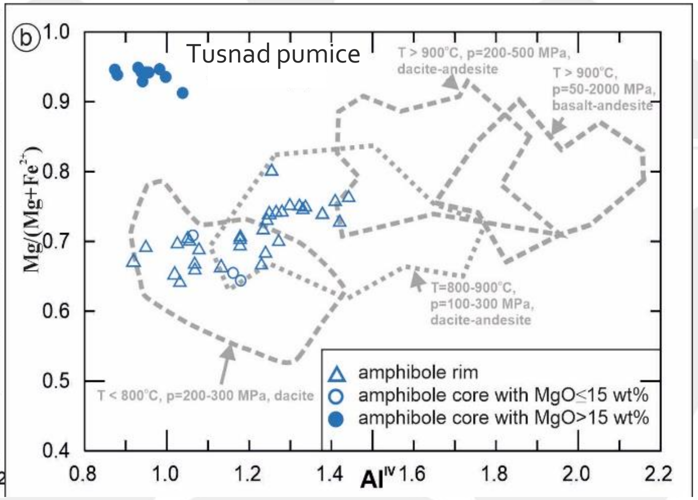


COMPARISON









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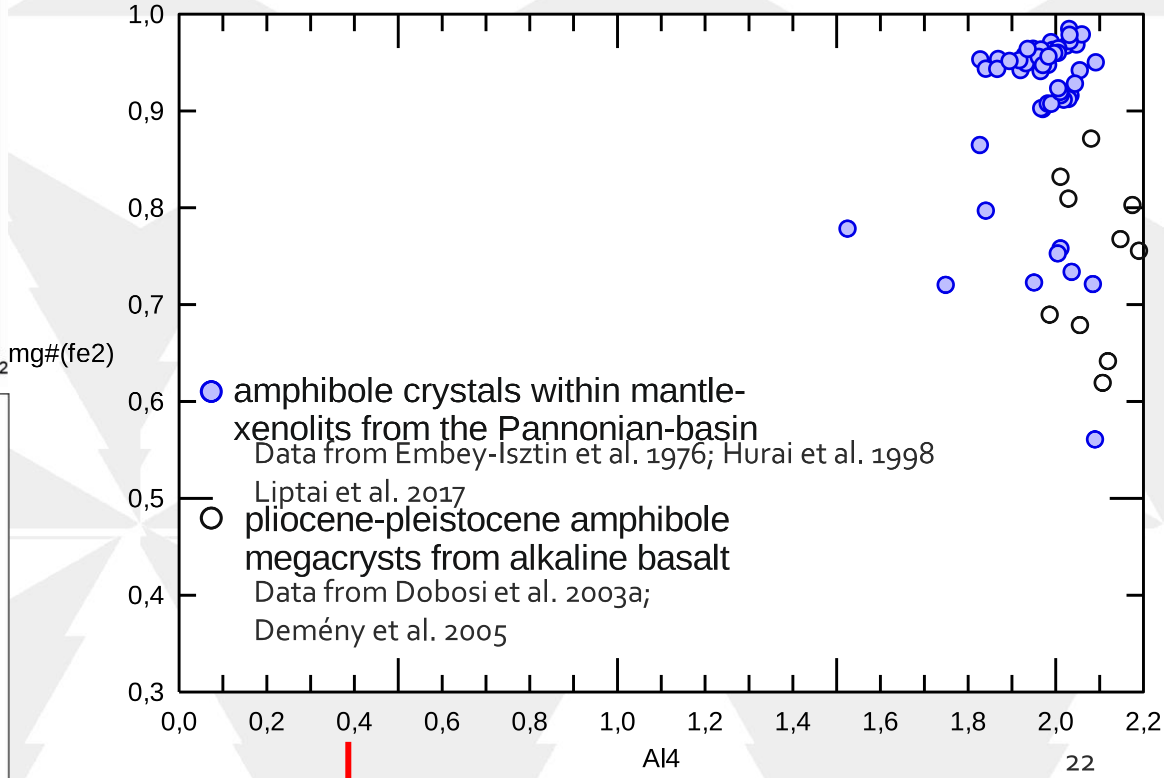
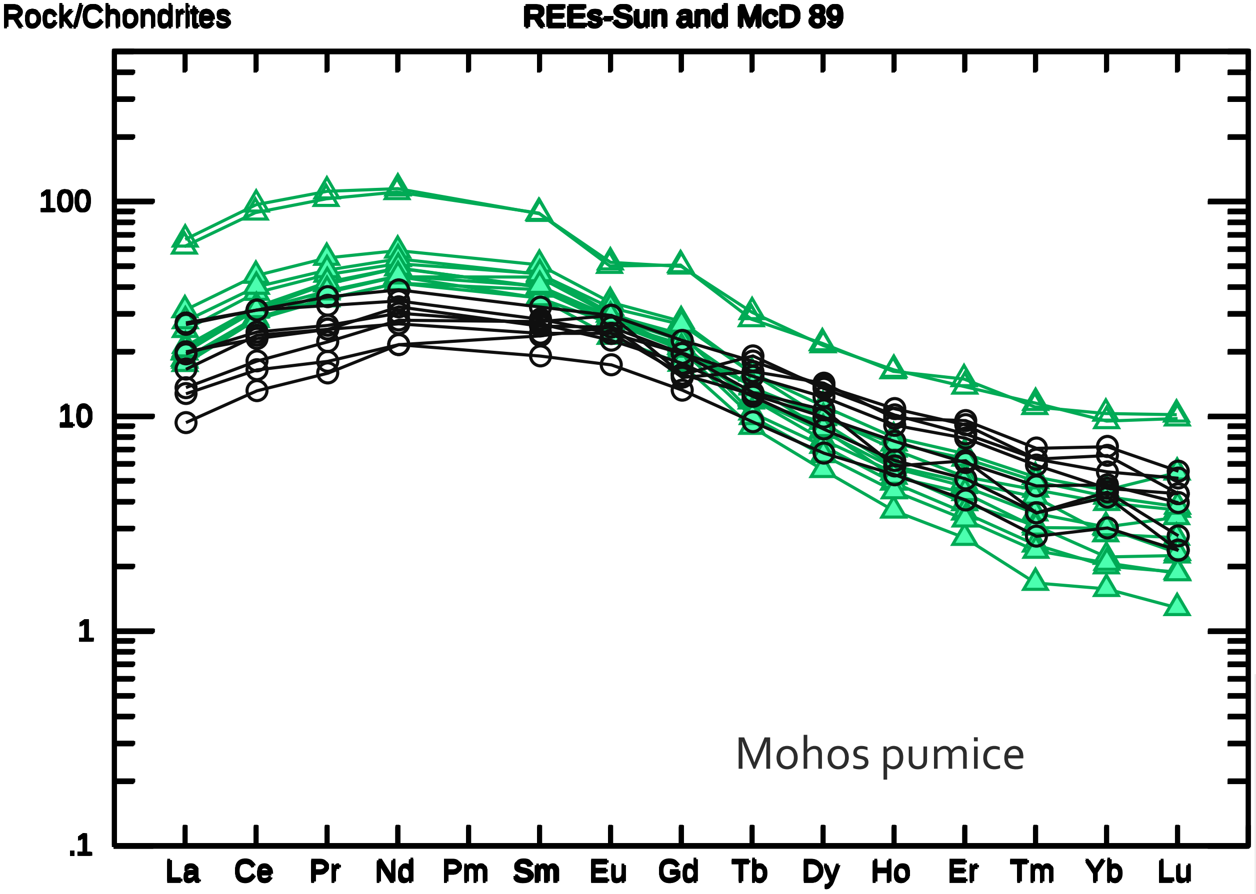
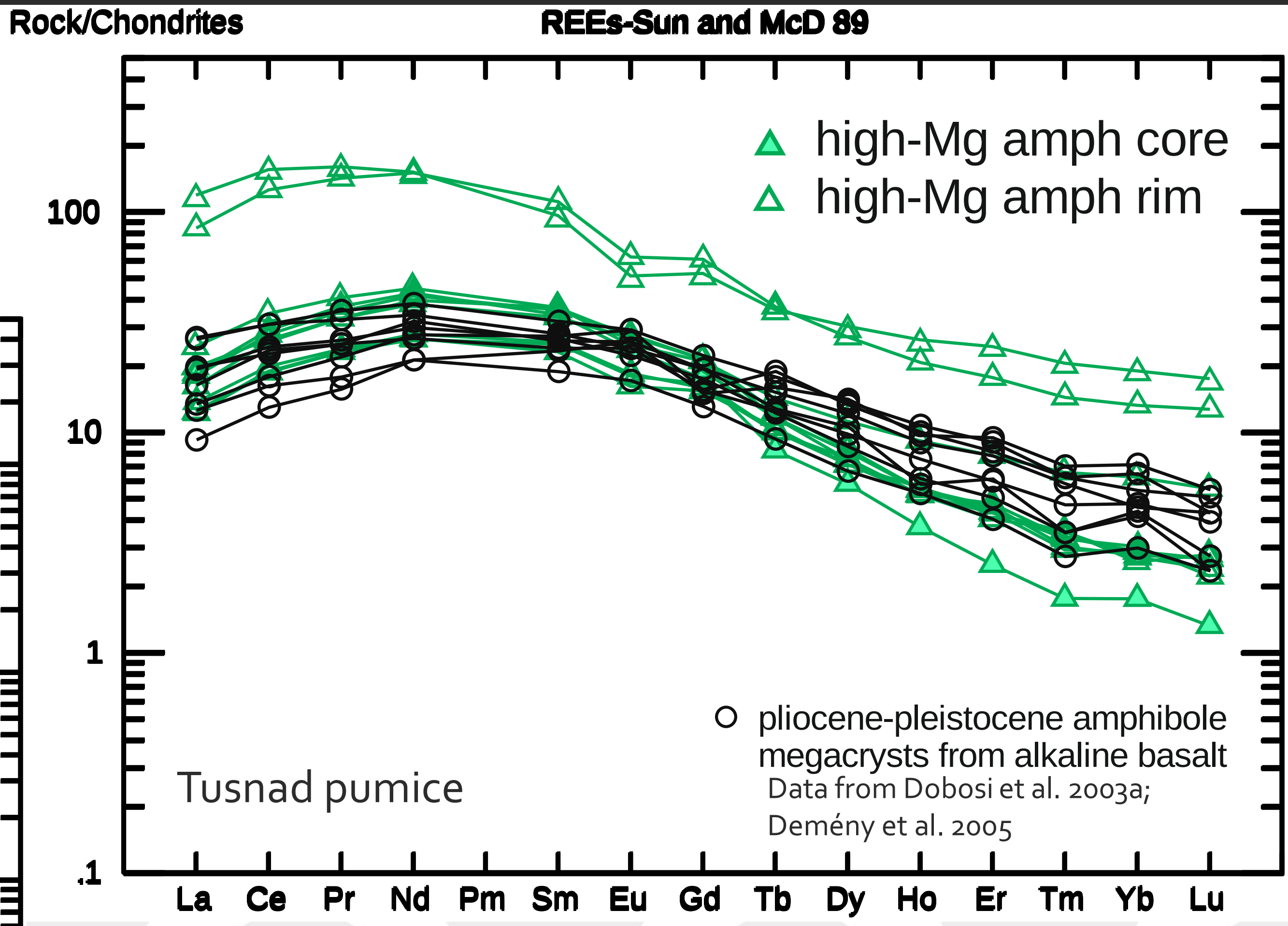


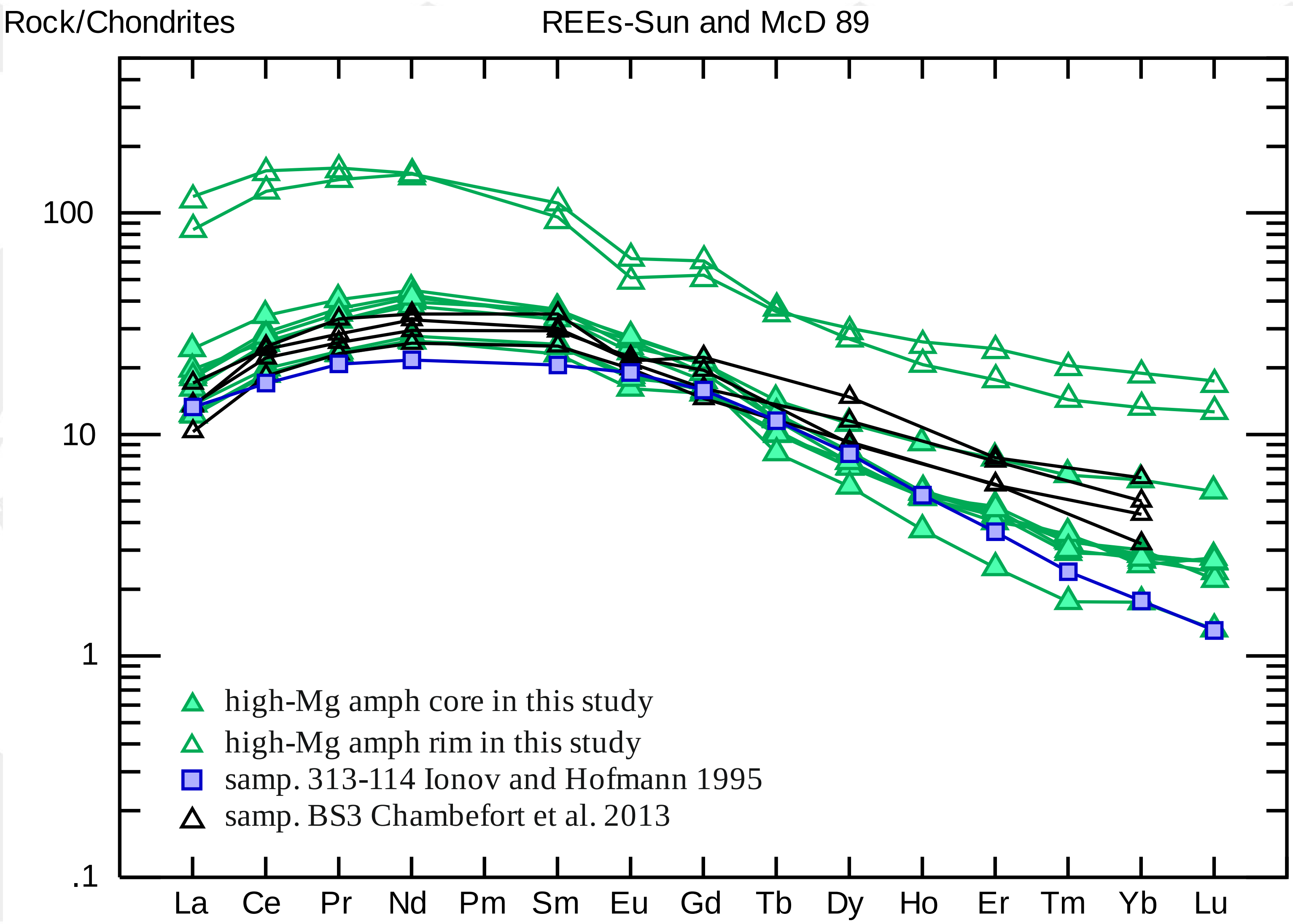
High Mg# amphibole crystallized at high T, high P from ultrahydrous (> 8 wt% magma) – Krawczynski et al. 2012 e.g., Mt. Shasta, Shiveluch

Similarly high Mg, but low Al content in Ciomadul amphibole

COMPARISON


Rock/Chondrites
REEs-Sun and McD 89
100
10
1
.1
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
Mohos pumice


Rock/Chondrites
REEs-Sun and McD 89
high-Mg amph core
high-Mg amph rim
100
10
1
.1
pliocene-pleistocene amphibole megacrysts from alkaline basalt
Data from Dobosi et al. 2003a; Demény et al. 2005
Tusnad pumice
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu



Magmatic amphibole with inherited metasomatic amphibole trace element pattern ~ similar to cpx

Partial melt of the metasomatic mantle source (e.g., Irving and Frey 1984; Dobosi et al. 2003a; Demény et al. 2005, Chambefort et al. 2013)

Near-liquidus amphibole crystals in equilibrium with a hydrous equilibrium melt (e.g., Irving and Frey 1984,Chambefort et al. 2013)

(High water content (>8%) could stabilize amphibole at high temperature and pressure in ultrahydrous (>8 wt% H_2O) magma)

INTERPRETATIONS

- Bulk-rock composition and high-Mg amphibole trace-element patterns imply garnet presence in the residue/early amphibole or garnet fractionation (e.g., Moyen 2009), in agreement with titanite compositions (Dy/Yb>2; unpublished data)
- Trace-element signatures of pumice show heavy REE depletion, suggesting that the primary magmas originated from partial melting of strongly metasomatized lithospheric mantle
- High-Mg, low-Al amphibole antecrysts have REE patterns distinct from magmatic phenocrysts (low REE content and strong HREE depletion)

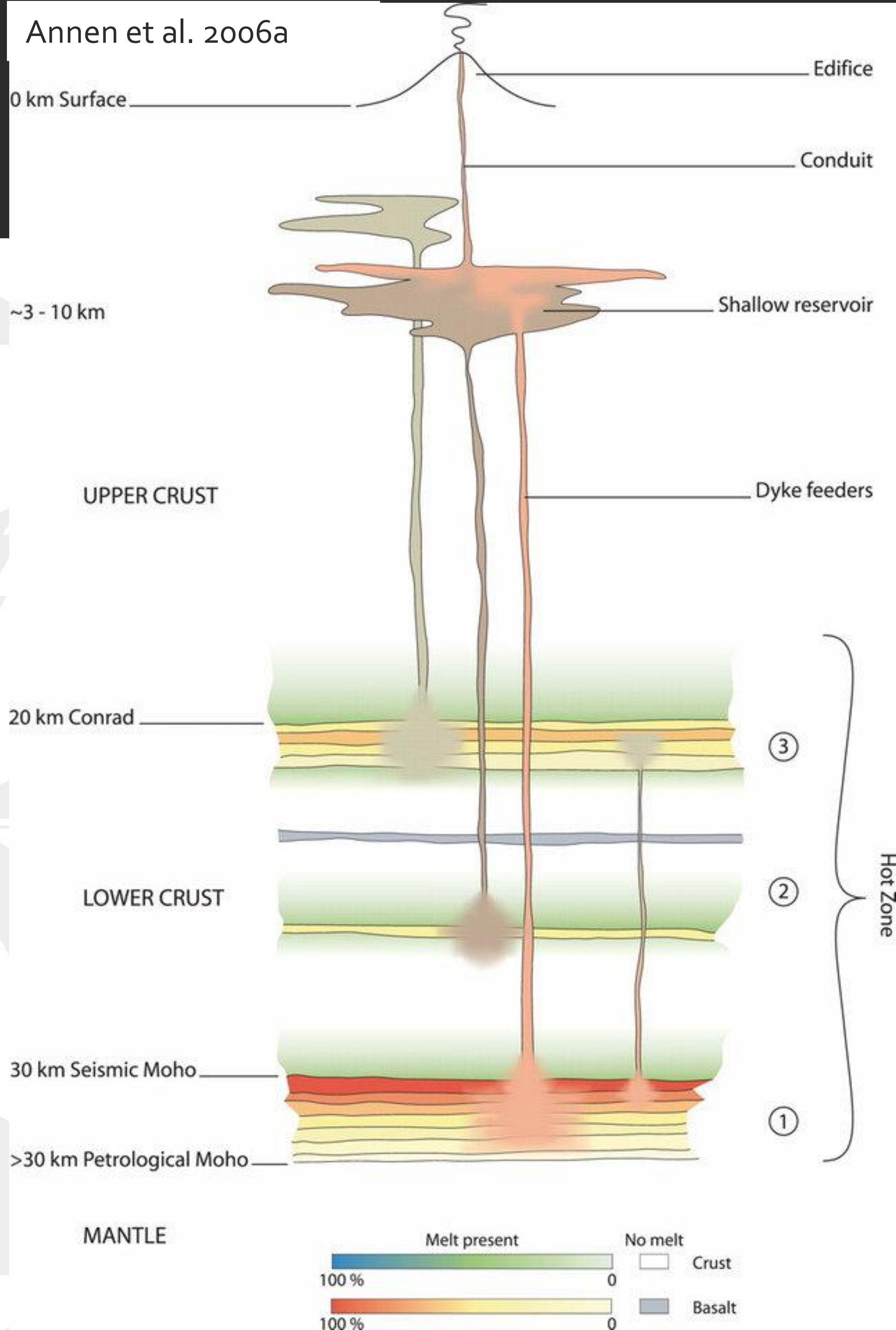
↓

- Similarity to amphiboles found within metasomatized spinel harzburgites and xenoliths showing melt-solid reaction.
- Partial melting of the source region and crystallization from a basaltic magma with high dissolved water content (>8 wt%) could have led to the crystallization of high-Mg low-Al magmatic amphibole

CONCLUSIONS

- Partial melting of a metasomatic mantle source region
- > 8 wt% dissolved water in the basaltic melt
- Magma ascent and mixing with the crystal mush
- Effect of the hydrous mafic magma on felsic crystal mush remobilization
- Key effect of H2O on magma explosivity and thus magmatic hazards

Annen et al. 2006a



- This research was supported by the Hungarian National Research, Development and Innovation Fund (NKFIH) within K135179 project and the ÚNKP-21-3 New National Excellence Program of the Ministry for Innovation and Technology from the source of the NKFIH.

Új Nemzeti Kiválóság Program

Innovácios es Technologiai Minisztérium