Permian–Triassic riftogenic processes

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This contribution is aimed to:

1) The Permian and Triassic meta-magmatics investigated in the Inner Western Carpathians and Austro-Alpine units (geology, petrology, geochemistry, geochronology);
2) The geodynamic background of the continuous Permian–Triassic tectono-magmatic events

Methods:

field (structural), laboratory (petrotectonic, EPMA, micro-Raman, LA-ICP-MS, ICP-MS, EPMA Mnz dating, SIMS and nano-SIMS isotopic U/Pb, and LA-MC-ICP-MS dating of Zrn, Rt, Nd-Sr-Pb isotope systematics

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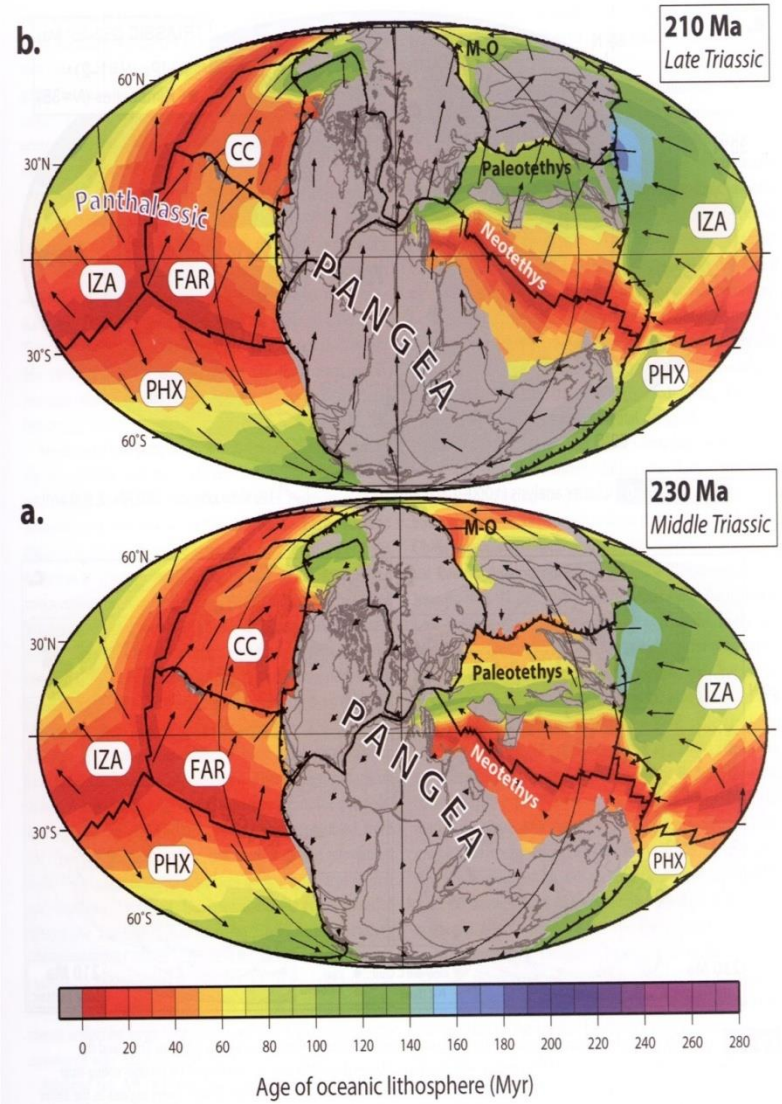


(Pangea Break-up from Torsvik and Cocks, 2017)

Fig. 11.1 Continental blocks (grey) and oceans (other colours) with plate velocity vectors and the ages of their oceanic lithosphere in the (a) Middle Triassic (230 Ma: Carnian) and (b) Late Triassic (210 Ma: Late Norian). CC, Cache Creek Oceanic Plate; FAR, Farallon Plate (including the continental Alexander and Wrangellia terranes near the plate boundary to CC); IZA, Izanagi Plate; M-O, Mongol–Okhotsk Ocean; PHX, Phoenix Oceanic Plate. EARTHBYTE mantle frame (see Chapter 2).

Permian-Triassic
Plum generation Zone (PGZ)
in red circle

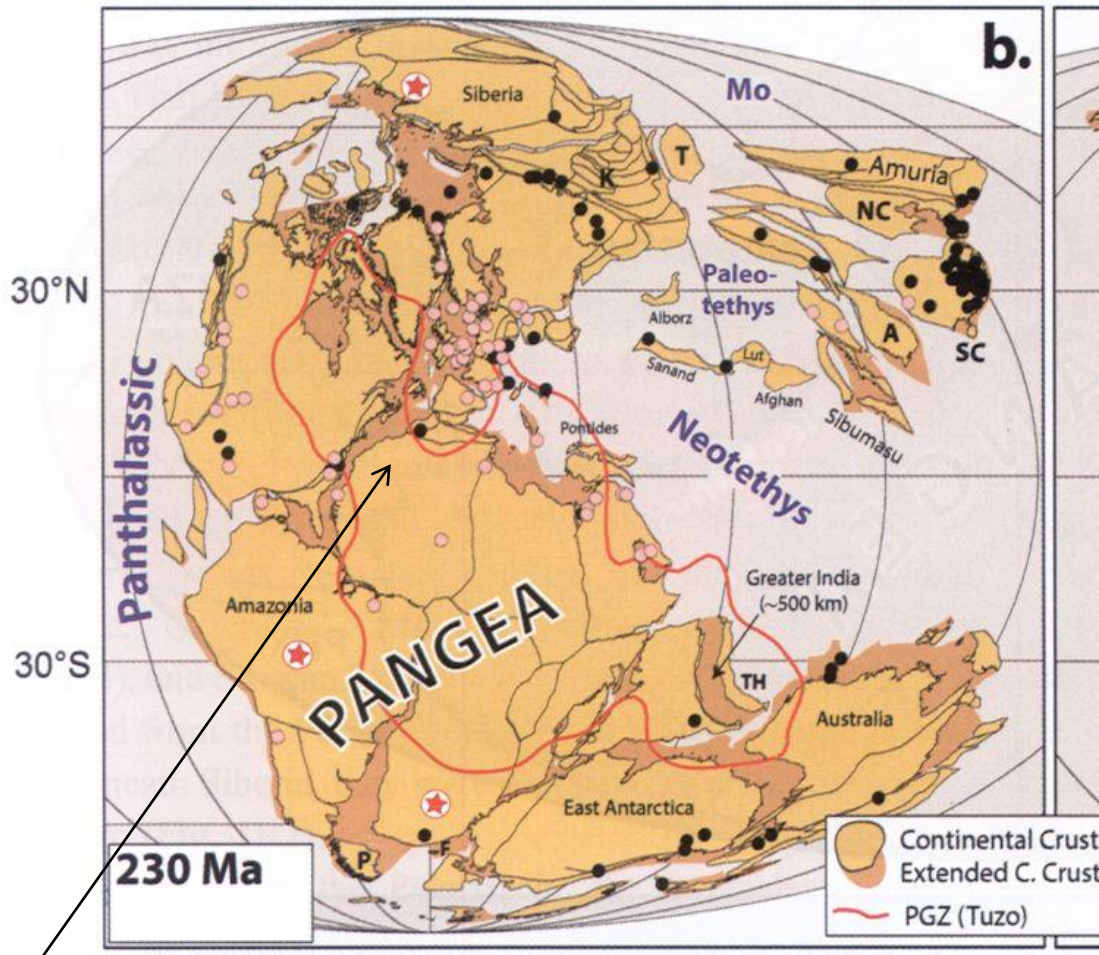
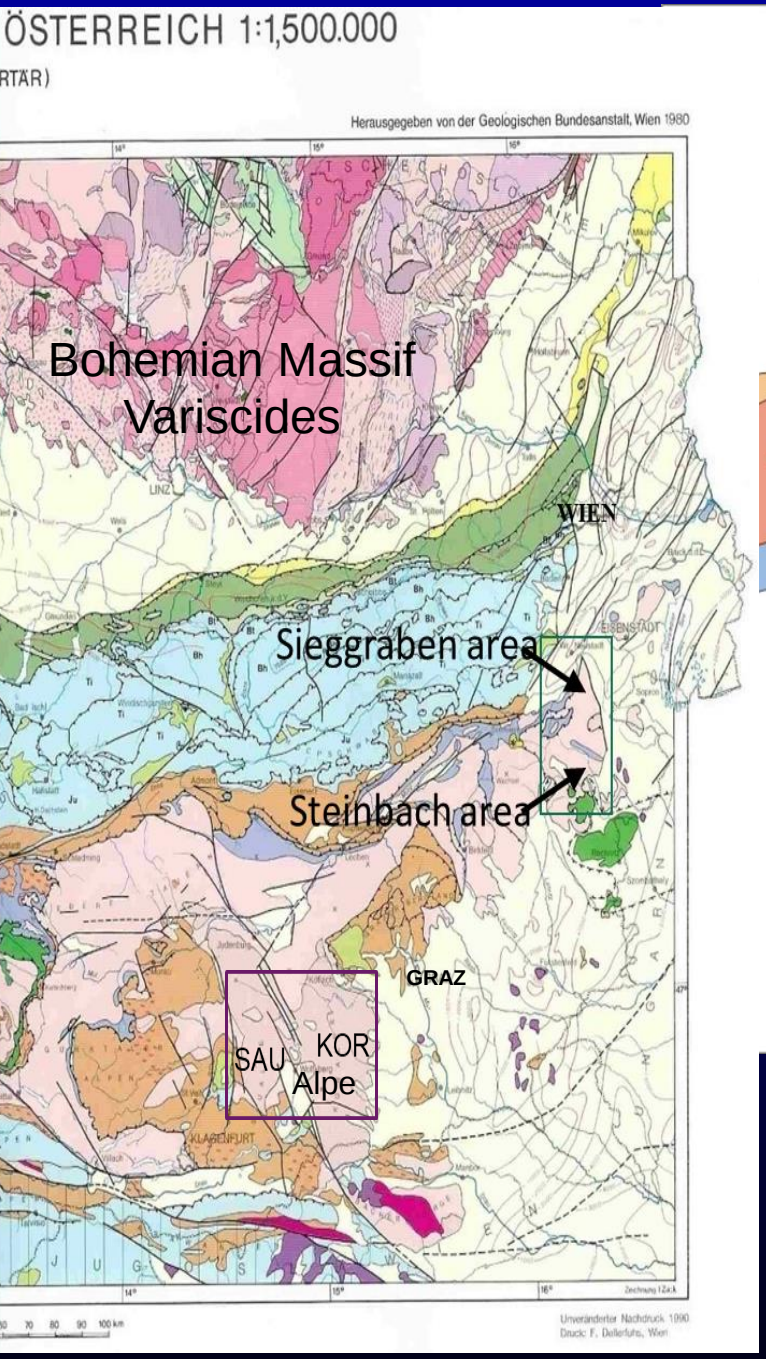
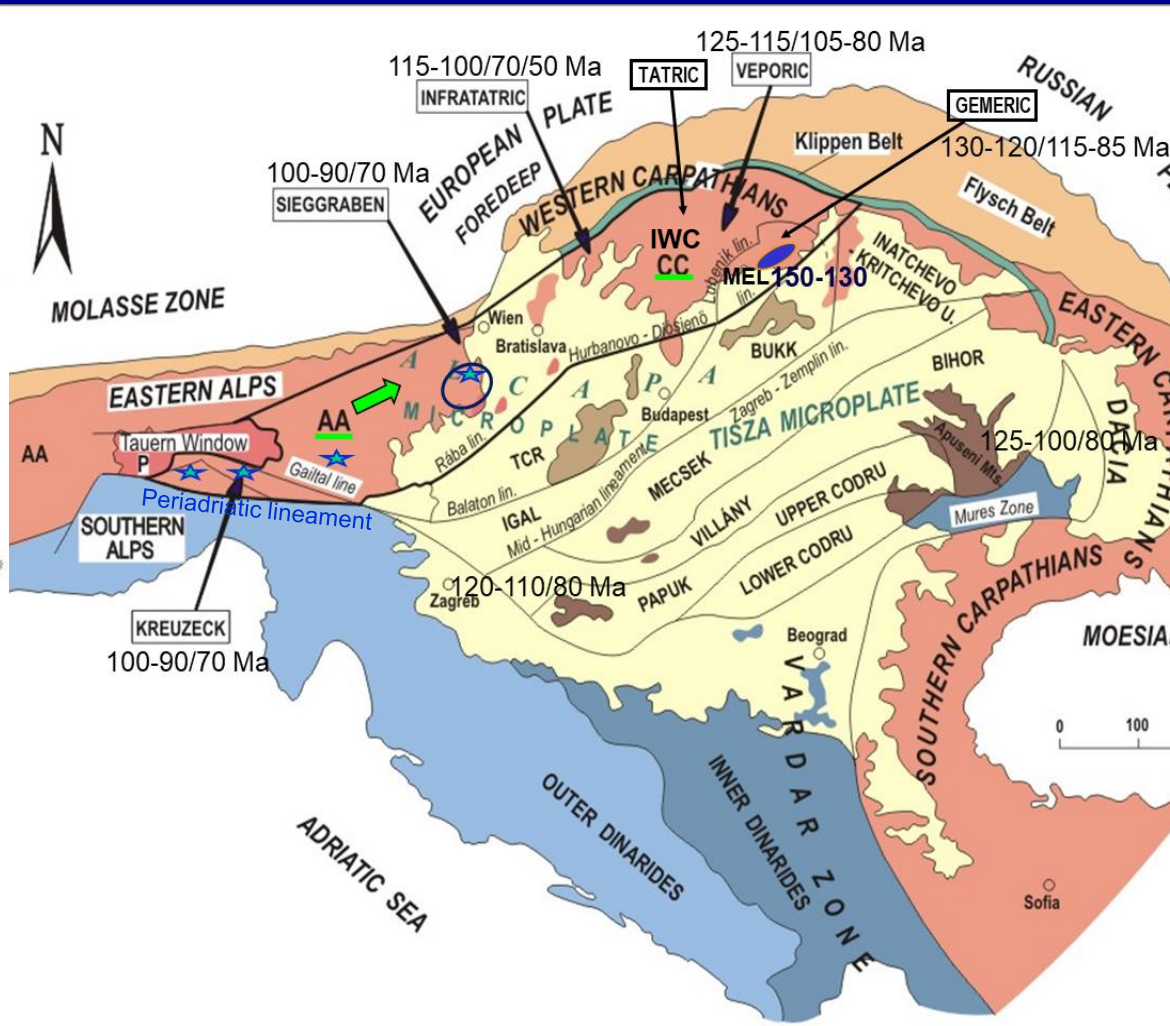


Fig. 11.2 (a) CEED mantle frame reconstruction of the estimated eruptio
Central Atlantic Magmatic Province (CAMP) together with 38 Triassic ki
contours in the lower mantle (Lekic et al., 2012). Areas 5, 3, and 1 define
mantle. The 1% slow SMEAN contour is shown for comparison (see Cha
locations erupted near or over the Tuzo Plume Generation Zone (PGZ) w
(231–215 Ma) appear to be related to the Perm Anomaly. Outline Earth g
(c) 210 Ma (Late Norian). A, Annamia; F, Falkland; K, Kazakh terranes;
SC, South China; T, Tarim; TH, Tethyan Himalaya. CEED palaeomagneti

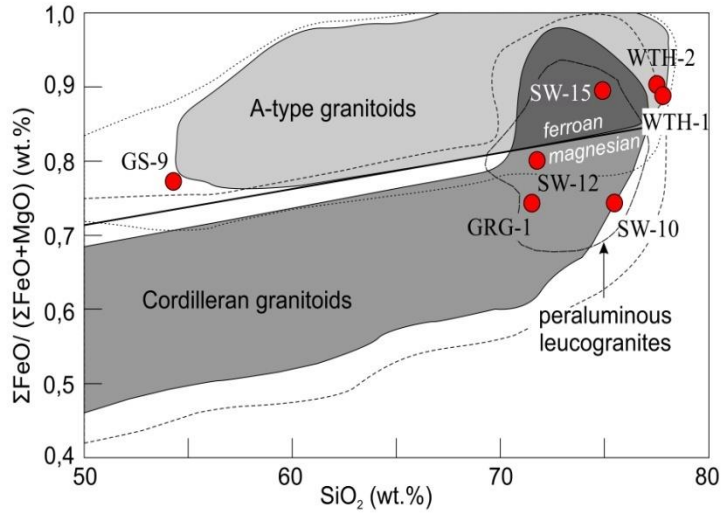


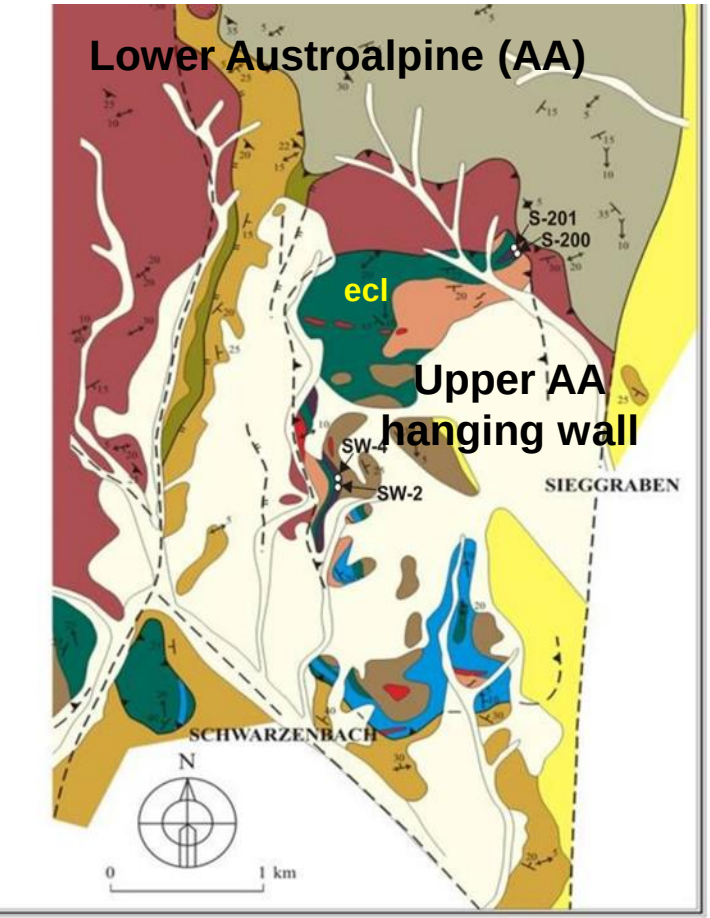


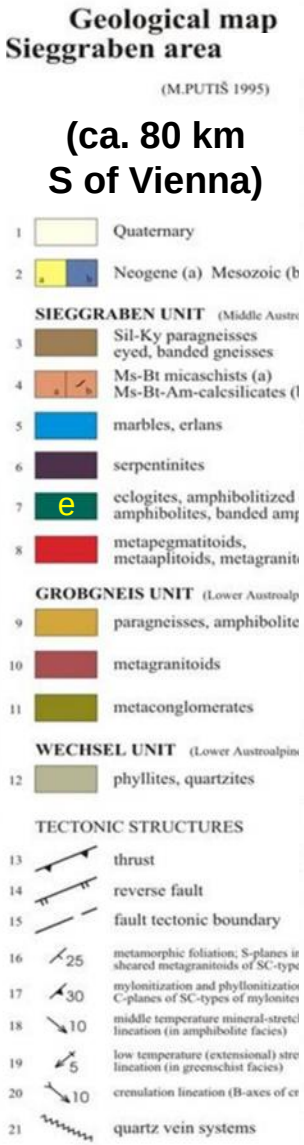
AUSTRO-ALPINE (AA) – INNER WESTERN CARPATHIANS (CC~IWC) BLOCK of ALCAPA: A REMNANT OF EOALPINE OROGENY

blue stars ~ Cretaceous eclogites

(Putiš 2002: Fig. 1, Geol. Carpath.)

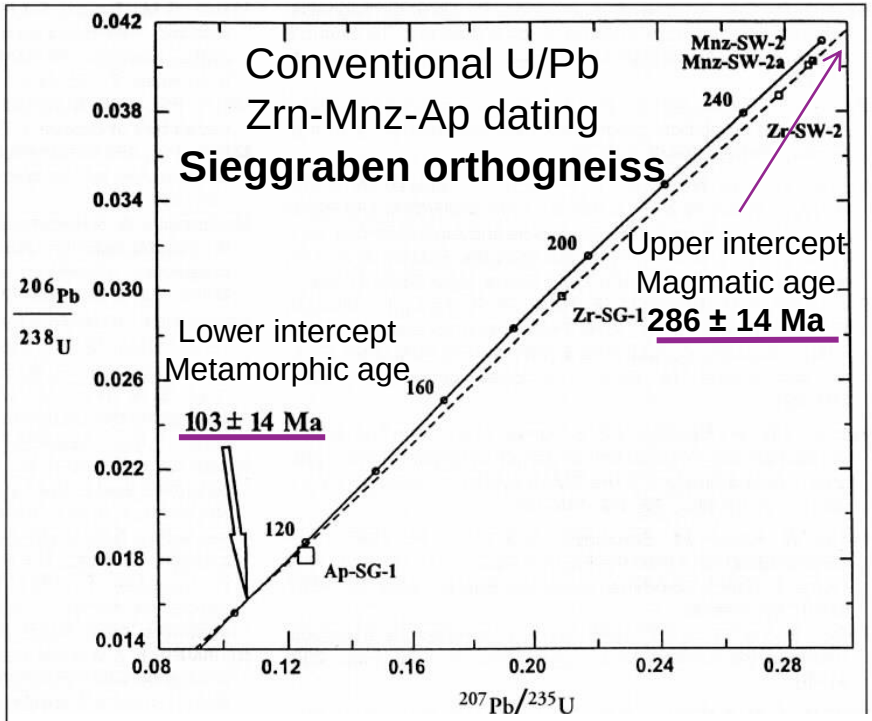


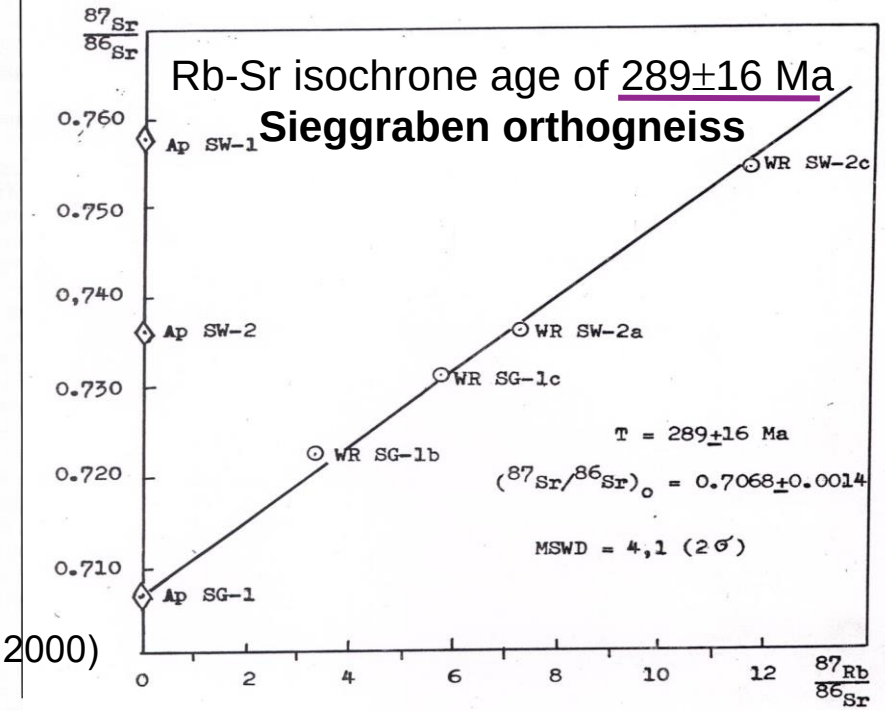




(ca. 80 km S of Vienna)

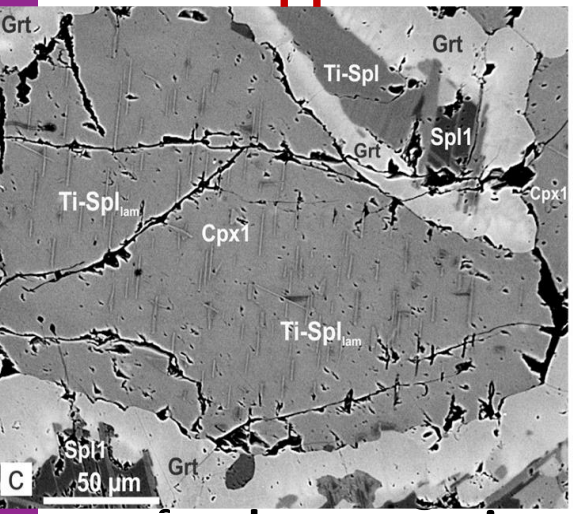
(Putiš et al., 1994; 2000)

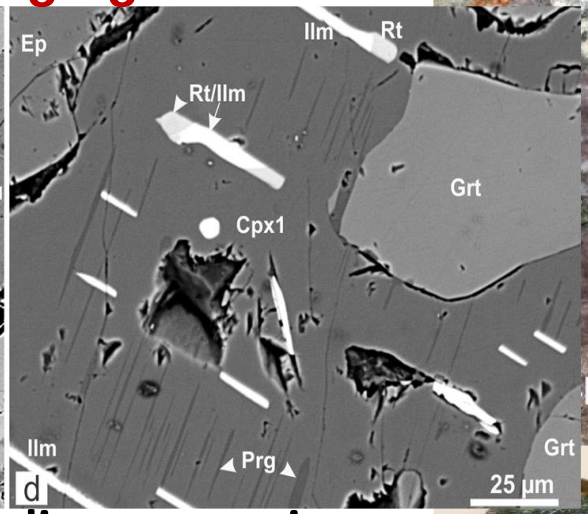




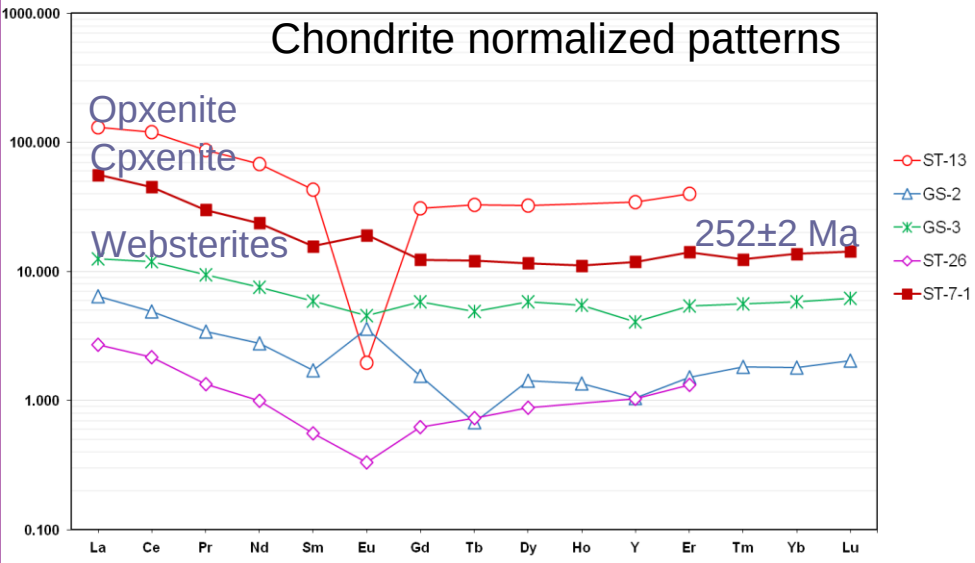
Steinbach – Gschorrholz Area

Upper AA hanging wall



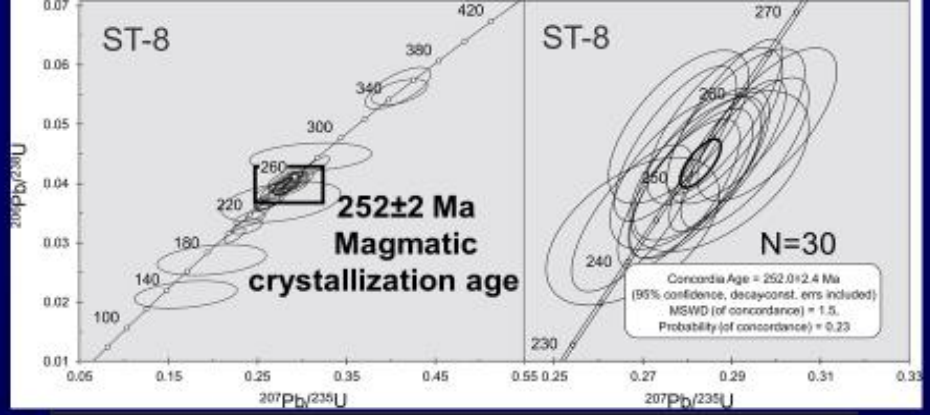


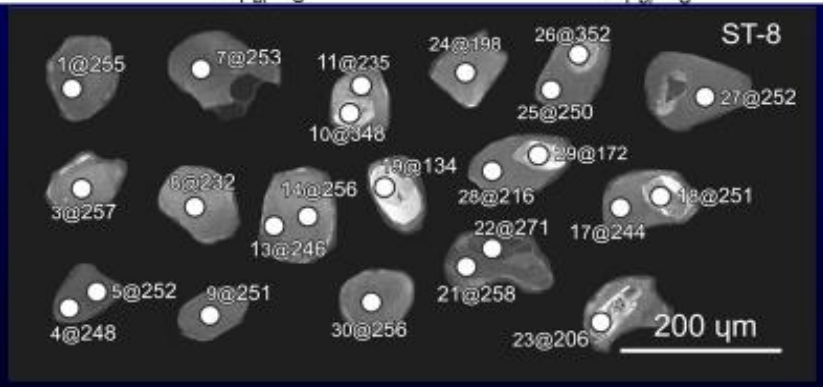
orthopyroxenite, **clinopyroxenite** and **websterite** dykes – Evidence of mantle melting



(Putiš et al., 2018, Lithos)

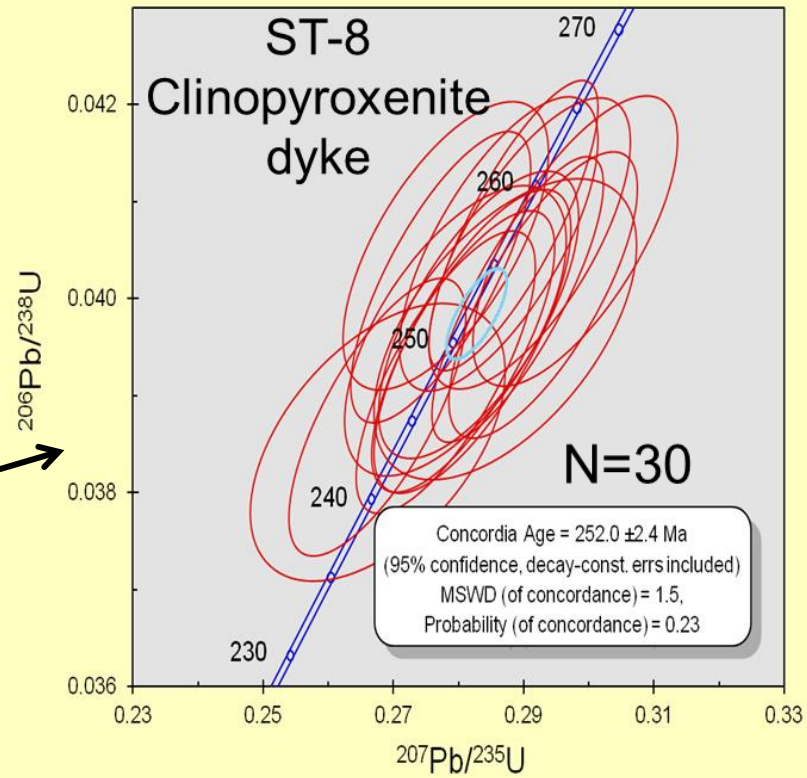
Upper A-Alpine hanging wall
HP Sieggraben
structural complex



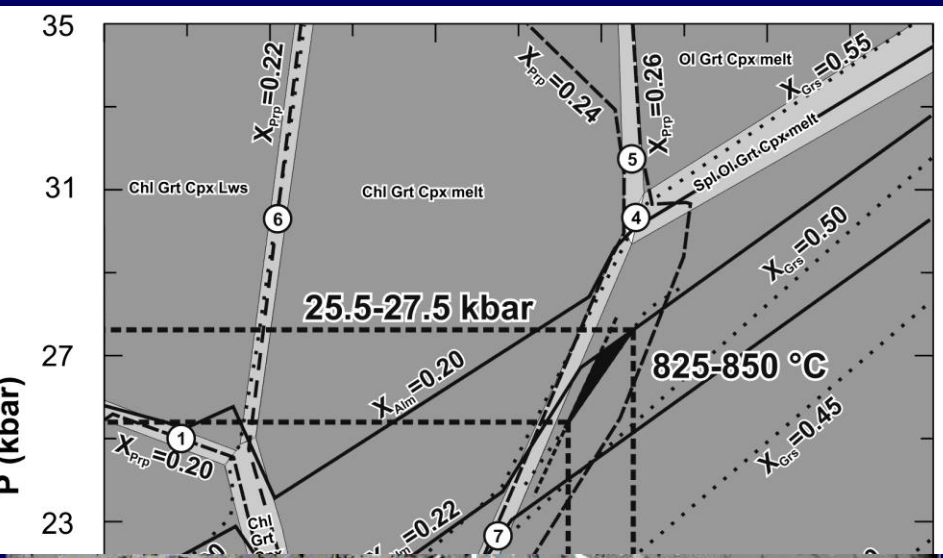


$\varepsilon_{Hf}(t)$ zircon values of 16–8 (average 11 from 18 spots) suggest a depleted mantle source of these sub-crustal cumulate-type melts

Steinbach
Clinopyroxenite dyke in harzburgite:
Permian magmatic age
252±2.4 Ma
Zircon U-Pb SIMS
(UAA HP Sieggraben str. c.)
Putiš et al. (2018, Lithos)

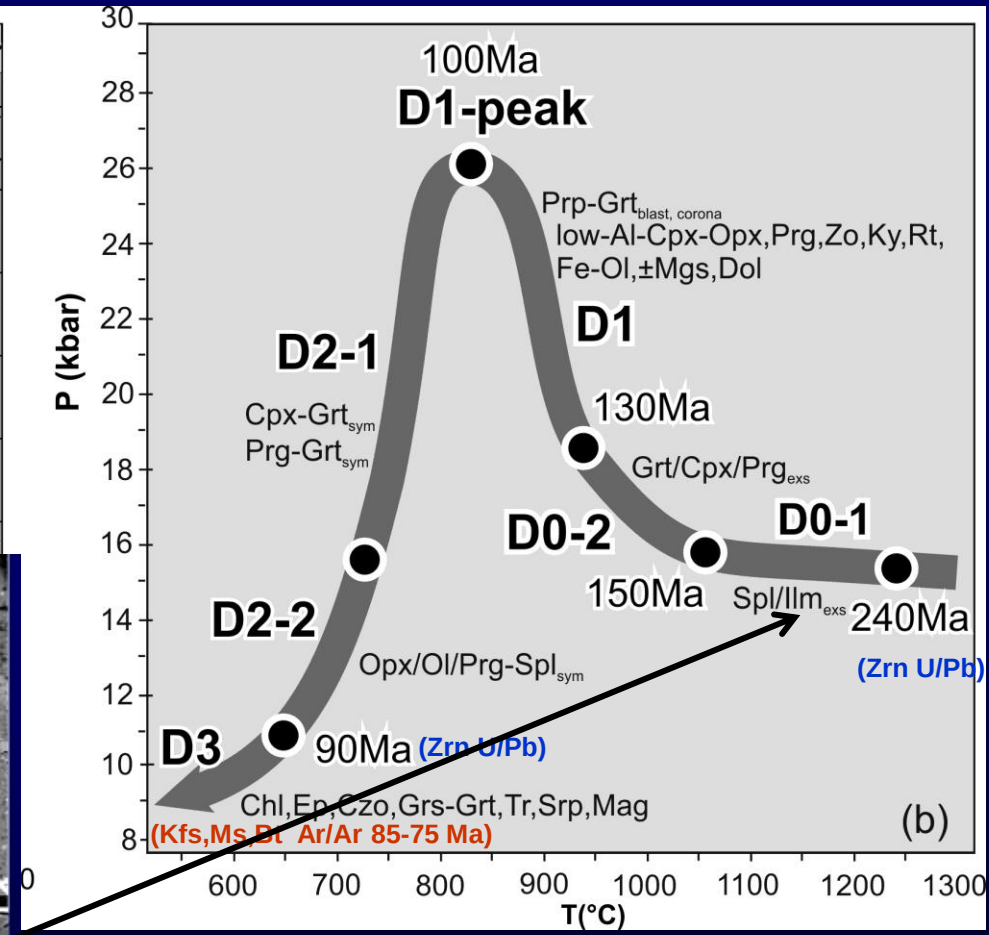


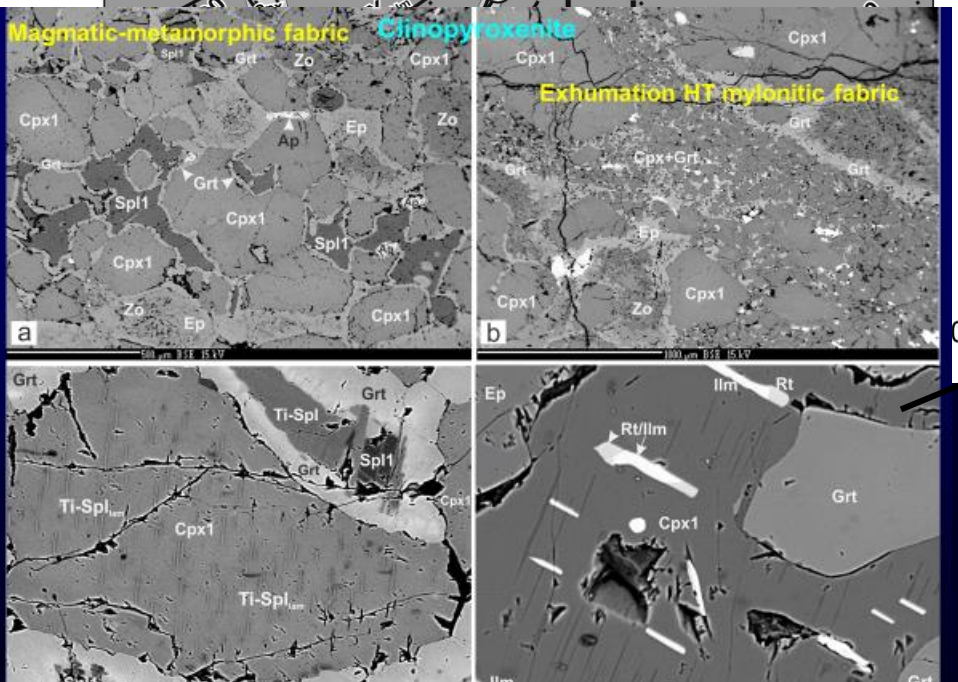
P–T calculated for D1 stage peak pressure conditions in clinopyroxenite by Perple_X



Reconstructed P–T path of pyroxenites in harzburgite block

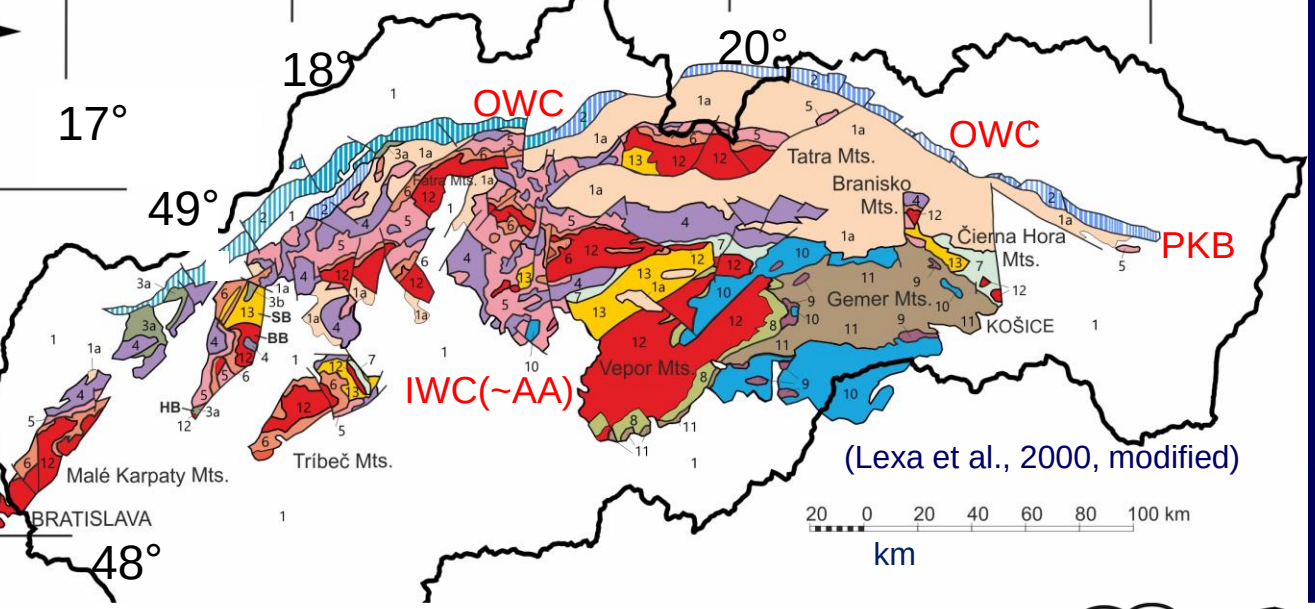
(Putiš et al., 2018, Lithos)



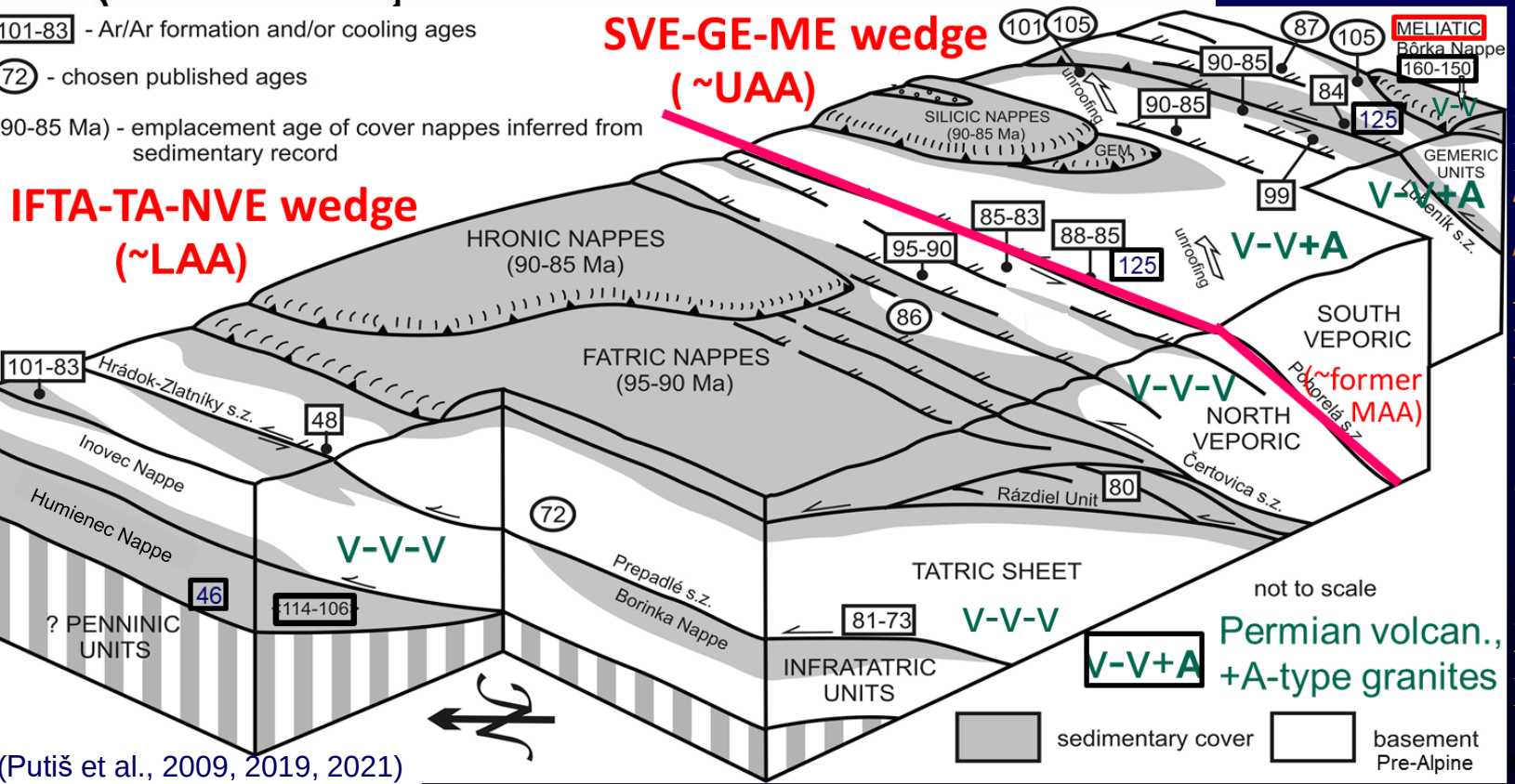


Spl-Ilm exsolutions in Cpx of a clinopyroxenite dyke in harzburgite required long-term hot mantle conditions and/or slow post-magmatic cooling

11–**Alpine Gemeric Unit** Paleozoic basement (*Variscan Lower Unit*) and cover; 12–*Variscan Upper Unit*, 13–*Variscan Middle Unit* of the **Alpine Veporic and Tatric units**, 8–South-Veporic cover, **9 – Meliaticum**, **10–Silicicum.**

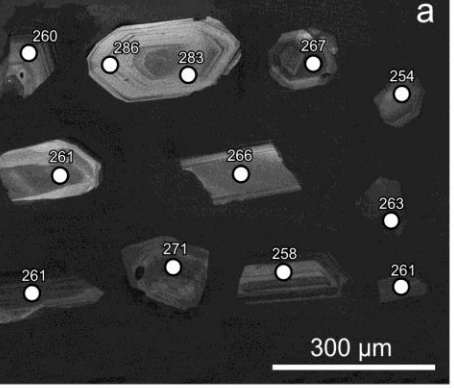


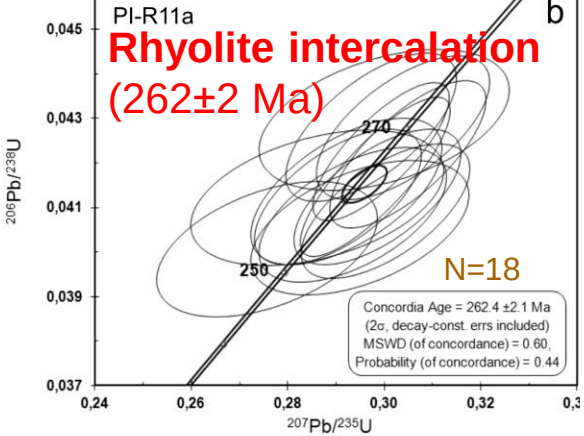
(Lexa et al., 2000, modified)

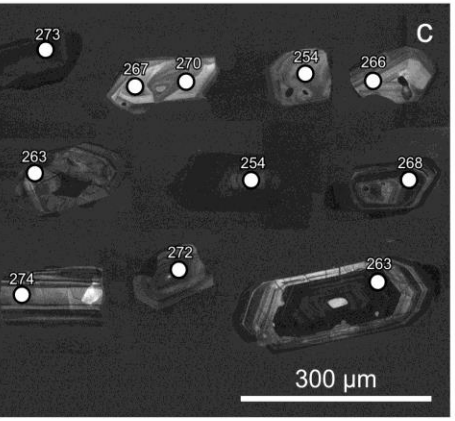


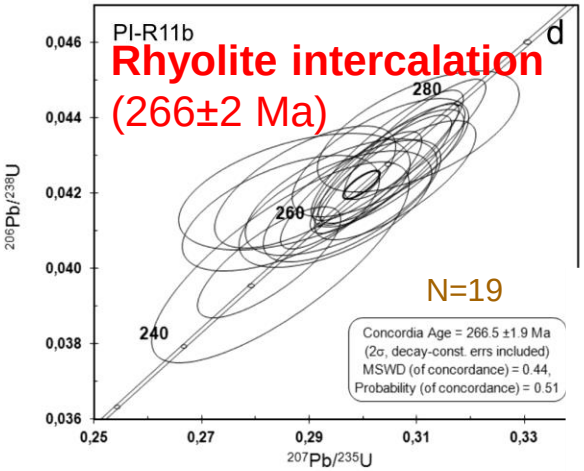
(Putiš et al., 2009, 2019, 2021)

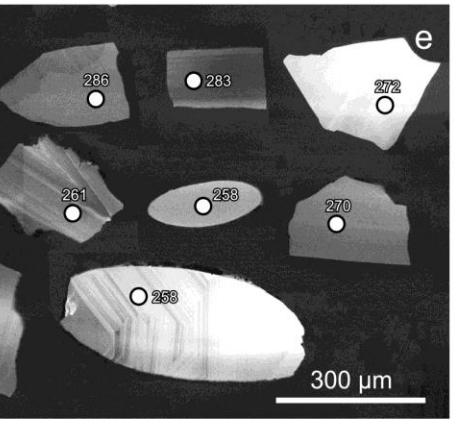
IFTA- Infratatric, **TA-** Tatric, **NVE-** North-Veporic, **SVE-** South-Veporic, **GE-** Gemeric, **ME-** Meliatic

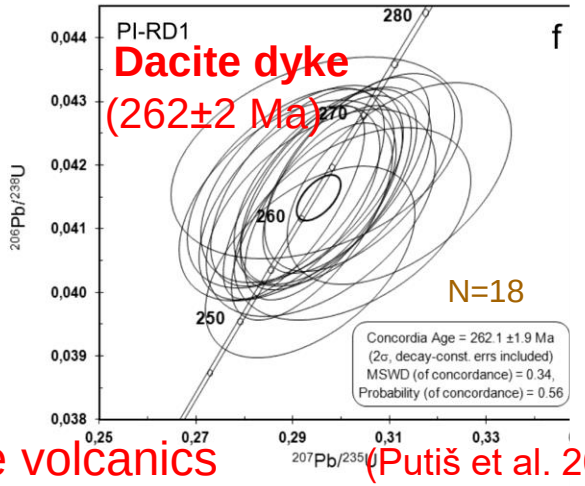


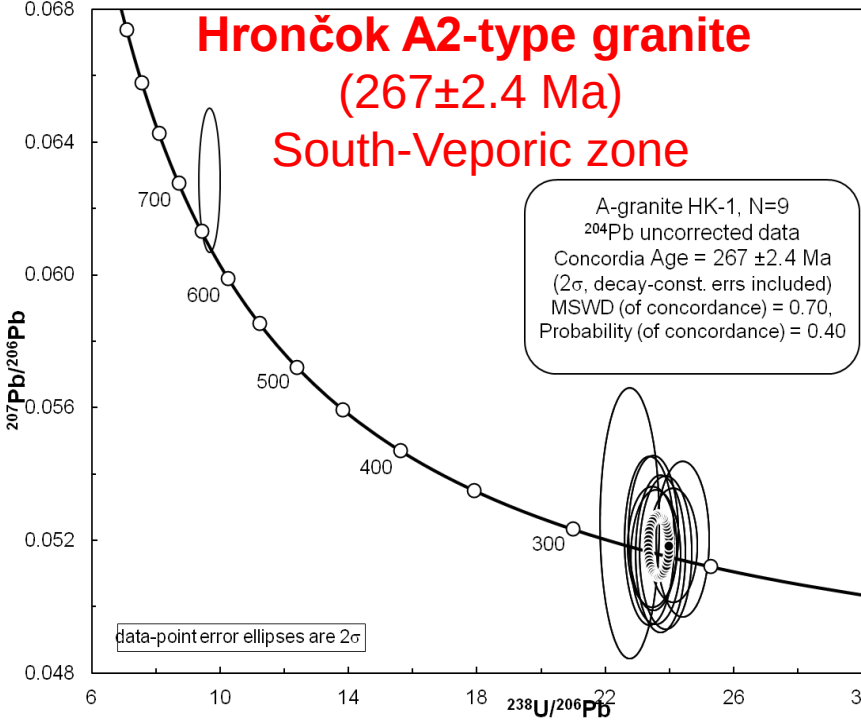


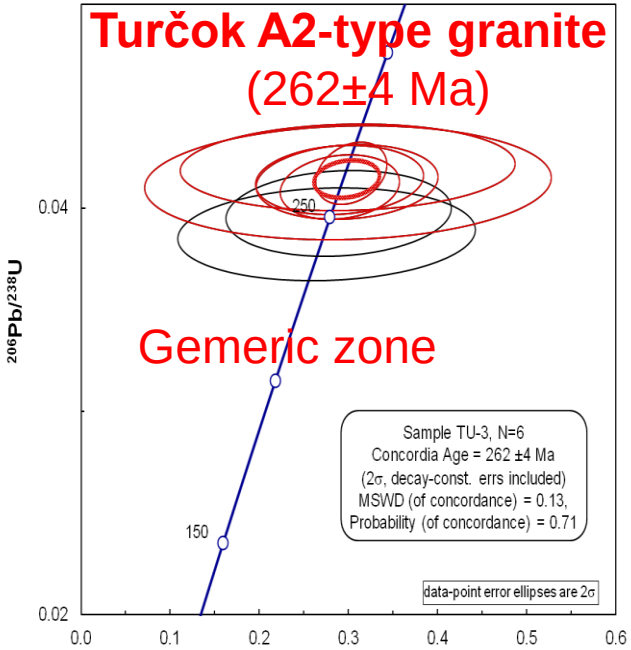






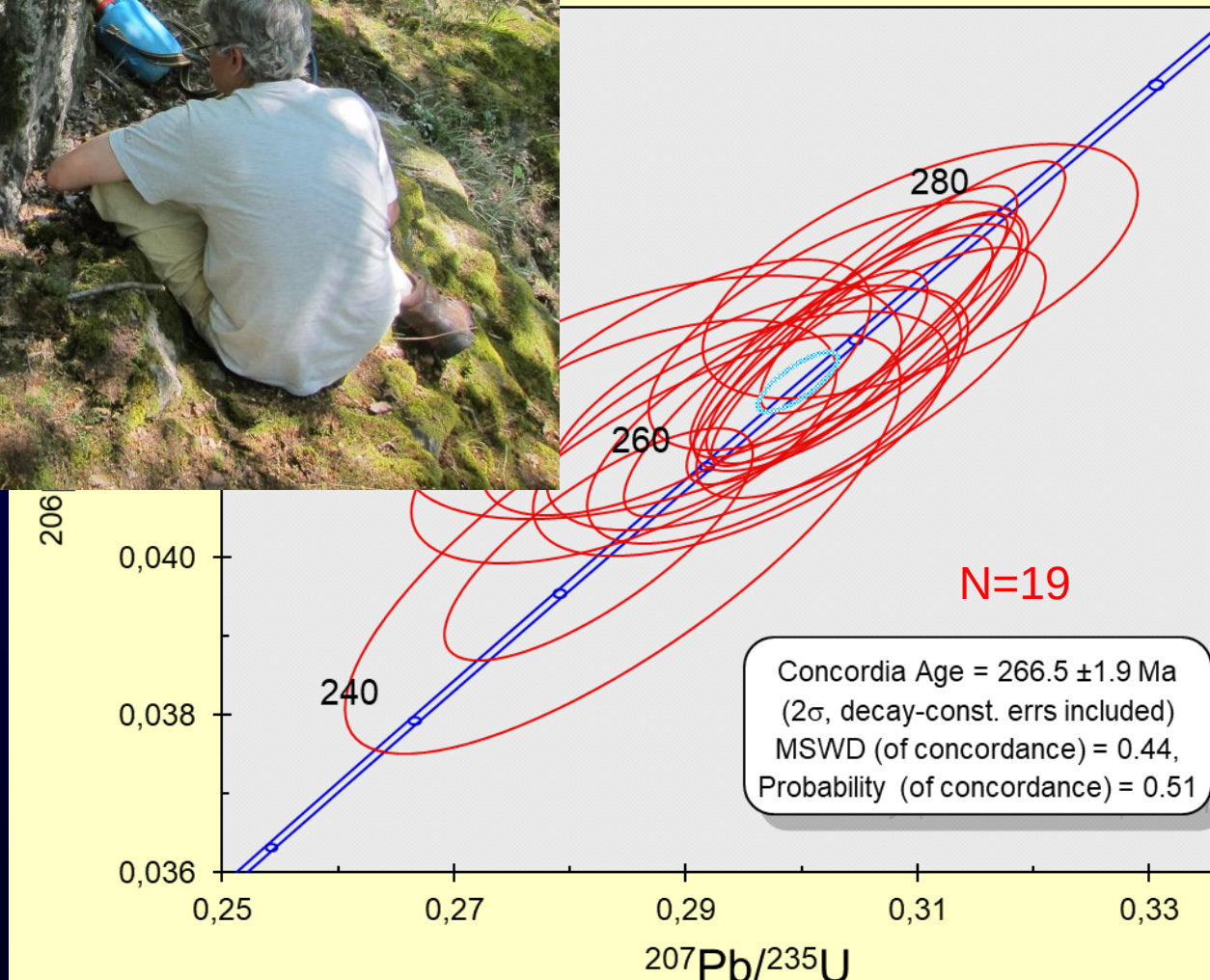






Infratatric calc-alkaline volcanics (Putiš et al. 2016) (Ondrejka et al. 2021)

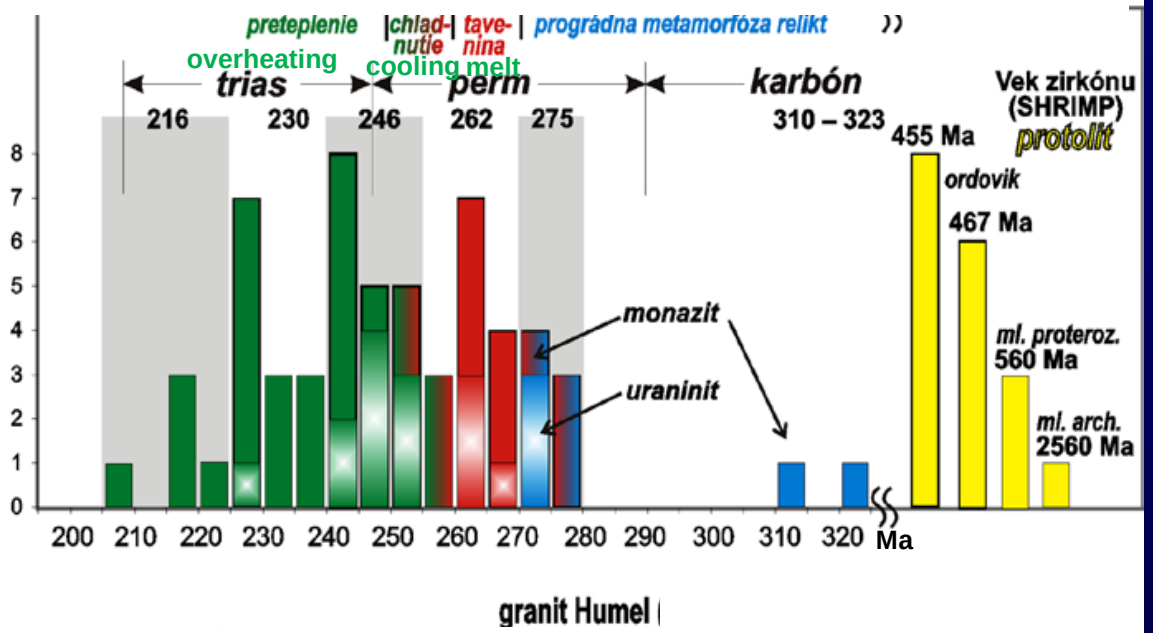
Infratatric sedimentary cover (Považský Inovec Mts.)



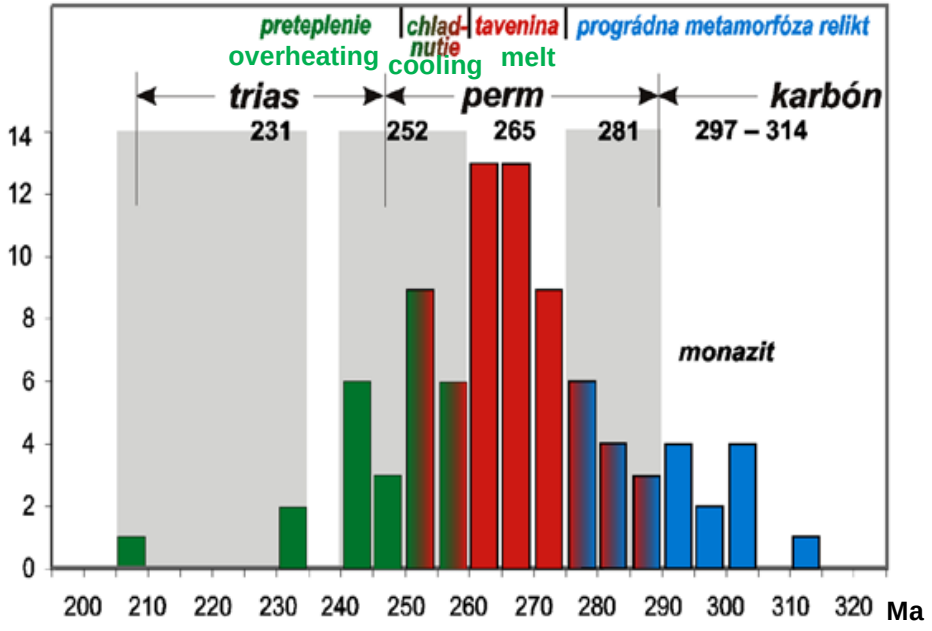
U/Pb SIMS
Permian 267±2 Ma
calc-alk. Meta-rhyolite
intercalation within
arkosic sandy shales

(Putiš et al., 2016)

The Gemeric Superunit Permian granites



granit Humel



The Gemeric Permian granites (**magmatic ages in red**)

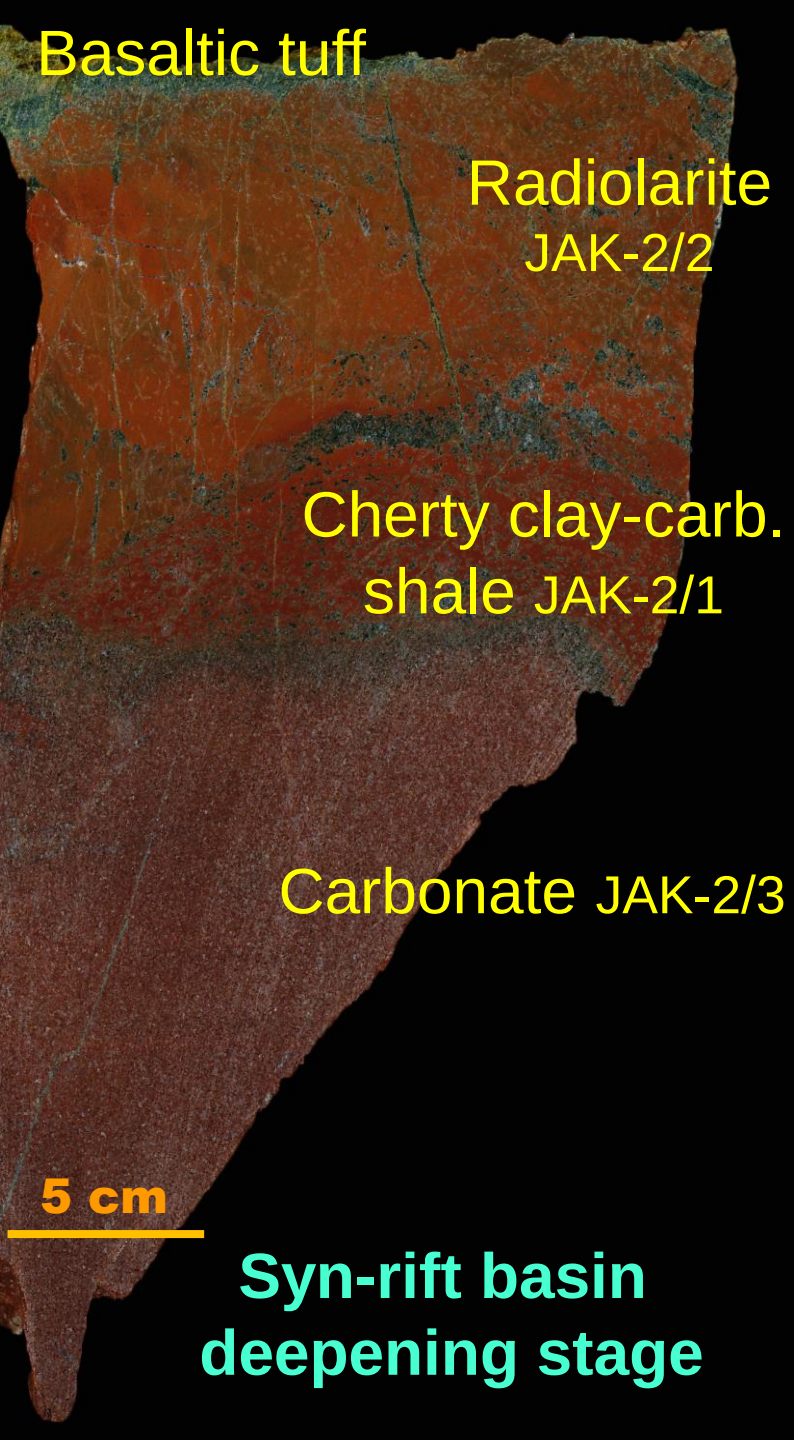
record a

Triassic overheating by **the green Mnz ages up to the Carnian-Norian,**

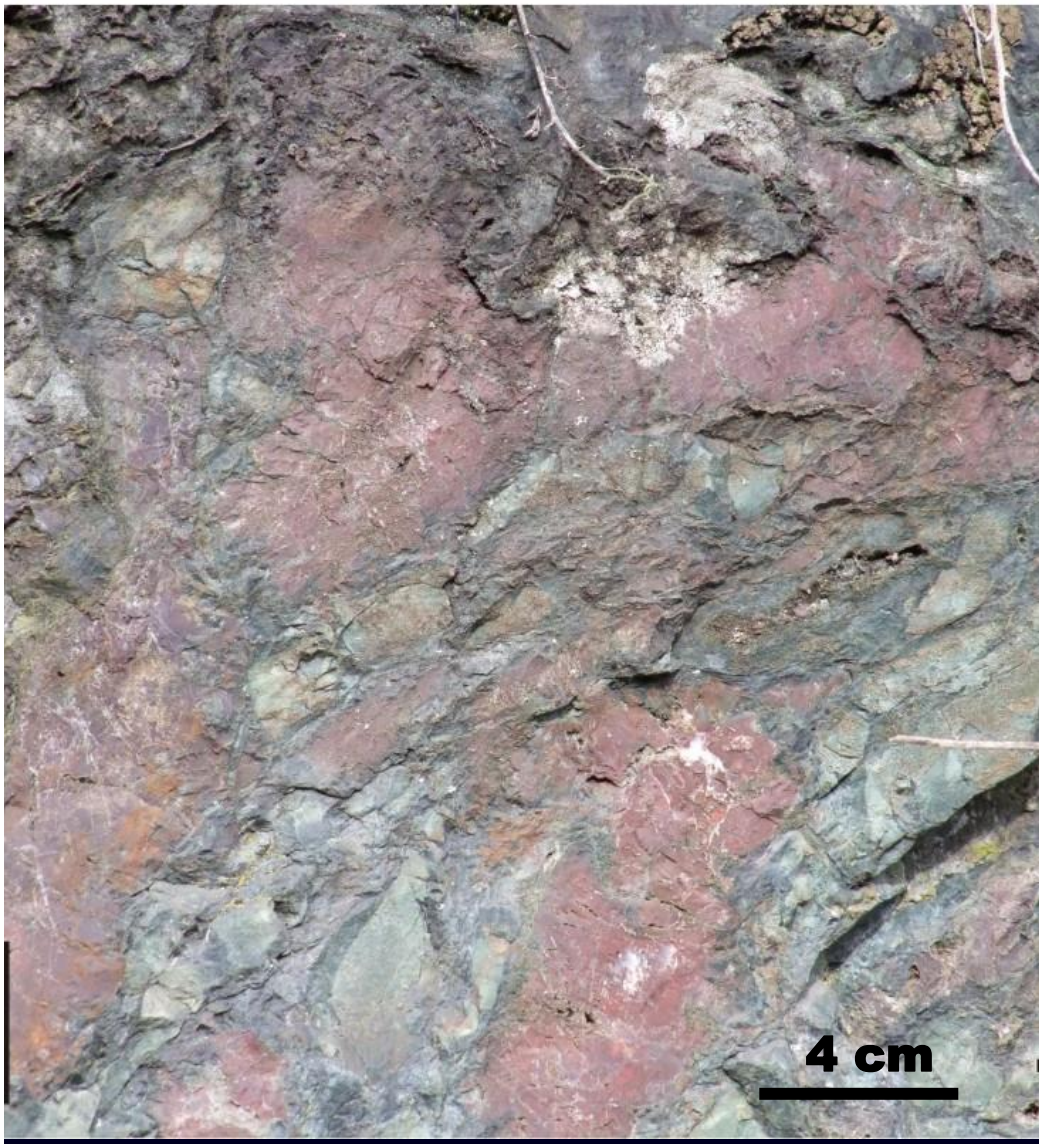
which may be related to the opening of the Meliata Basin during

Advanced continental (~250-240 Ma) and incipient oceanic (from~240 Ma) rifting stages

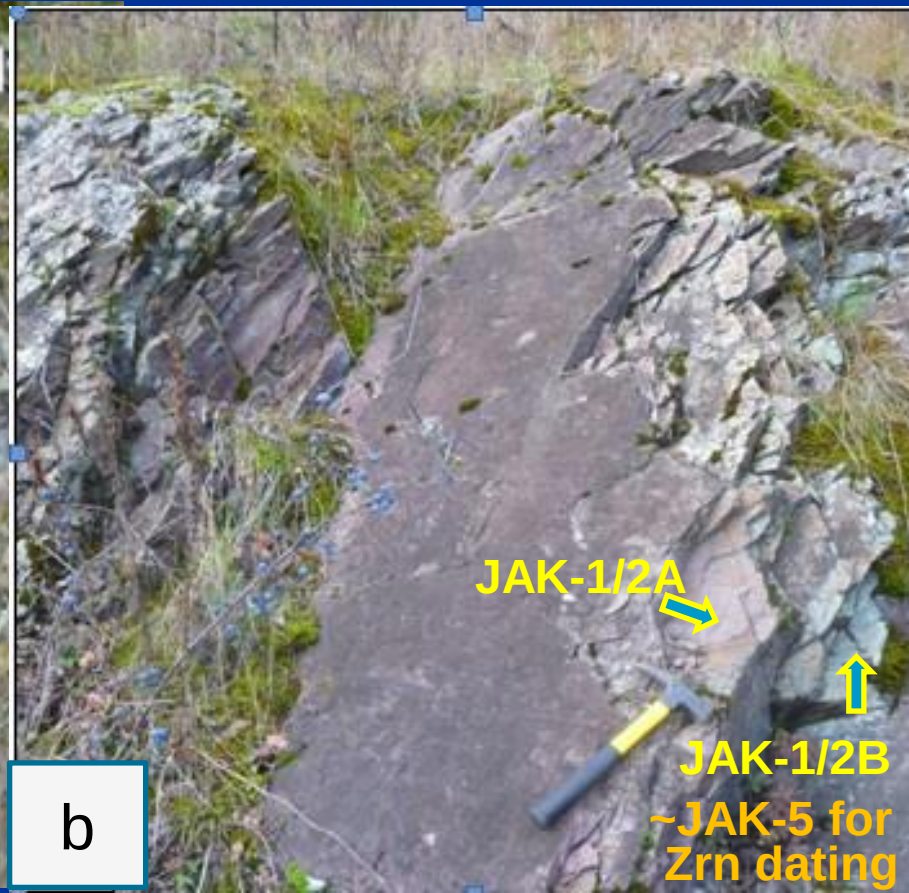
Radvanec, Németh, Putiš et al. (2009)

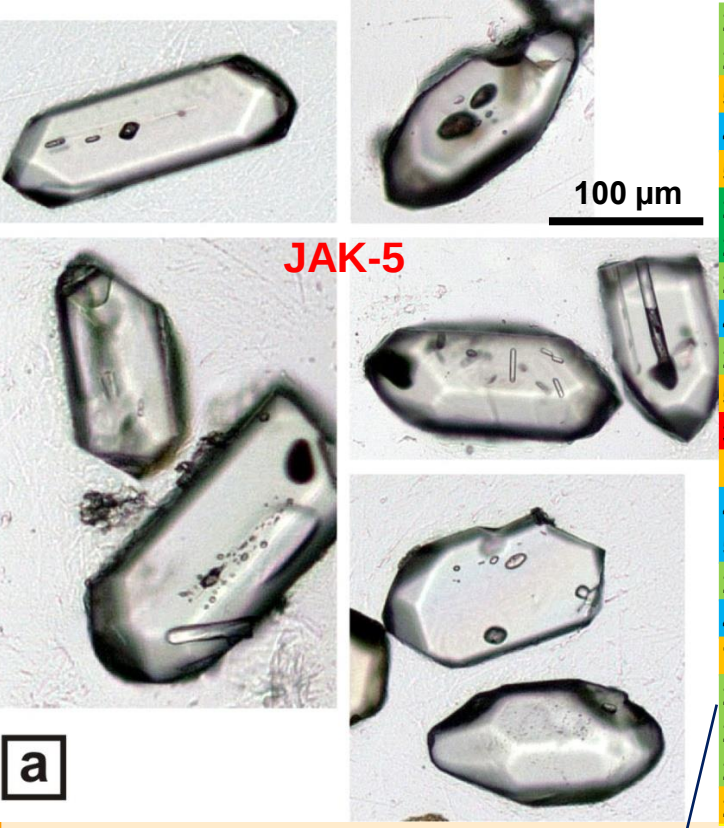


Peperitic breccia horizon

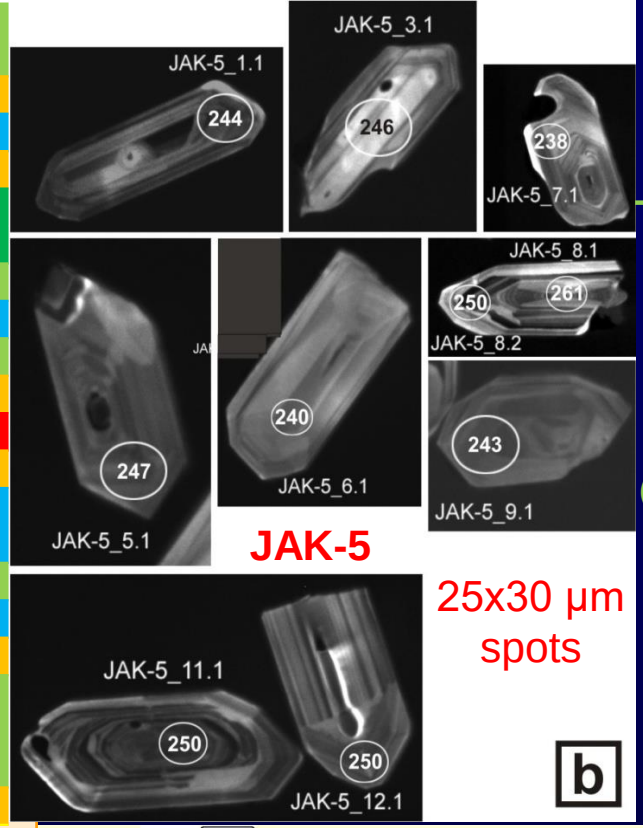


Detrital Zircon in Ladinian cherts
(the Meliatic oceanic Jaklovce Succession), with ca. 0.5 m thick N-MORB layers



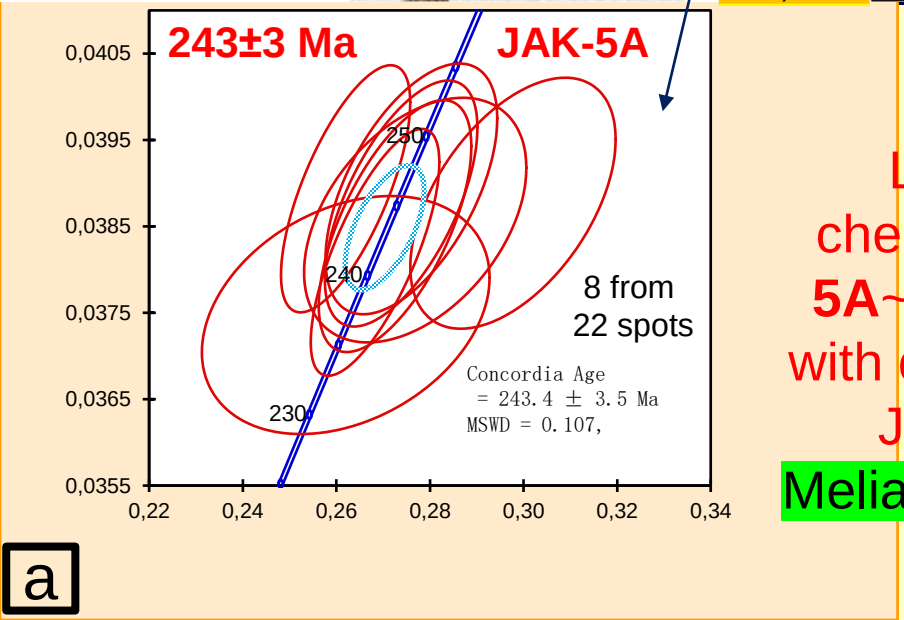


Ma
246,2
241,7
559,1
484,8
586,4
264,8
264,4
237,2
471,8
245,2
564,9
387,8
1353,4
454,9
511,3
243,6
466,6
739,3
245,2
246,2
244,0
2052,3

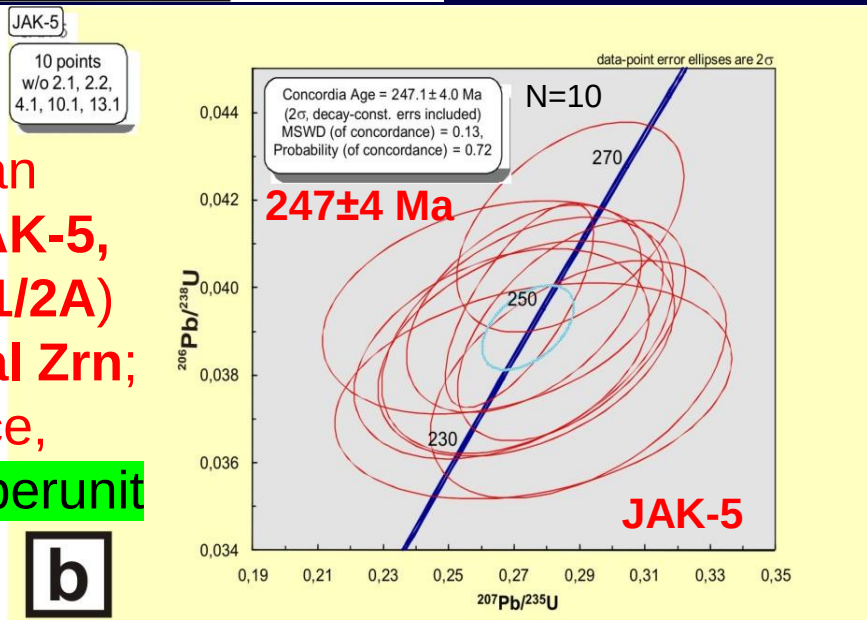


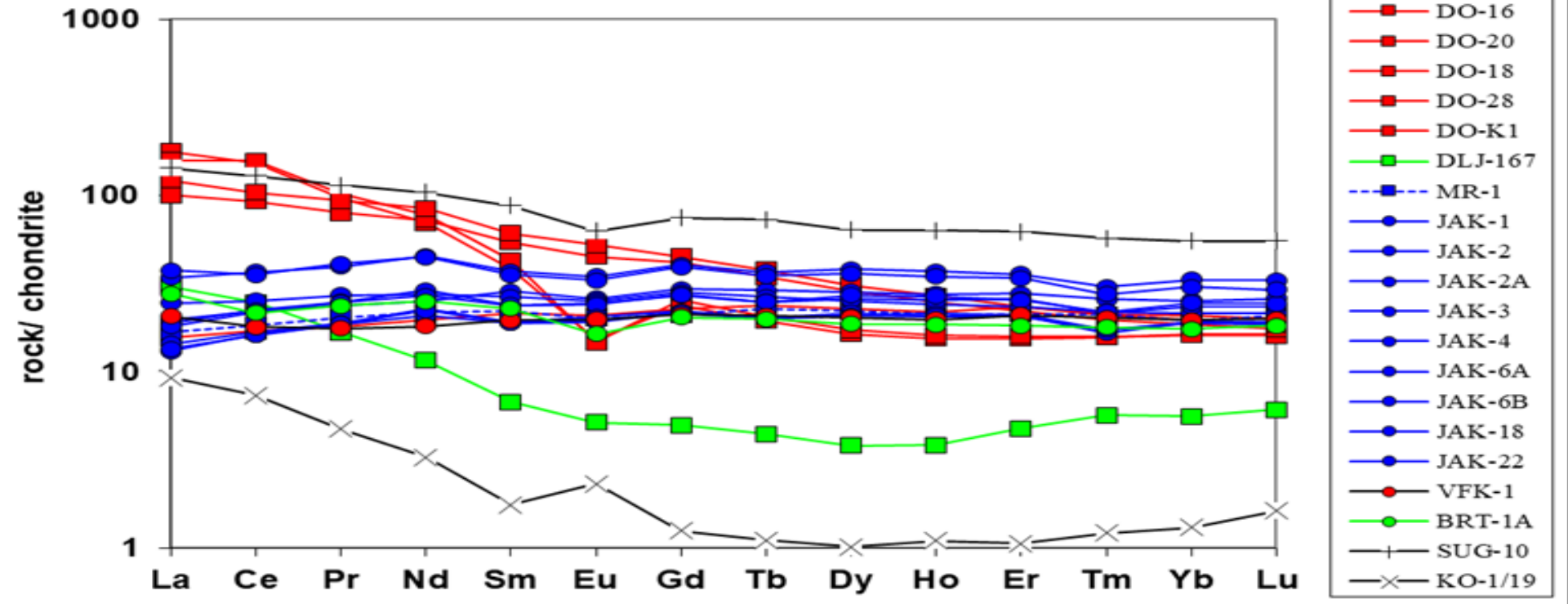
early Middle Triassic-Anisian magmatic source

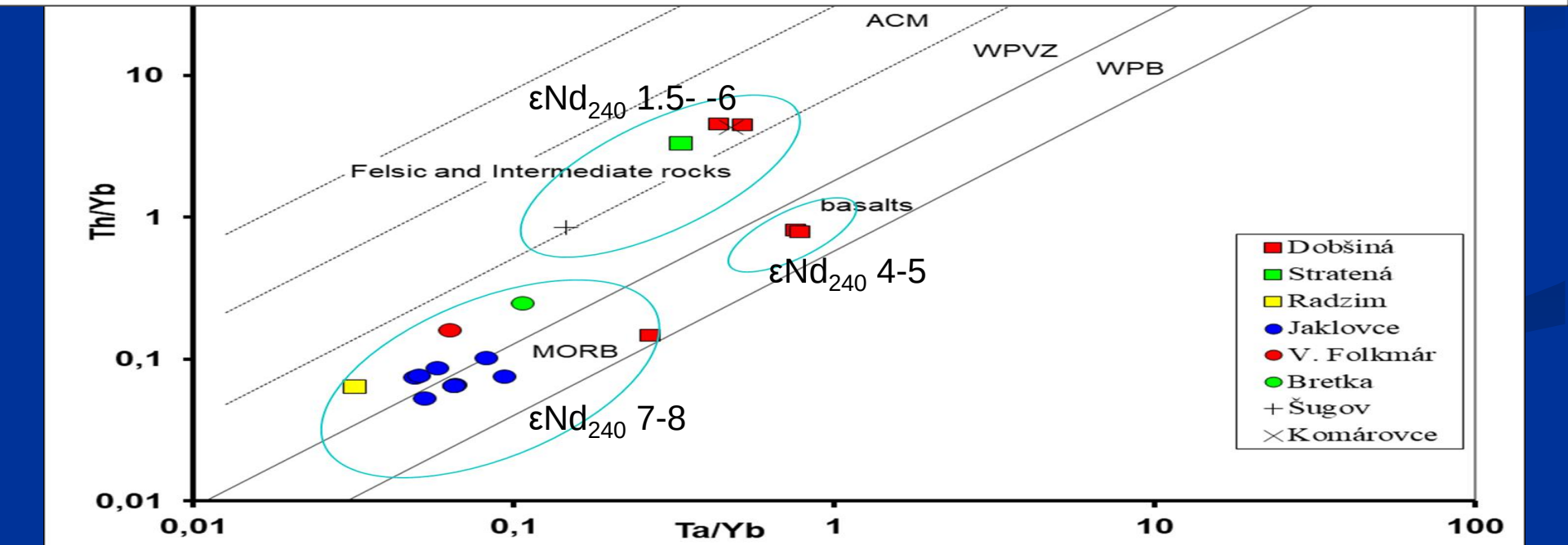
(Putiš et al., 2011, 2019)

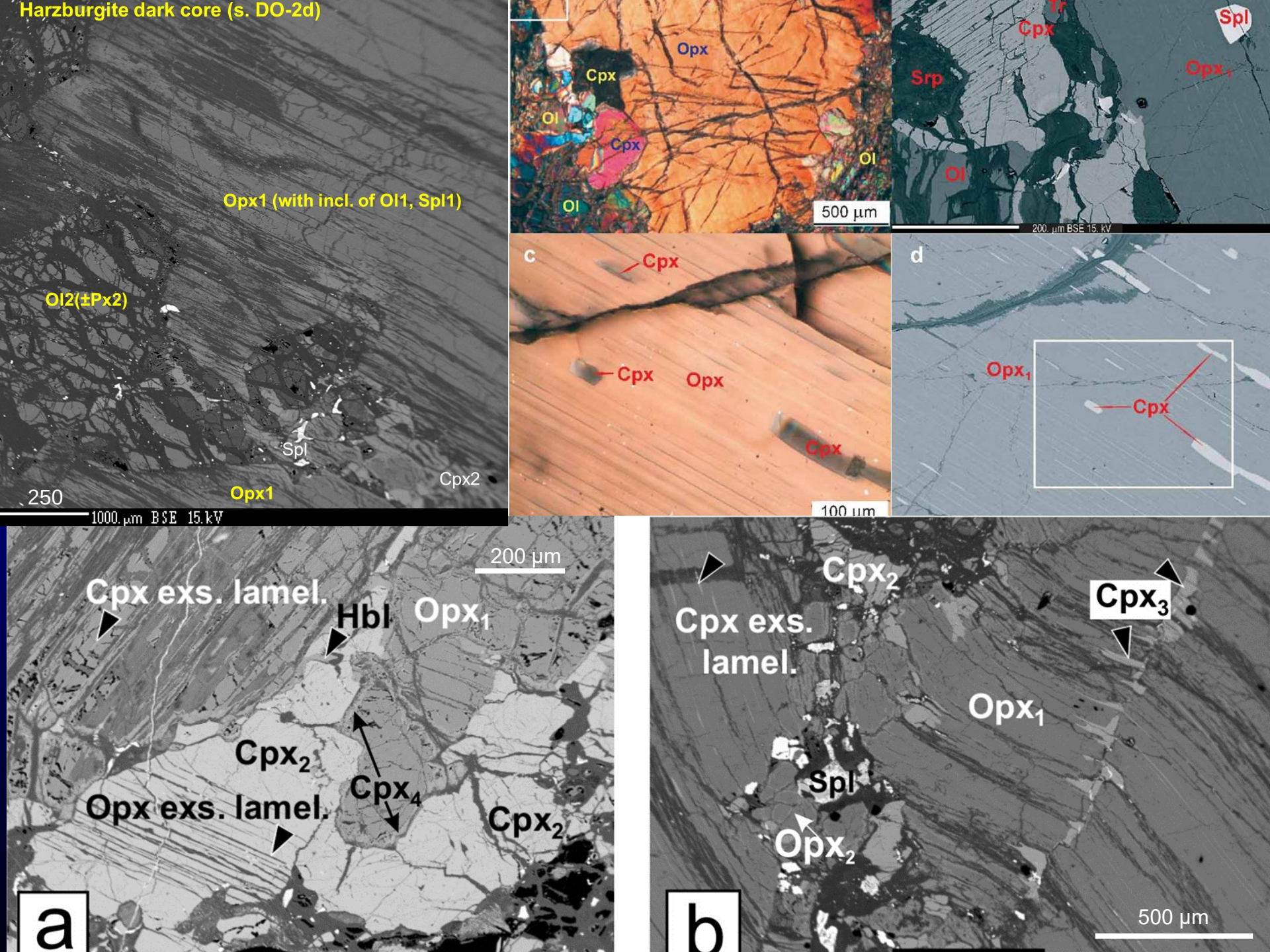


Ladinian cherts (**JAK-5, 5A~JAK-1/2A**) with **detrital Zrn**; Jaklovce, Meliata Superunit

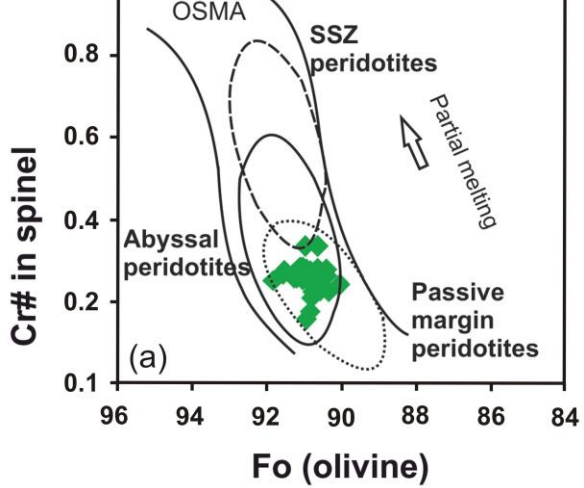


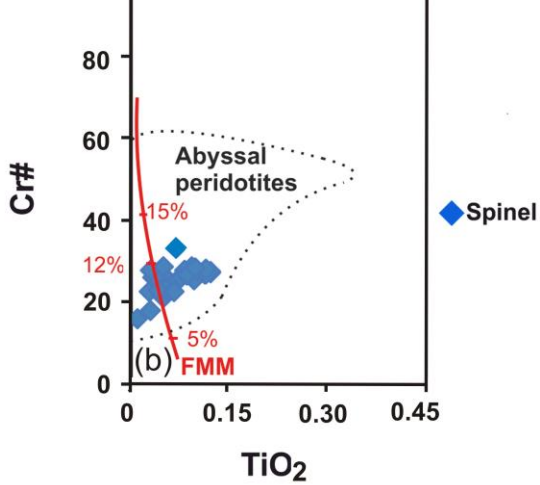

1000
100
10
1
rock/ chondrite
La
Ce
Pr
Nd
Sm
Eu
Gd
Tb
Dy
Ho
Er
Tm
Yb
Lu
DO-16
DO-20
DO-18
DO-28
DO-K1
DLJ-167
MR-1
JAK-1
JAK-2
JAK-2A
JAK-3
JAK-4
JAK-6A
JAK-6B
JAK-18
JAK-22
VFK-1
BRT-1A
SUG-10
KO-1/19

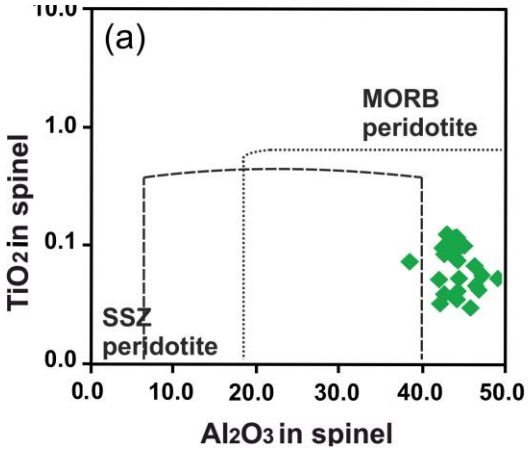

ACM
WPVZ
WPB
εNd240 1.5- -6
Felsic and Intermediate rocks
basalts
εNd240 4-5
MORB
εNd240 7-8
Th/Yb
10
1
0,1
0,01
0,01
0,1
Ta/Yb
1
10
100
Dobšiná
Stratená
Radzim
Jaklovce
V. Folkmár
Bretka
Šugov
Komárovce

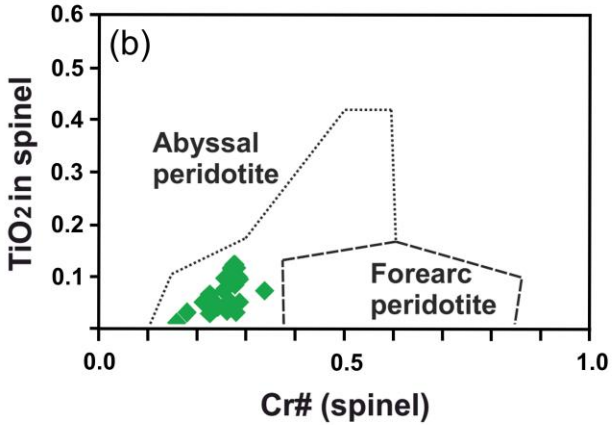

Harzburgite dark core (s. DO-2d)
Opx1 (with incl. of Ol1, Spl1)
Ol2(±Px2)
Spl
Cpx2
Opx1
250
1000 µm BSE 15 kV
Opx
Cpx
Ol
Cpx
Ol
Ol
500 µm
Tr
Cpx
Spl
Srp
Opx1
Ol
200 µm BSE 15 kV
c
Cpx
Cpx
Opx
Cpx
100 µm
d
Opx1
Cpx
200 µm
Cpx exs. lamel.
Hbl
Opx1
Cpx2
Cpx4
Opx exs. lamel.
Cpx2
a
Cpx2
Cpx exs. lamel.
Cpx3
Opx1
Spl
Opx2
b
500 µm

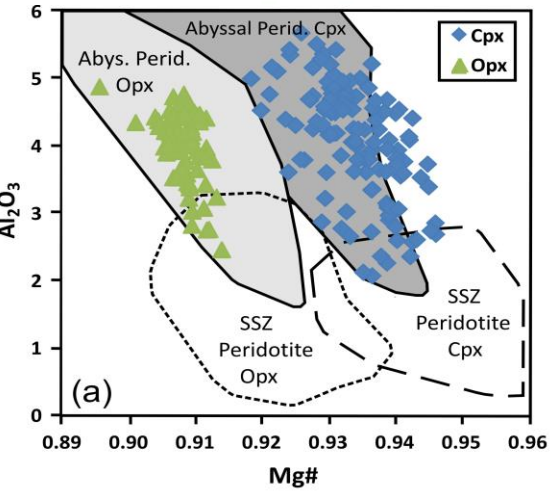
Ultramafics from the Dobšiná serpentinite mélange (Meliaticum)

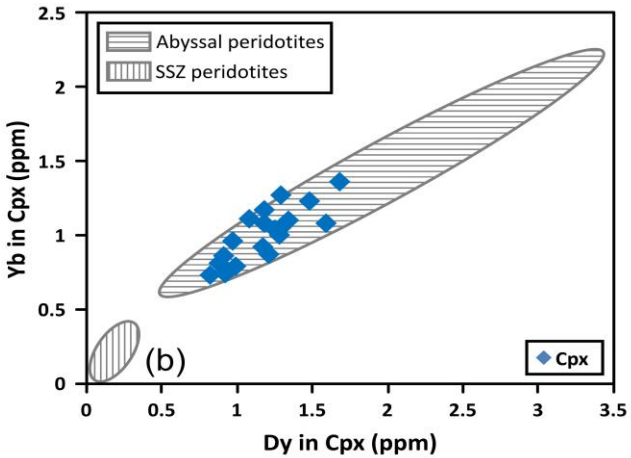


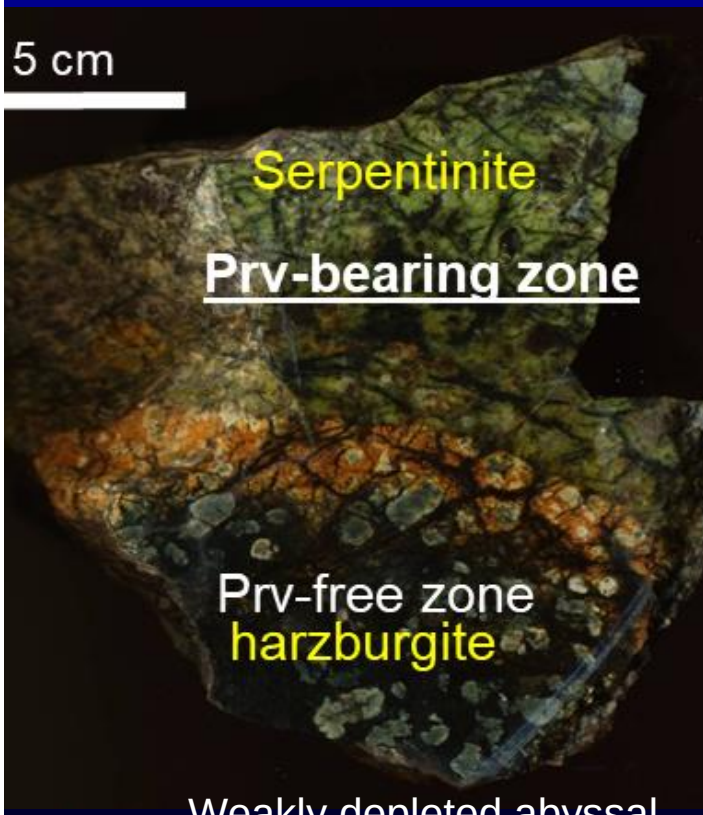






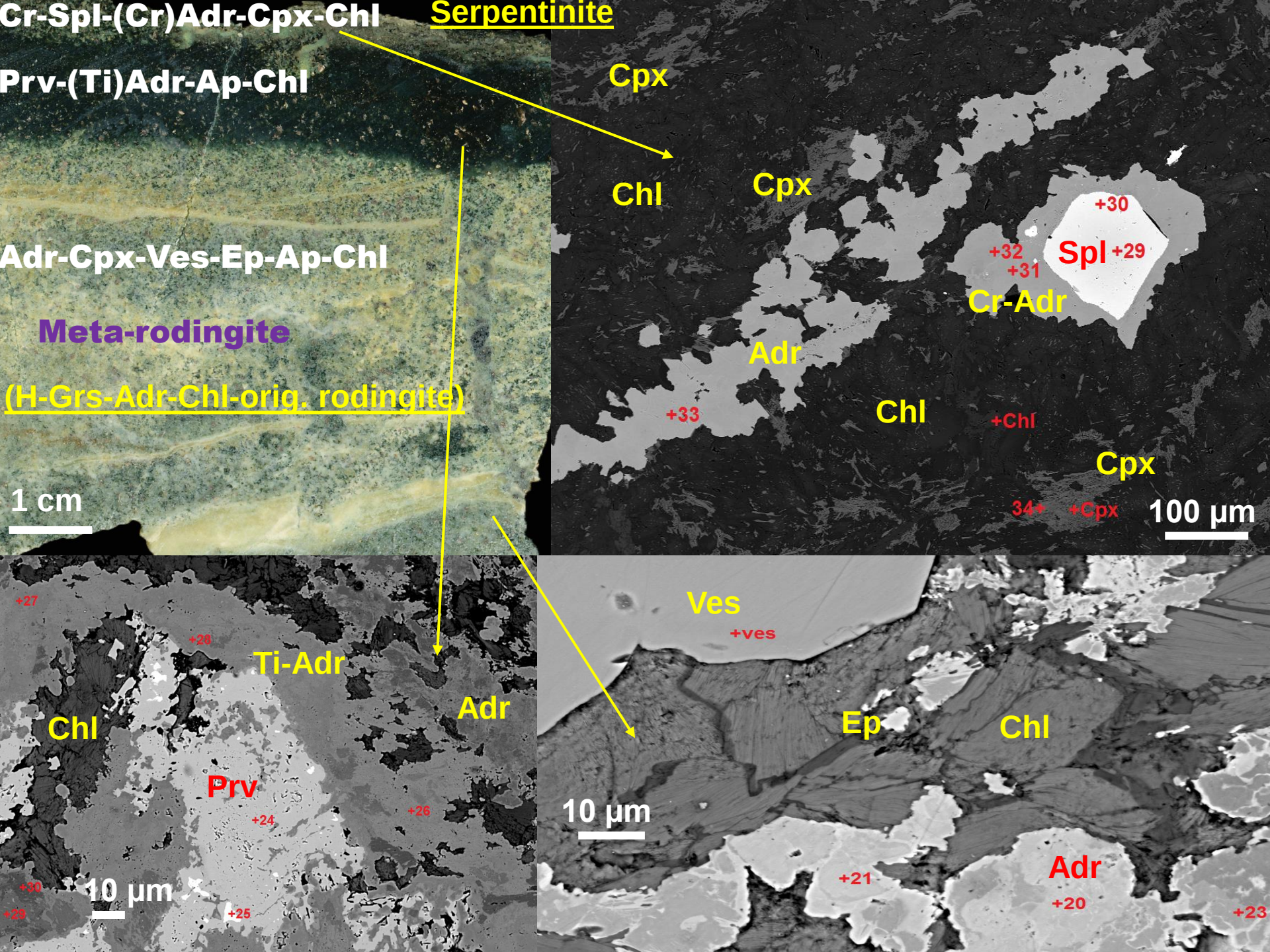






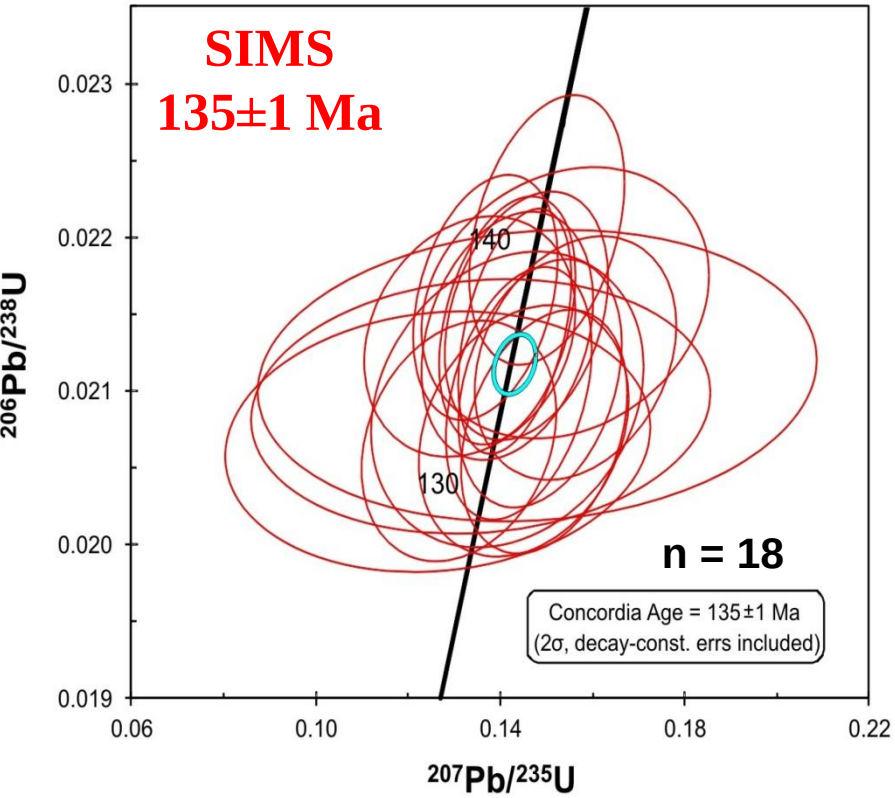
Weakly depleted abyssal Spl Harzburgite

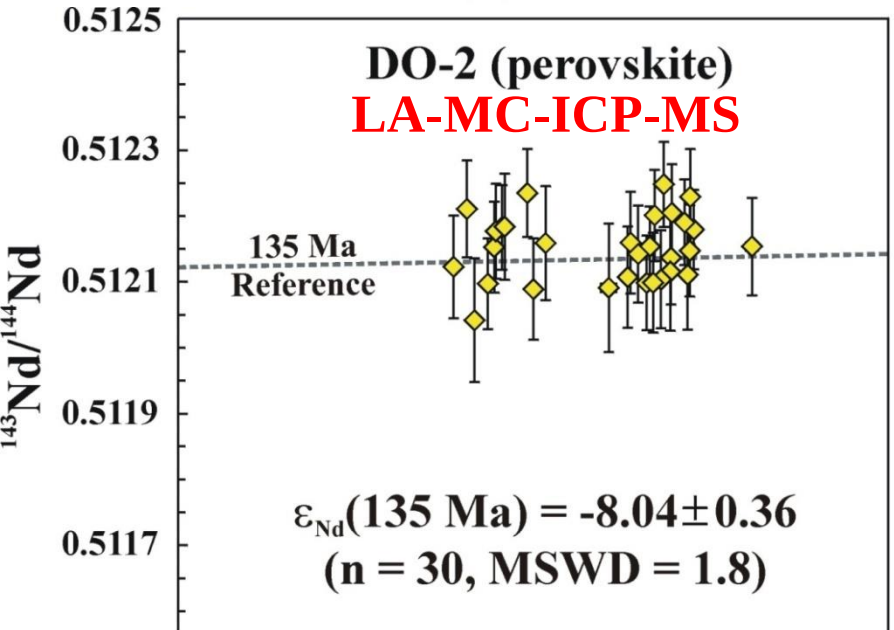
Putiš et al. (2016)

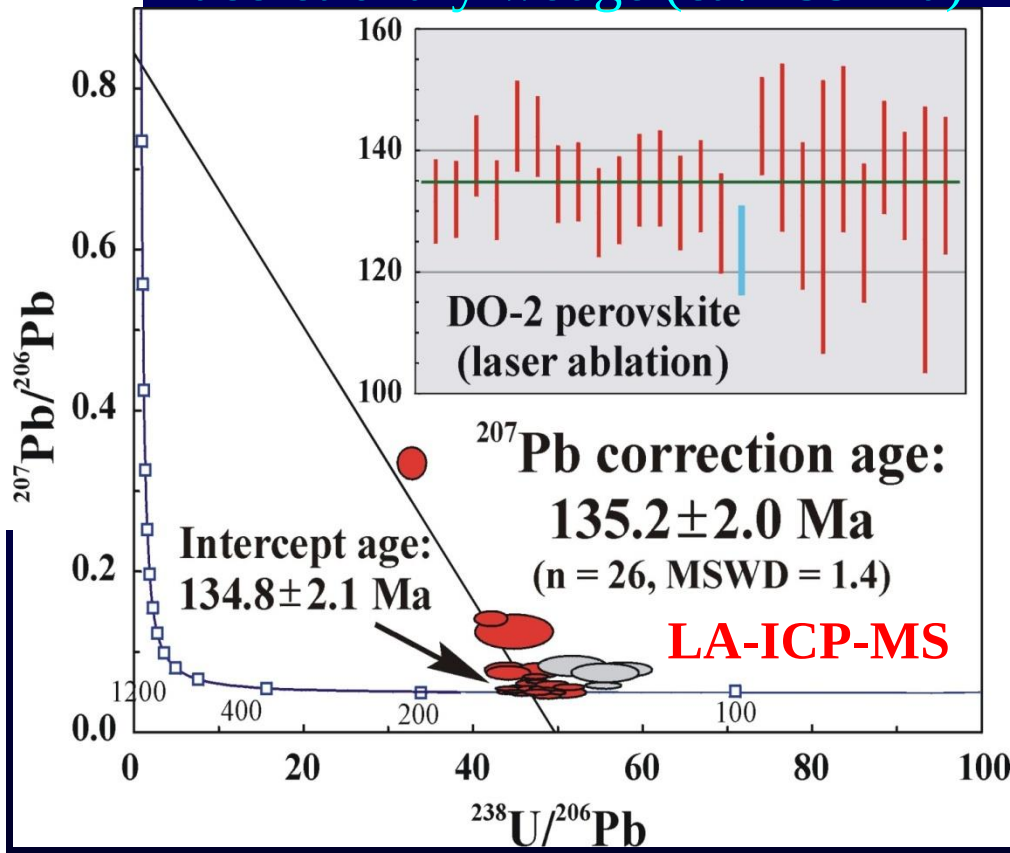

Cr-Spl-(Cr)Adr-Cpx-Chl
Serpentinite
Prv-(Ti)Adr-Ap-Chl
Adr-Cpx-Ves-Ep-Ap-Chl
Meta-rodingite
(H-Grs-Adr-Chl-orig. rodingite)
1 cm
Cpx
Chl
Cpx
+30
+32
+31
Spl
+29
Cr-Adr
Adr
+33
Chl
+Chl
Cpx
34+
+Cpx
100 µm
+27
+28
Ti-Adr
Adr
Chl
Prv
+24
+26
+30
+29
+25
10 µm
Ves
+ves
Ep
Chl
10 µm
+21
Adr
+20
+23

U-Pb age of perovskite from SIMS (Li, Putiš et al., 2014)

Dating the post-HP fluid/rock interaction in the Meliatic accretionary wedge (ca. 135 Ma)

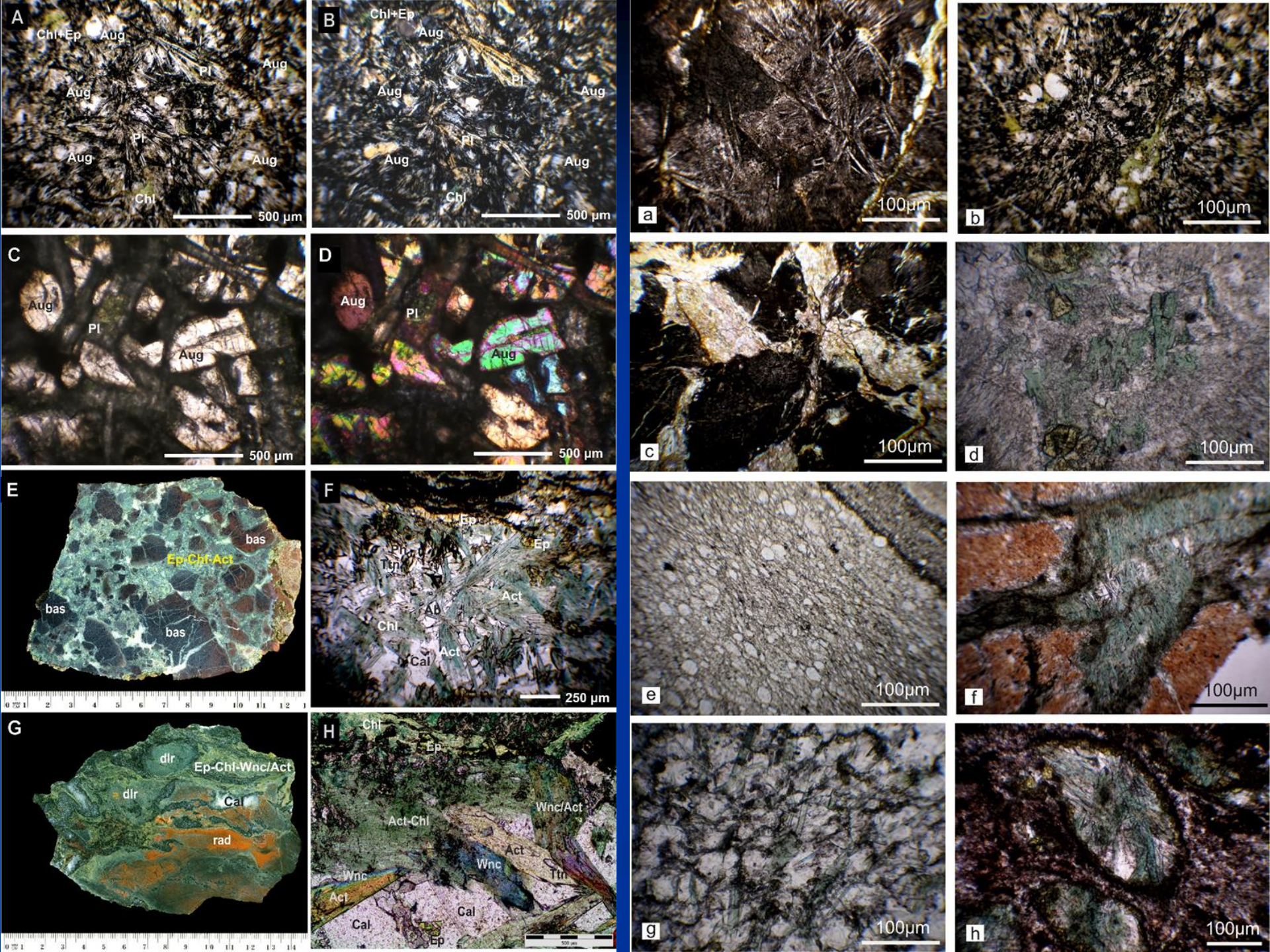


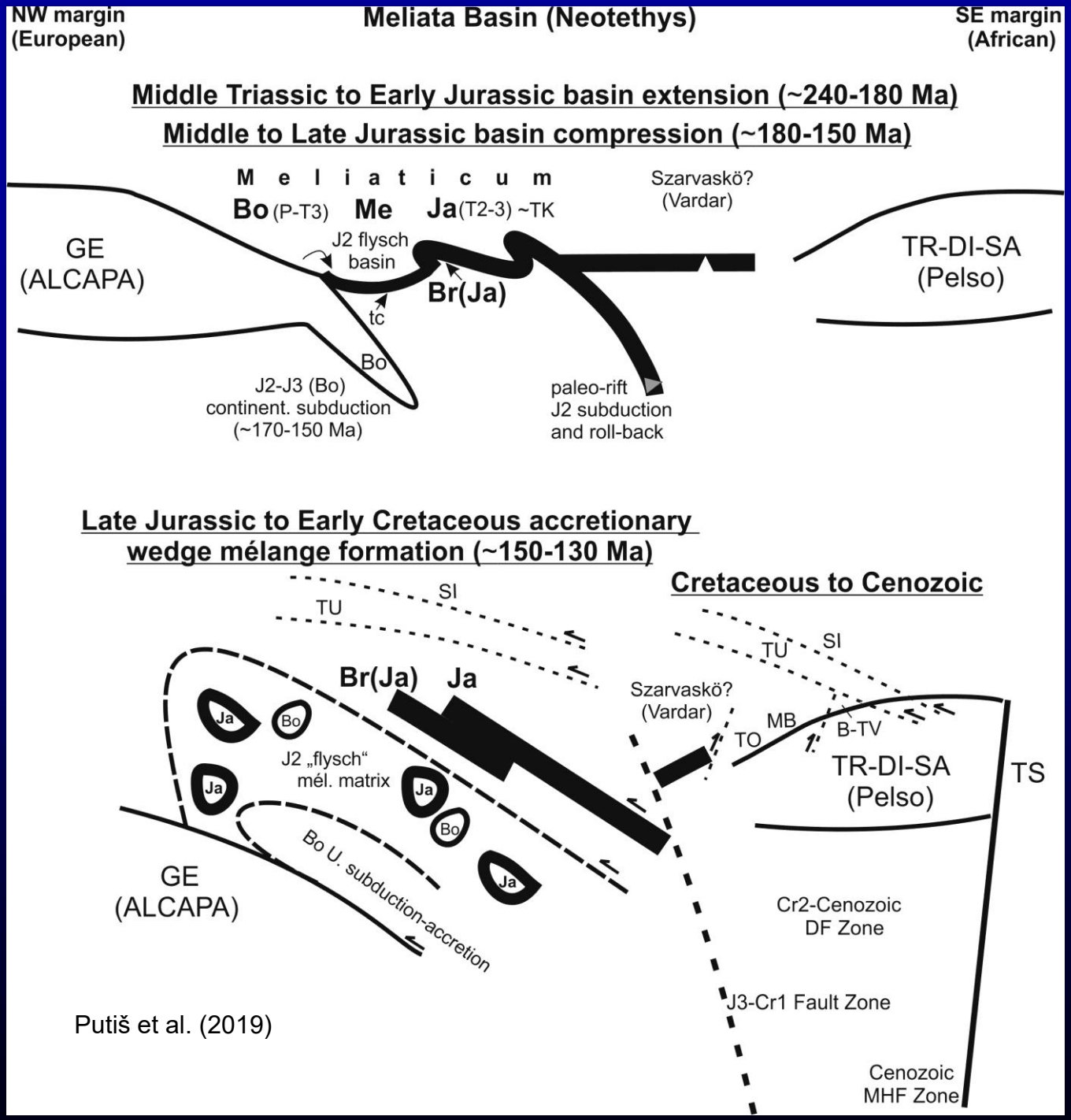




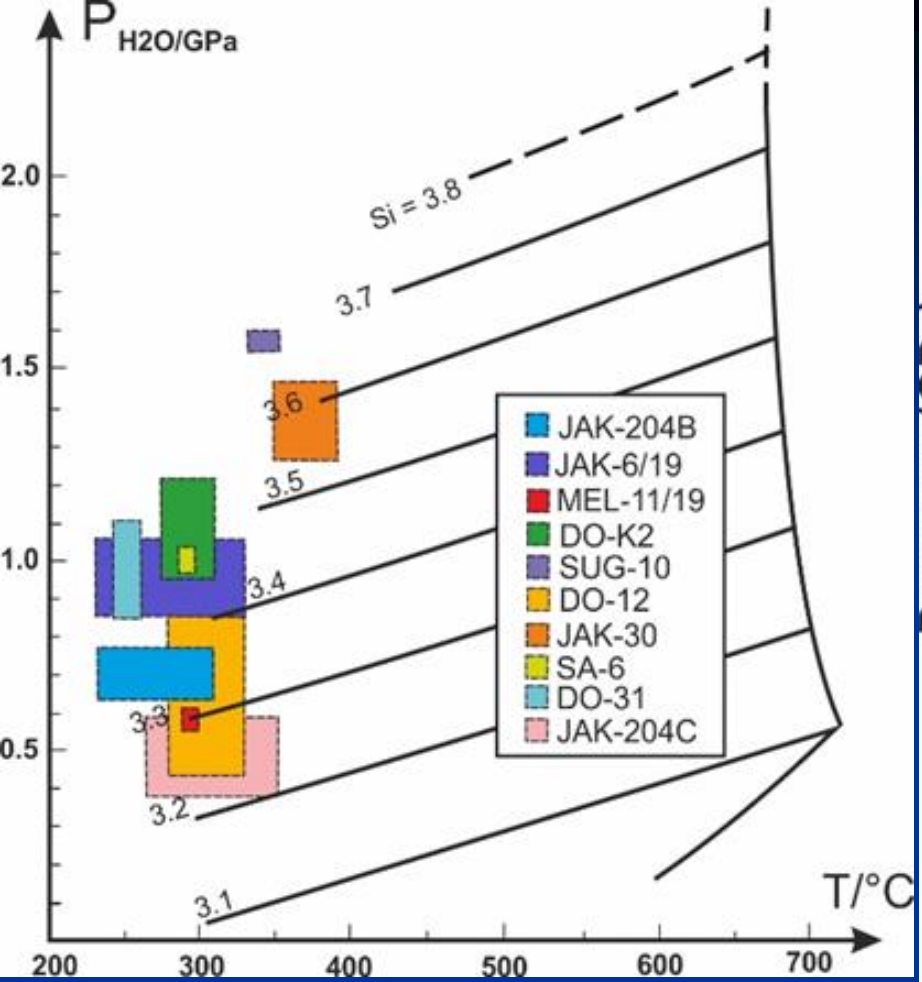
U-Pb age of perovskite from LA-MC-ICP-MS

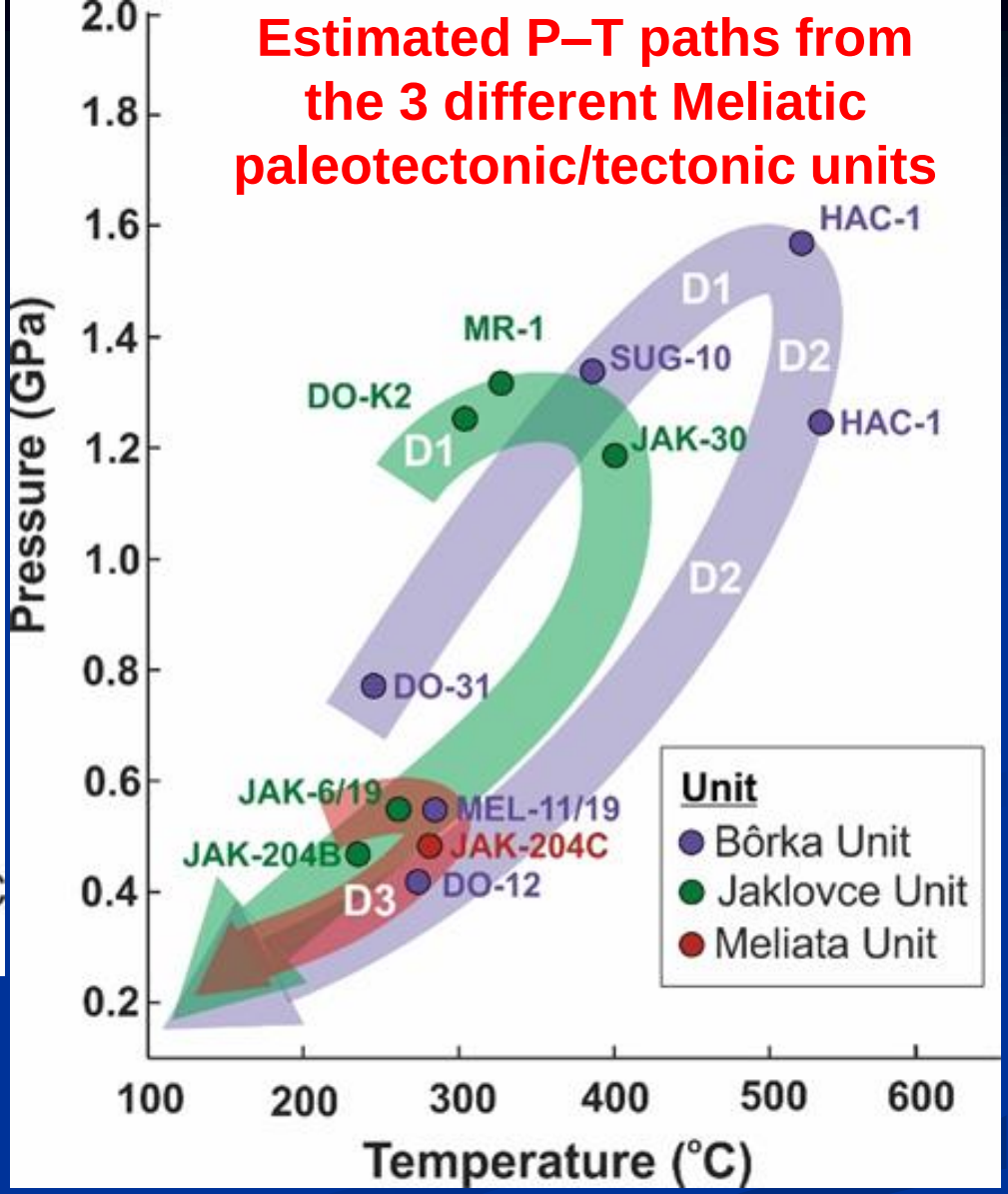
(Putiš, Yang et al., 2015)


A
Chl+Ep
Aug
Pl
Aug
Aug
Pl
Aug
Aug
Chl
500 µm
B
Chl+Ep
Aug
Pl
Aug
Aug
Pl
Aug
Aug
Chl
500 µm
C
Aug
Pl
Aug
500 µm
D
Aug
Pl
Aug
500 µm
E
bas
Ep-Chl-Act
bas
bas
F
Ep
Ep
Pl
Ttn
Act
Ab
Chl
Act
Cal
250 µm
G
dlr
Ep-Chl-Wnc/Act
dlr
Cal
rad
H
Chl
Ep
Wnc/Act
Act-Chl
Act
Wnc
Ttn
Wnc
Act
Cal
Cal
Ep
a
100µm
b
100µm
c
100µm
d
100µm
e
100µm
f
100µm
g
100µm
h
100µm



Putiš et al. (2019)





Pressure estimates from Ph barometry of Meliatic metamorphic rocks. Temperatures derived from Chl therm.

Bôrka Unit: SUG-10, DO-12B, DO-31;

Jaklovce Unit: JAK-30, JAK-204B, JAK-6/19;

Meliata Unit: JAK-204C, MEL-11/19 (olistolith of Bôrka Unit);

Sillica Nappe: SA-6.

Putiš et al. (2019)
Nemec et al. (2020)

Discussion

- Pyroxenites and websterites, related to sub-crustal cumulate-type melt derivates (less evolved for websterites and highly evolved for clino- and orthopyroxenites) in the AA Unit provide an evidence about the Late Permian/Early Triassic (~252 Ma) mantle melting.
- Permian–early Middle Triassic (Anisian) magmatism (~280–245 Ma) from the continental crust AA and IWC units belong to the same tectono-magmatic event which culminated with the Neotethyan oceanic Meliata Basin opening in the Middle Triassic (Ladinian).

Preliminary Conclusion

- The major Permian–Triassic magmatism exceeded the inferred active Paleotethyan margin and continued W-ward along the Paleotethyan suture zone. This unstable zone suffered from a long-term (from ca. 300 to 200 Ma) hot lithosphere, where the Late Variscan orogen post-collisional collapse continued by thermal erosion of the crustal and mantle lithosphere due to the asthenosphere upwelling and thermal perturbation through the extensionally thinned continental crust. **A support from the mantle plum generated from Paleozoic subductions can be considered.**