# Constraints on the formation and nature of the Hellenic Triassic rift-related lavas

Koutsovitis P.[1*], Magganas A.[2], Ntaflos T.[3], Koukouzas N.[4] Rassios A.[5], Soukis K.[2]

[1]University of Patras, Department of Geology;
[2]National and Kapodistrian University of Athens, Faculty of Geology;
[3]University of Vienna, Department of Lithospheric Research;
[4]Centre for Research and Technology, Hellas (CERTH);
[5]Hellenic Survey for Geology and Mineral Exploration.

*correspondence: pkoutsovitis@upatras.gr

EGU General Assembly 2020

# Greek Tectonostratigraphic Terrenes


**Continental domains**

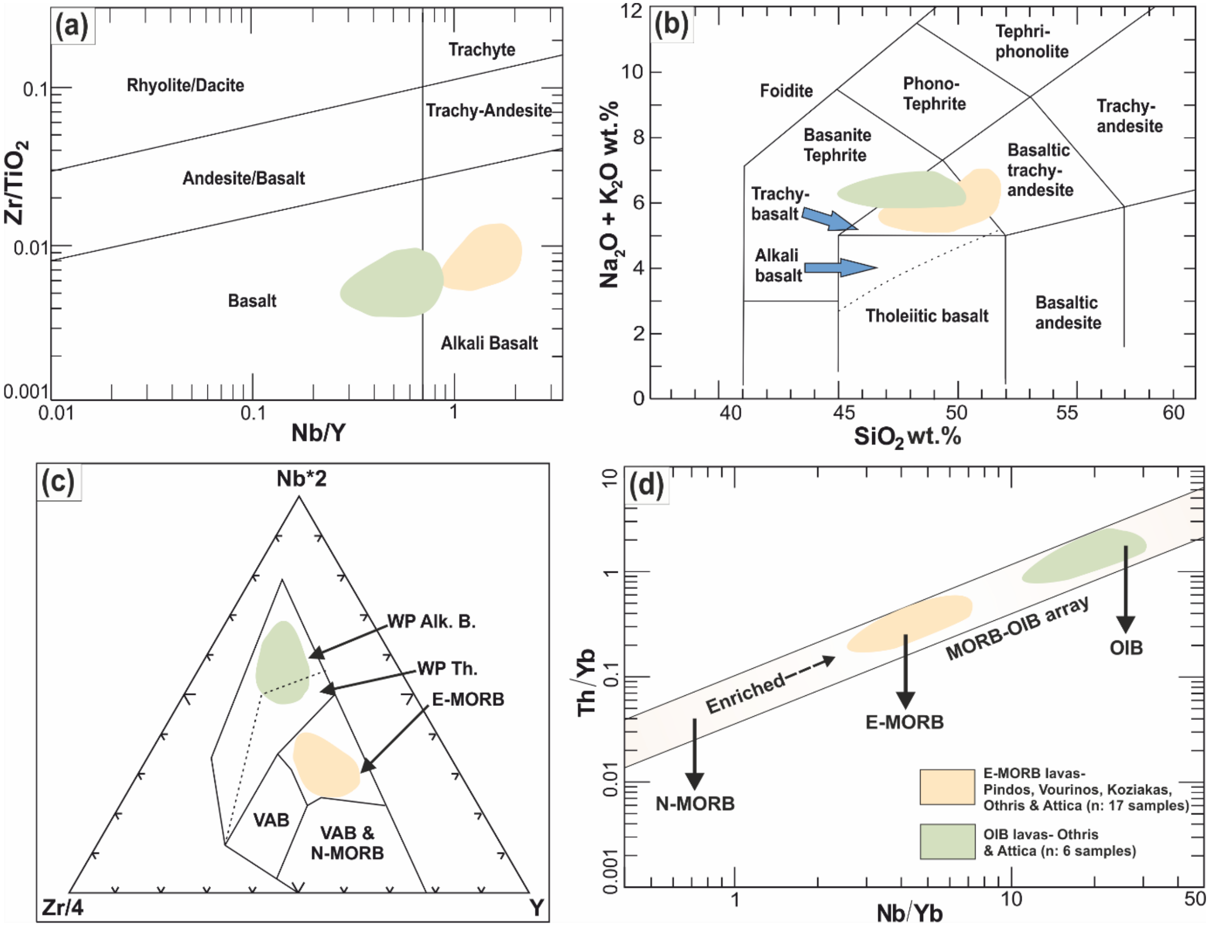
- External Hellenides
- Pelagonian microcontinent
- Rhodope massif

**Oceanic domains**

- Pindos
- Vardar

- Though not abundant, oceanic Triassic volcanic rocks occur over all mainland Greece.
- Triassic magmatism is interpreted to have been developed during the rifting stage of Gondwana, with subsequent formation and development of a Tethyan oceanic basin.
- These lavas were grouped within rock units associated with the Pelagonian continental complex and adjacent geotectonic zones.

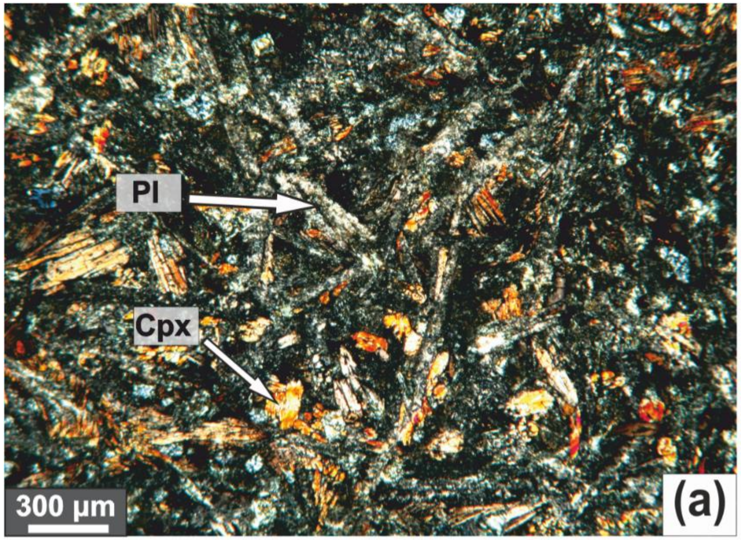
# Classification

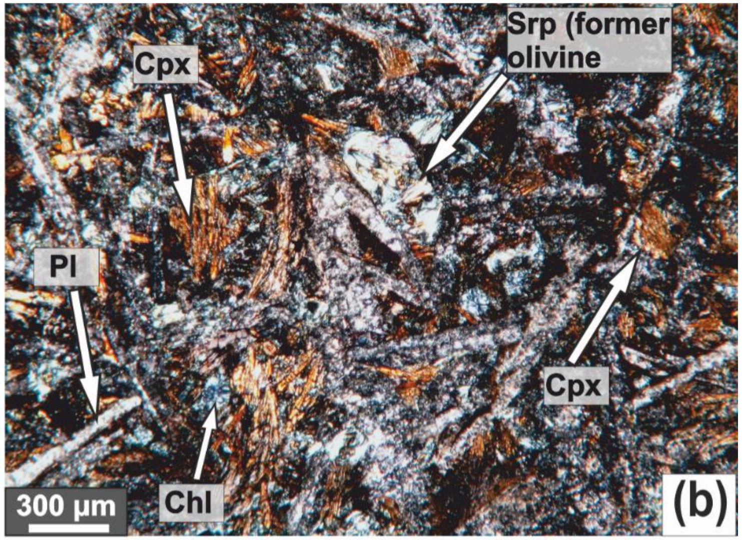


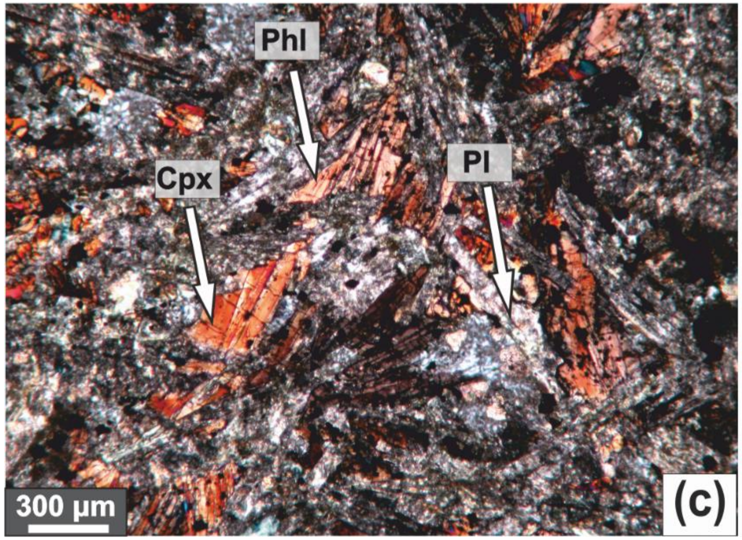

a) Zr/Ti versus Nb/Y (Winchester and Floyd 1977; modified by Pearce 1996). b) Total alkalis vs. SiO2 classification diagram (Le Bas et al., 1986), c) Zr/4-Y-2Nb (Meschede, 1986) discrimination diagram. d) Binary diagram of Th/Yb versus Nb/Yb. The MORB-OIB array is projected according to Pearce (2008); N-MORB, E-MORB and OIB are from Sun and Mcdonough (1989).

- The rift-related Triassic volcanic rock samples plot within the fields of alkali basalt and tholeiitic basalt.
- Tectonic discrimination diagrams that rely on relatively immobile elements show that the studied lavas are OIB and E-MORB basalts.
- From the preceding plots, OIB lavas are trachybasalts, whereas E-MORB lavas comprise of trachybasalts and basaltic trachyandesites.

# Petrography

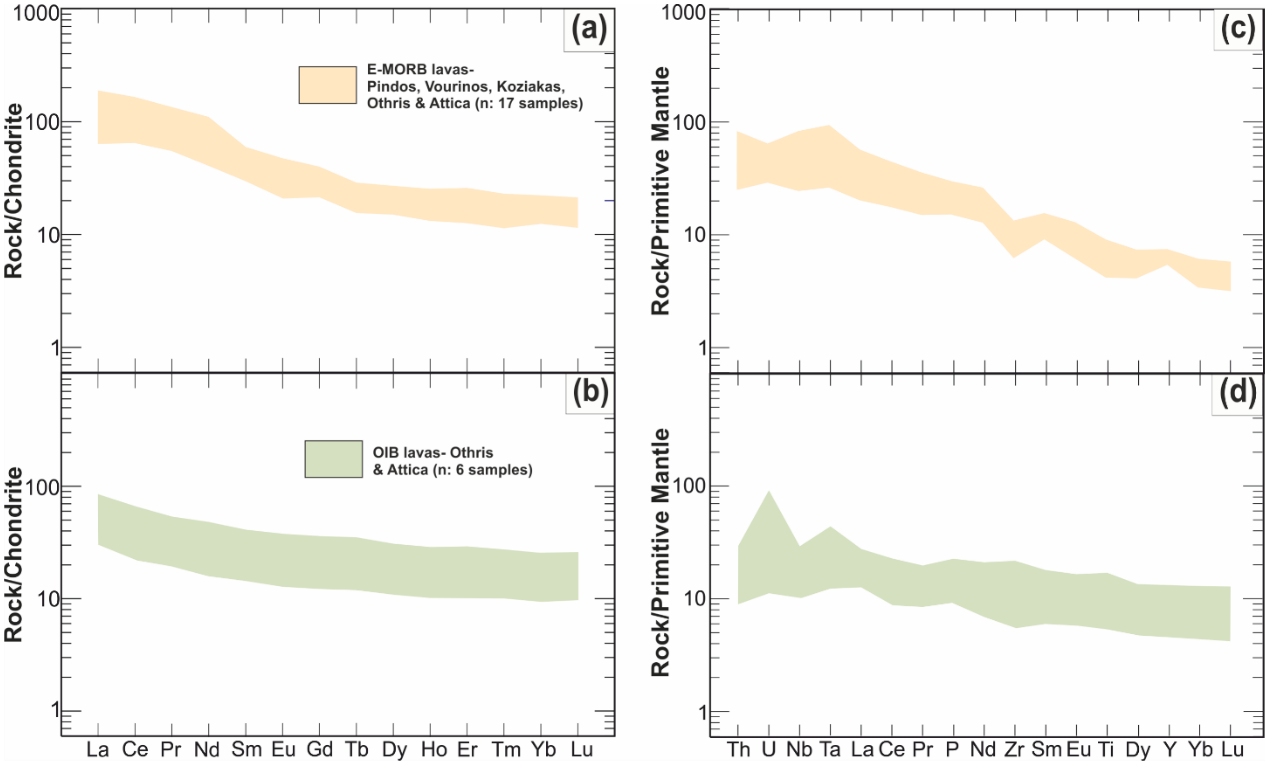



- Basaltic lavas commonly display subophitic, variolitic and intergranular textural features.
- E-MORB lavas differ from OIB, as they also include vitrophyric, porphyritic to glomeroporphyritic textures amongst clinopyroxene and plagioclase grains.
- Rare subhedral clinopyroxene phenocrysts are medium grained, fractured and typically zoned from core to rim. The matrix consists of acicular clinopyroxene, plagioclase laths, and microphenocrysts of pyroxene and plagioclase.

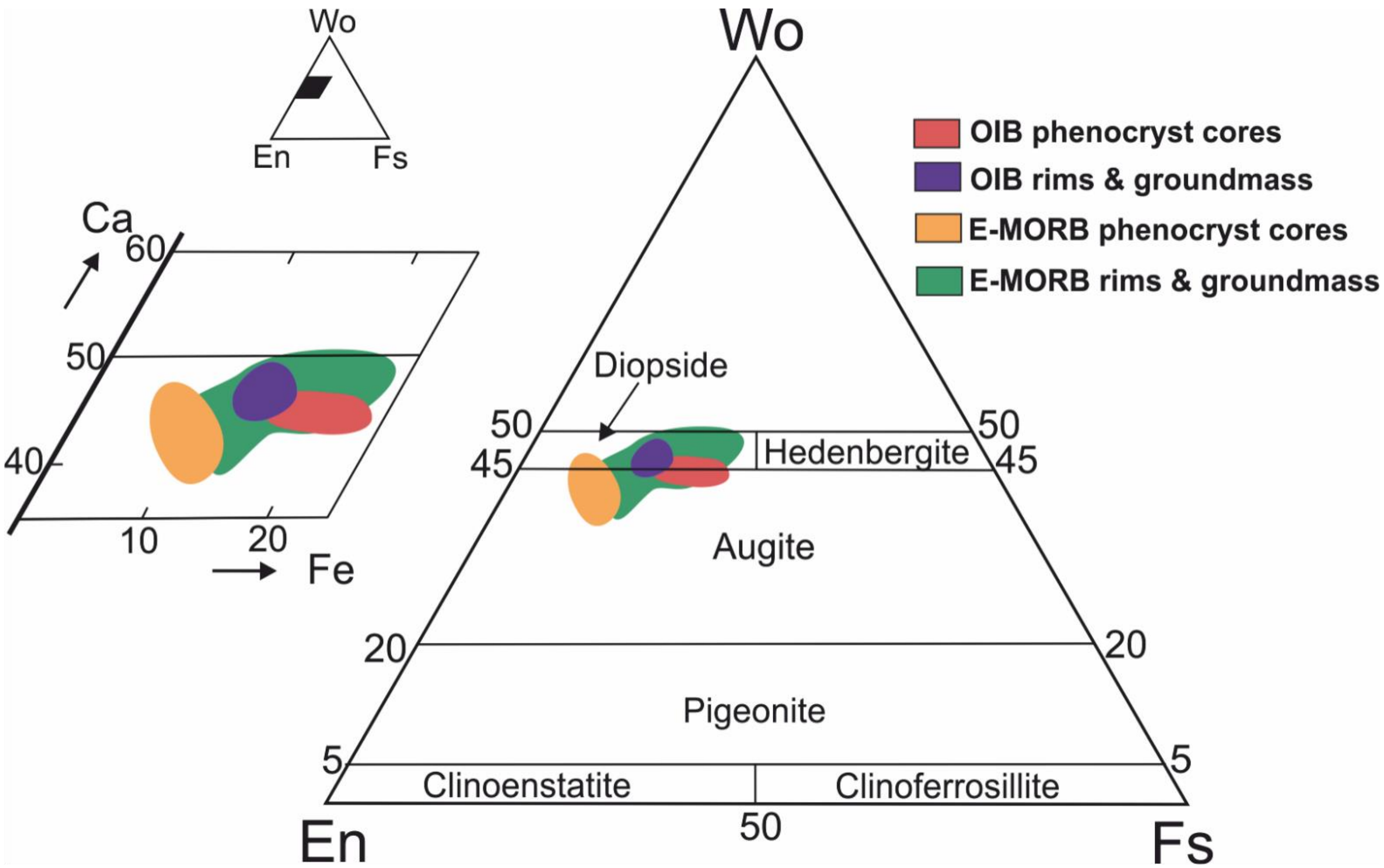
# Geochemistry

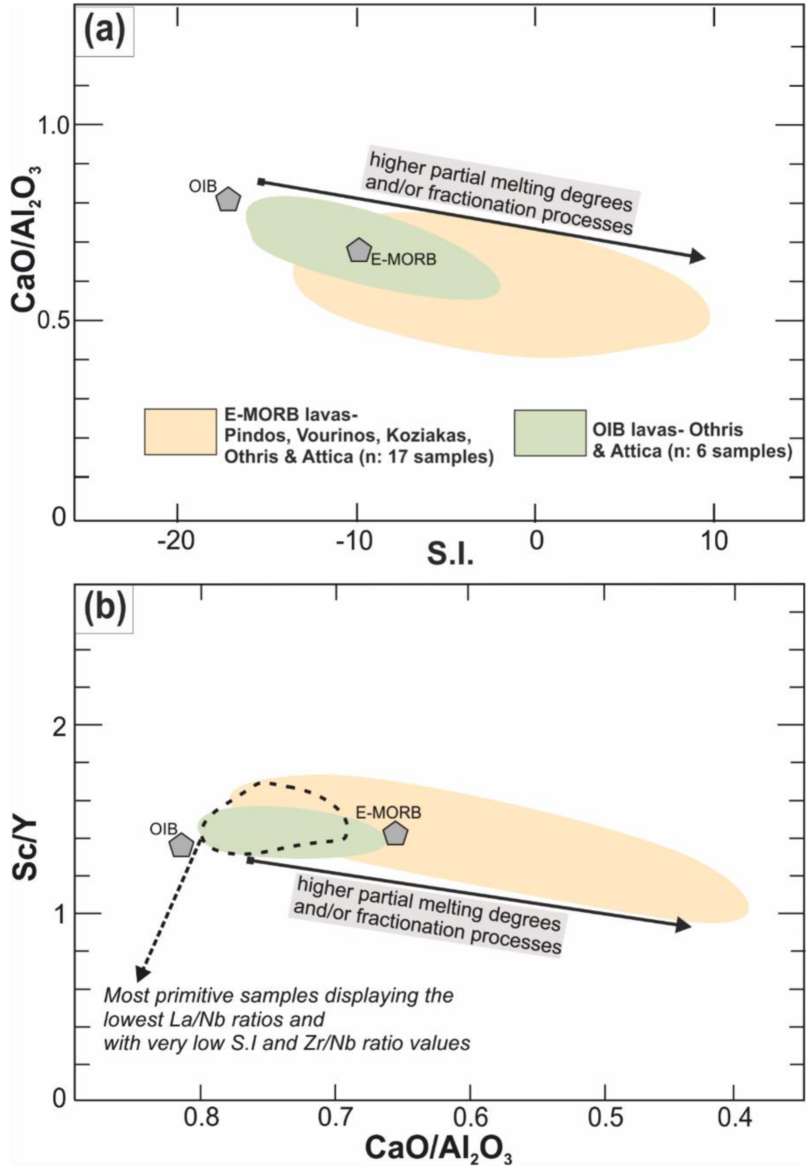



*Chondrite-normalized REE patterns of (a) OIB and (b) E-MORB lavas; Primitive mantle-normalized incompatible trace element patterns [normalization factors after McDonough and Sun (1995)] of (c) OIB and (d) E-MORB lavas.*

- The LREE of the OIB Triassic lavas appear enriched [LREE=53.8-170.2xChondrite; (La/Yb)N= 7.3-11.0] compared to LREE within the E-MORB lavas [LREE=23.6-74.3xChondrite; (La/Yb)N=1.6-4.3].
- HREE contents are highly comparable between the two groups (HREE=14.8-18.5 and 15.0-28.4xChondrite for the OIB and E-MORB respectively).
- PM-normalized incompatible trace element patterns of the OIB and E-MORB lavas resembles those of OIB and E-MORB patterns of Sun and Mcdonough (1989).
- Lavas show no apparent Ti anomalies: this lack suggests that this particular Hellenic Triassic lava system was not affected by subduction processes and/or carbonatitic liquids. Some of the lava samples contain slight to moderate negative Zr anomalies, likely associated with changes in the degrees of partial melting.

# Microprobe analyses of Cpx



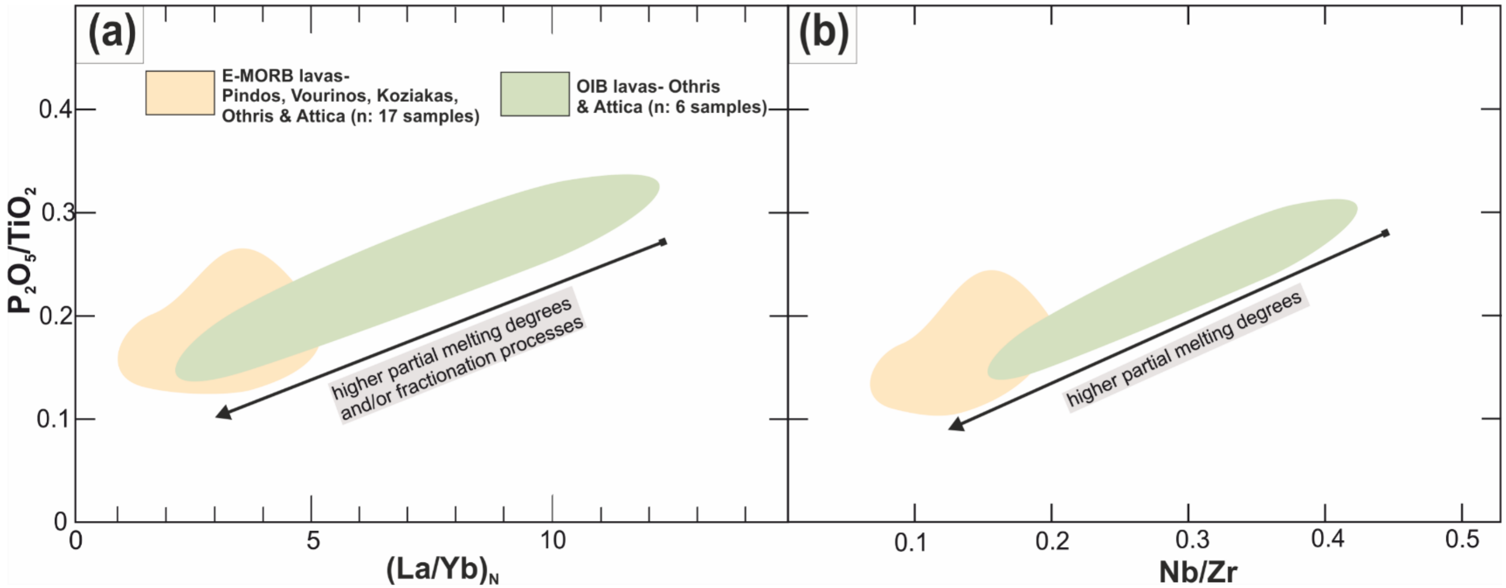



*(a) Binary plot of CaO/Al2O3 vs. S.I (silica-saturation index), (b) Binary plot of Sc/Y vs. CaO/Al2O3. Average primitive OIB and E-MORB compositions are displayed (data from Sun and McDonough 1989; Fitton et al. 1991; Donnelly et al. 2004; Wilson and Downes 2006; Arevalo and McDonough, 2010; Gale et al. 2013).*

# Petrogenetic constraints

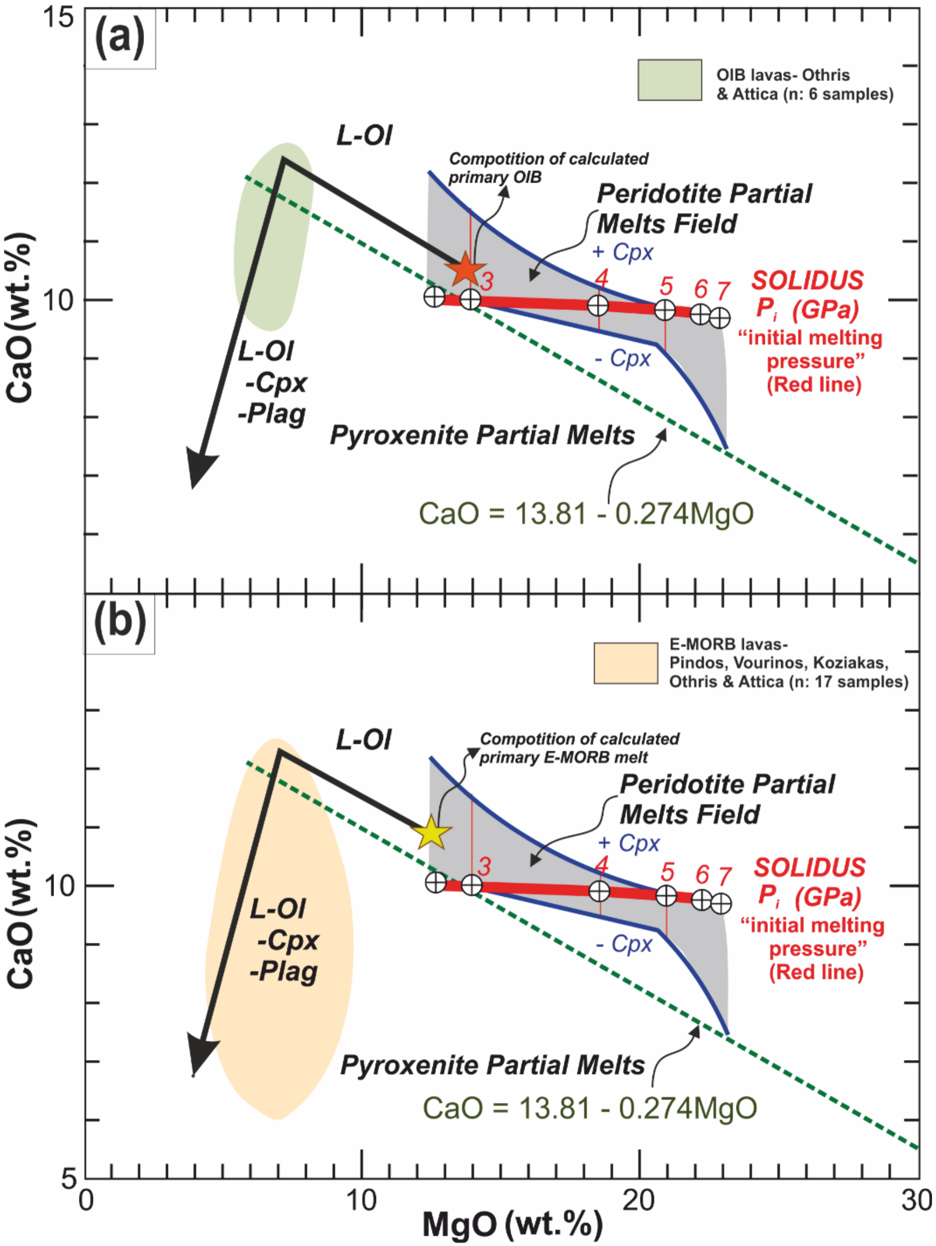
- OIB lavas tend to display low S.I. values along with high CaO/Al2O3 ratio values, consistent with lavas that were derived from low partial melting of a rather deep mantle source but which were also not subjected to extensive fractionation processes.
- Most E-MORB lava samples tend to display higher S.I. values and lower CaO/Al2O3 ratio values, which in some cases suggest profound effects of differentiation.
- The Sc/Y ratio is considered as a good indicator for identifying clinopyroxene fractionation processes. In the relavant binary diagram it is evident that E-MORB lavas tend to display a negative correlation trend. This may either be attributed to higher partial degrees of melting and/or to higher degrees of differentiation.

# Petrogenetic constraints




*Binary plots of P2O5/TiO2 vs. (a) (La/Yb)N and (b) Nb/Zr, with increasing degrees of partial melting trend displayed.*

- The P2O5/TiO2 ratio is inversely correlated to the degree of partial melting and is not significantly affected by fractionation of olivine and clinopyroxene.
- The P2O5/TiO2 ratios of OIB and E-MORB lava samples correlate positively with (La/Yb)N and with Nb/Zr ratios, implying that the primary magmas of the OIB volcanics were deduced from lower partial melting degrees than those of the E-MORB group.

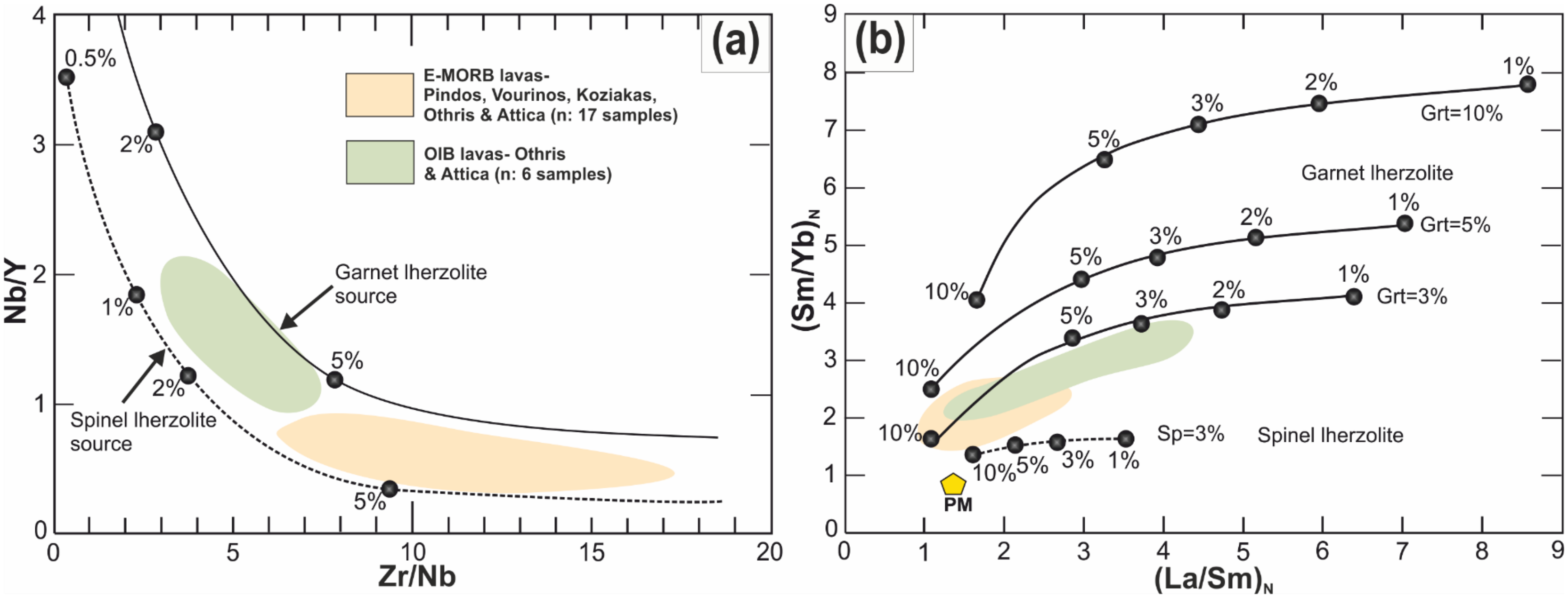



# Petrogenetic modelling

- Results from applying accumulated fractional melting calculations from the PRIMELT3 software (Herzberg and Asimow 2015) upon primitive OIB and E-MORB samples that experienced exclusively olivine fractional crystallisation show that the average mantle temperatures can be estimated at 1410 ± 20 ˚C (OIB) and 1370 ± 10 ˚C (E-MORB).

*CaO and MgO contents of a) OIB lavas, b) E-MORB lavas, compared with partial melts of pyroxenite and peridotite after Herzberg and Asimow (2008). Blue lines define upper and lower CaO filters of these primary magmas. Lavas with CaO contents below the thin dotted line are potential pyroxenite partial melts and/or peridotite partial melts that had clinopyroxene removed. Black arrow: liquid line of descent for primary magmas that crystallize gabbro in the crust. Estimated primary compositions of OIB and E-MORB lavas are plotted.*

# Petrogenetic modelling




*(a) Variation of Nb/Y vs. Zr/Nb for the most primitive mafic volcanic rocks. Curves are model melting curves from Harangi (2001) for 0.5-5% partial melting of spinel- and garnet-peridotite facies mantle and dotted line is garnet-lherzolite. b) (Sm/Yb)N vs. (La/Sm)N trace element binary plot. Batch melting trends depending on the non-modal batch melting equations of Shaw (1970). Melt curves are drawn for spinel-lherzolite (Kinzler, 1997) and for garnet-lherzolite (Walter, 1998).*

- Modelling based upon the most primitive OIB and E-MORB samples of selected trace element ratios (Nb/Y vs. Zr/Nb and (Sm/Yb)N vs. (La/Sm)N) suggest similar partial melting degrees (~3% for the OIB and 5-8% for the E-MORB lavas) compared to those calculated with the PRIMELT3 software.

# Concluding remarks

- Triassic rift-related volcanic rocks in Greece comprise of trachybasalts and basaltic trachyandesites. Geochemical abundances classify the volcanics into OIB and E-MORB lavas.
- Most rocks were affected by moderate to extensive differentiation processes, mostly expressed by Cpx fractionation. Some of the OIB and E-MORB volcanics are considered as primitive undersaturated, displaying low $SiO_2$, Zr/Nb and S.I. values and also high Mg# and $CaO/Al_2O_3$ and La/Nb ratios.
- Calculated average mantle potential temperatures are comparable (1410 ˚C OIB; 1370 ˚C E-MORB), with melt fractions estimated at 3-5% for primary OIB magmas and 6-8% for primary E-MORB magmas.
- An asthenospheric origin is inferred for the OIB lavas, with melting in the garnet stability field (75-95 km; 2.5-3.0 GPa), whereas E-MORB parent magmas were formed with melting in the garnet/spinel (transitional) stability field (55-70 km; 1.8-2.2 GPa).
- Temperature results indicate that the Hellenic Triassic rift-related magmas were generated from mantle at ambient temperature, precluding a mantle plume-based scenario.

# Reference

Koutsovitis P., Magganas A., Ntaflos T., Koukouzas N., Rassios A.E., Soukis K. 2020. Petrogenetic constraints on the origin and formation of the Hellenic Triassic rift-related lavas. **Lithos** (Under Review).

**Part of Special Issue**: Advances in the Comprehension of Mantle Paradigms.