Seeking the mantle source and storage system of carbonatite magmas: case studies from Fuerteventura (Canary Islands) and Mt. Vulture volcano (southern Italy)

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Carbonatite magmatism is mainly associated with intraplate continental tectonic settings, with a temporal distribution from Archean to the present. The growing number of carbonatite occurrences from unconventional tectonic settings, such as oceanic contexts (e.g., Carnevale et al., 2021) or subduction zones (e.g., D'Orazio et al., 2007), received considerable attention during last two decades, given their importance as source of rare elements, and, most importantly, because they provide meaningful information about the geochemical cycle of carbon and mantle metasomatism as well.

This work shows how the study of fluids trapped within minerals from carbonatites and carbonatite magmas can provide important constrains about the mantle source and storage system of carbonatite magmas, reporting two different case studies from Fuerteventura (Canary Islands) and Mt. Vulture volcano (southern Italy), in two different tectonic contexts.

FUERTEVENTURA (CANARY ISLANDS)

I Location and Sampling

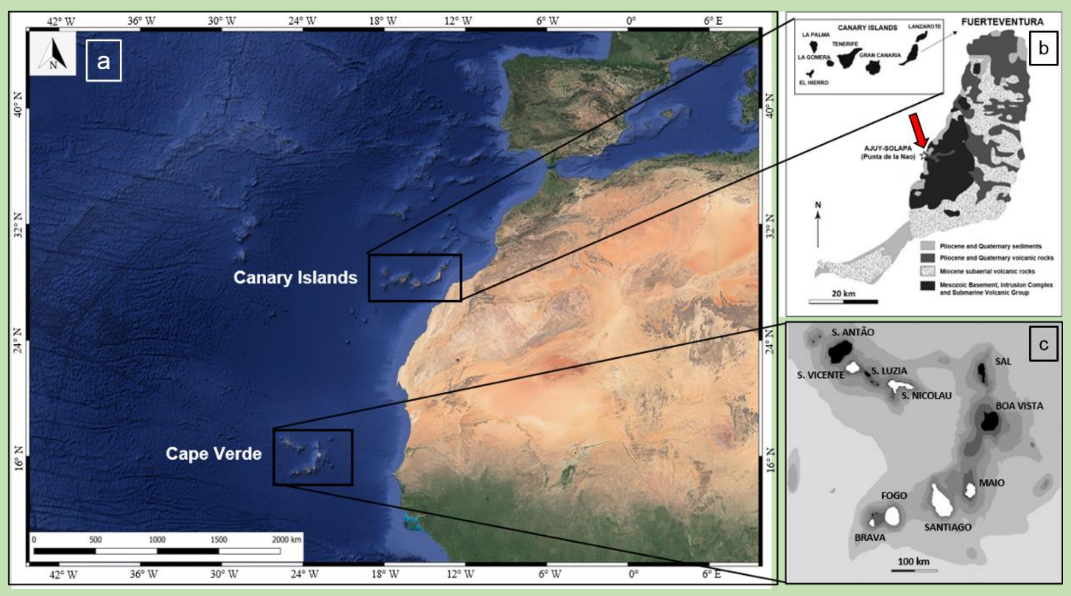

Fig.1: (a) Canary Islands and Cape Verde Archipelago in their geographic contest. (b) Simplified geology map of Fuerteventura showing the location of carbonatite studied samples (red arrow) and (c) detail of Cape Verde Archipelago, where the islands in which carbonatites are present are shown in white. Fuerteventura and Cape Verde represent the only two occurrences of carbonatites in oceanic context.

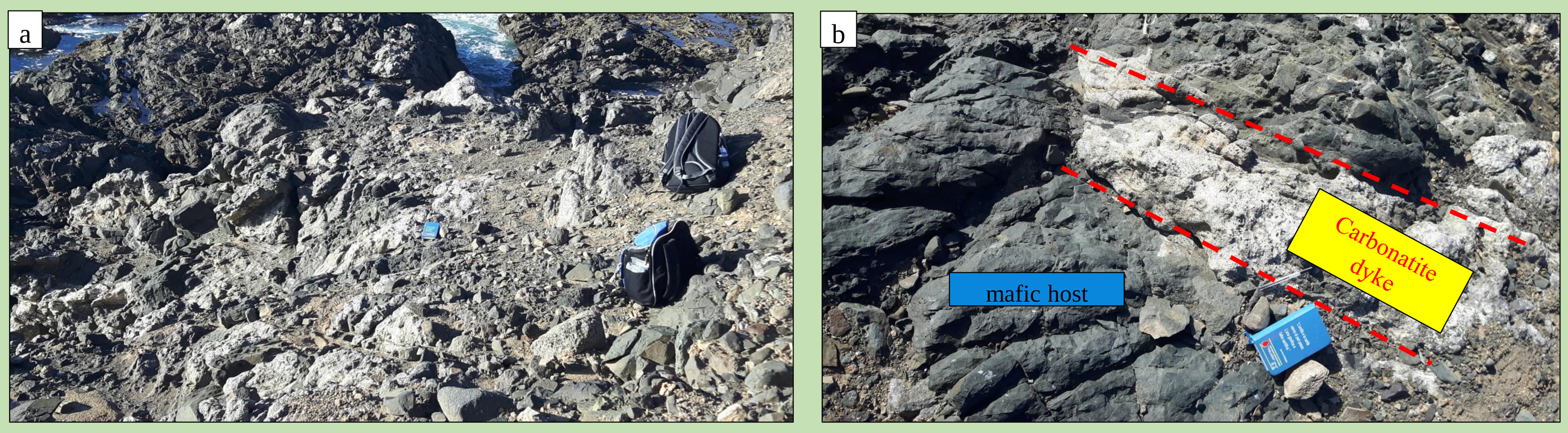

Fig. 2: (a) Field aspects of the study carbonatite complex. (b) Carbonatite dyke within mafic host.

II Noble Gases (He, Ne)

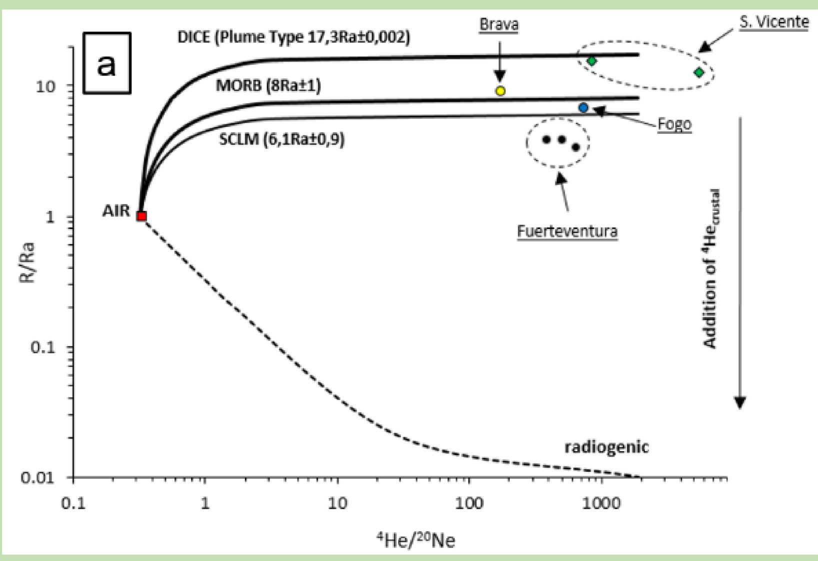

Fig. 3: (a) R/Ra ratios vs $^4He/^{20}Ne$ ratios obtained by crushing calcite in Fuerteventura and Cape Verde carbonatites.

Mineral Type	^4He (10^{-7})	^3He (10^{-12})	R/Ra	1σ
Carbonatite				
Apatite				
FUE1-03	221	0.08	0.003	0.002
FUE1-04	51.6	0.50	0.08	0.02
Calcite				
FUE1-03	15.2	7.09	3.35	0.03
FUE3-01	8.55	4.57	3.84	0.04
FUE3-01 duplicate	5.77	3.10	3.86	0.04
Clinopyroxene				
FUE3-01	4.96	1.54	2.23	0.04
Clinopyroxenite				
Clinopyroxene				
FUE4-03	0.83	0.76	6.66	0.07
Air			1.00	

Table I: He concentrations (ccSTP/g) and He isotopic ratios on mineral separates from Fuerteventura carbonatites and clinopyroxenite.

Using a magma aging model and considering
1. $^3He/^4He$ concentration
2. Th and U contents
3. contribution of $^4He^*$ radiogenic

initial R/Ra ratios are not significantly modified: **5.10Ra** (*calcite*) and **5.24Ra** (*cpx*)
6.82Ra (*cpx* from *clinopyroxenite*)

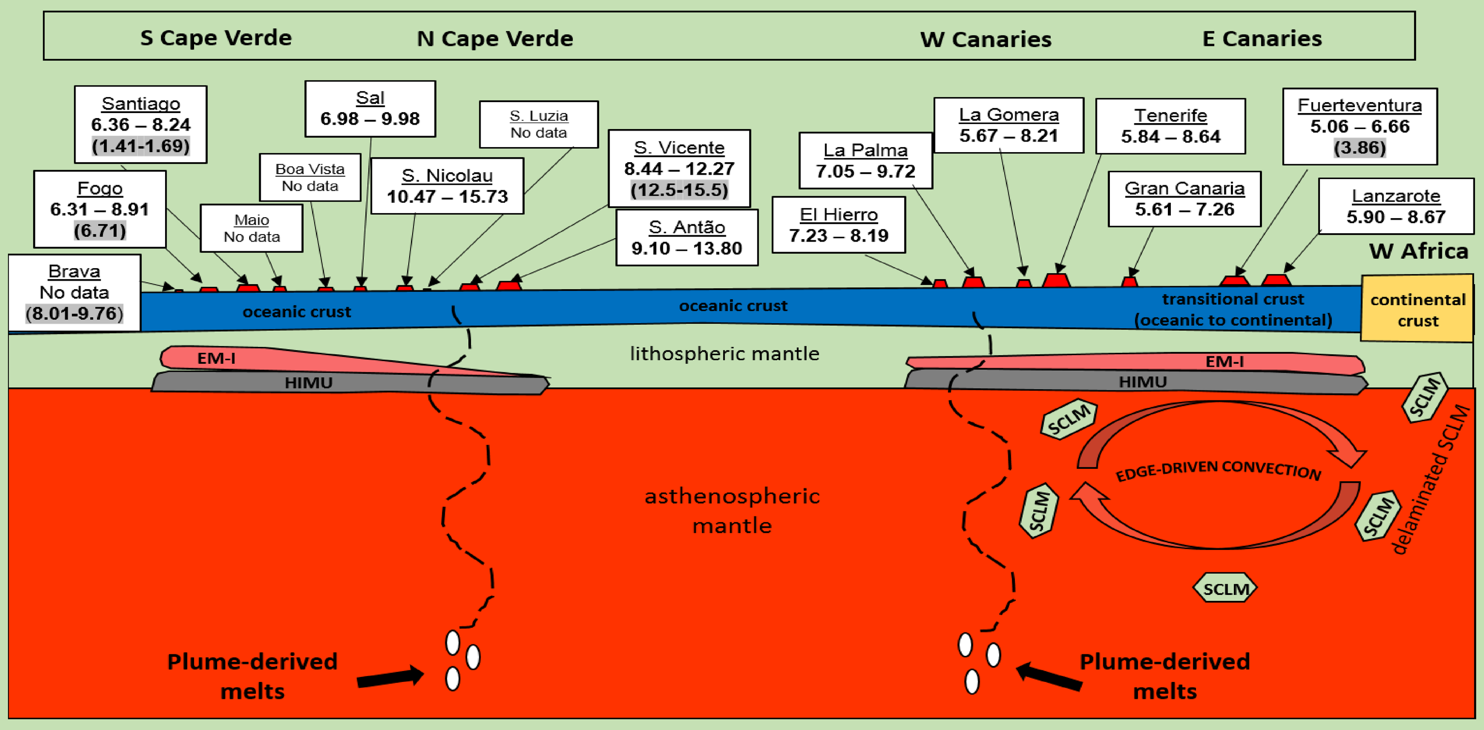

Fig. 4: Hypothetical schematic profile view of the upper mantle/crust under Cape Verde and Canary Archipelago (not in scale) with the mechanism of physical detachment of the sub-continental lithospheric mantle (SCLM) caused by edge-driven convection and incorporated into the oceanic lithospheric mantle beneath at least some Canary Islands. It is also shown a geographical distribution of the R/Ra range for each island of olivine (clinopyroxene in the case of Fuerteventura) from mafic/ultramafic rocks, and calcite from carbonatites (values in grey field).

MT. VULTURE VOLCANO (SOUTHERN ITALY)

I Location and Sampling

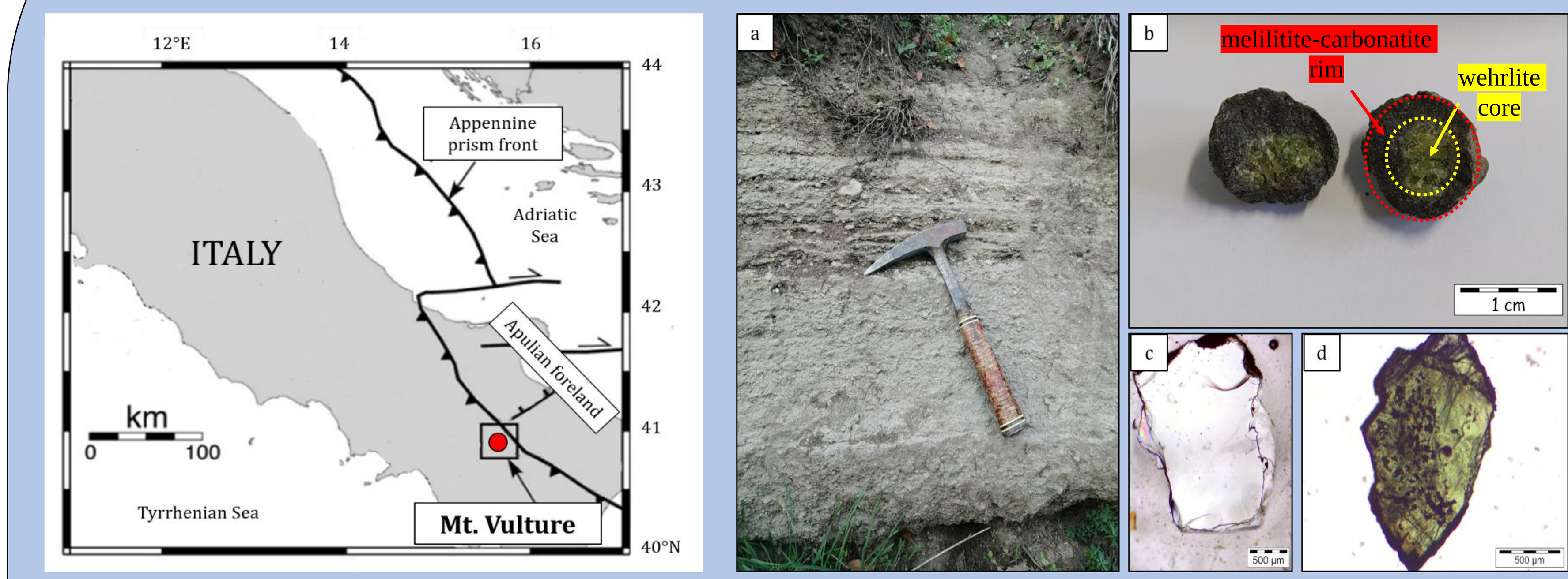

Fig. 1: Sketch map of central-southern Italy with location of Mt. Vulture volcano at the western margin of the Apulian foreland and within the geodynamic context of the Apennine subduction zone. (a) Ash-rich tuff surge deposit of Lago Piccolo Sub-Synthem (sampling site). (b) Pelletal lapilli with ultramafic xenolith cores (wehrlites) and melilitite-carbonatite rims. (c) Loose olivine and (d) Cr-diopside xenocrysts from the fine-grained matrix (parallel polars).

II Microthermometry of Fluid Inclusions (FIs)

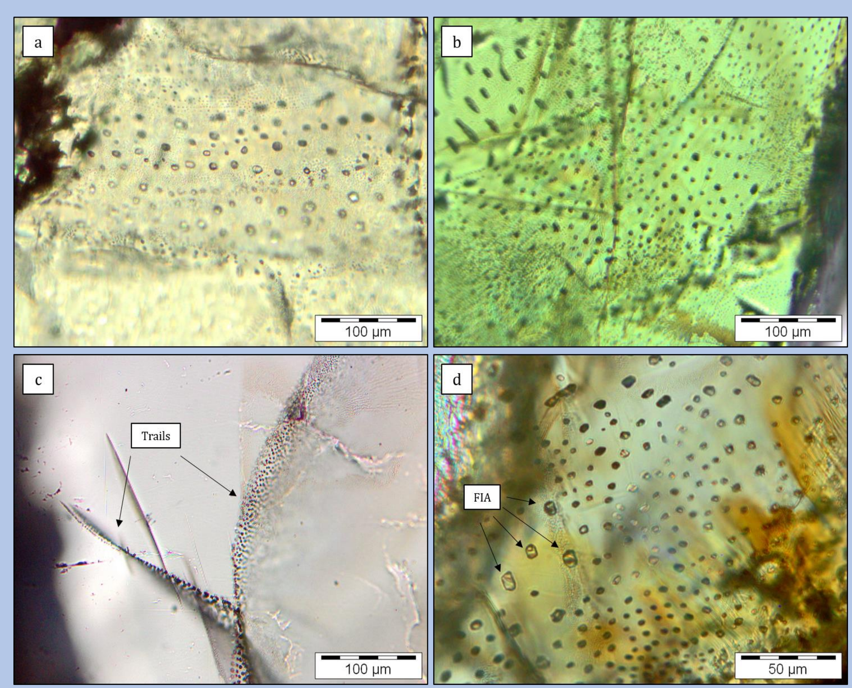

Fig. 2: Thin section photomicrographs (parallel polars) of FIs within loose (a) olivine and (b) Cr-diopside xenocrysts. (c) Intragranular trails of FIs in loose olivine xenocryst. (d) Fluid inclusions assemblage (FIA) in Cr-diopside from the ultramafic core of a pelletal lapillus. All FIs are characterised by pure CO_2.

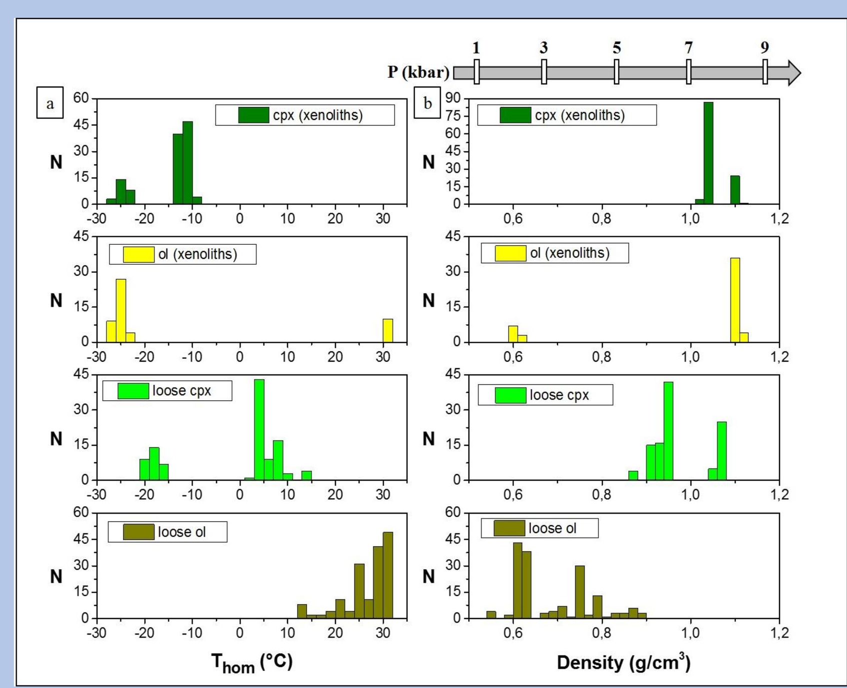

Fig. 3: Frequency distribution of (a) homogenization temperatures and (b) densities of FIs hosted in loose olivine and Cr-diopside xenocrysts and in ultramafic cores of pelletal lapilli from Vulture volcano.

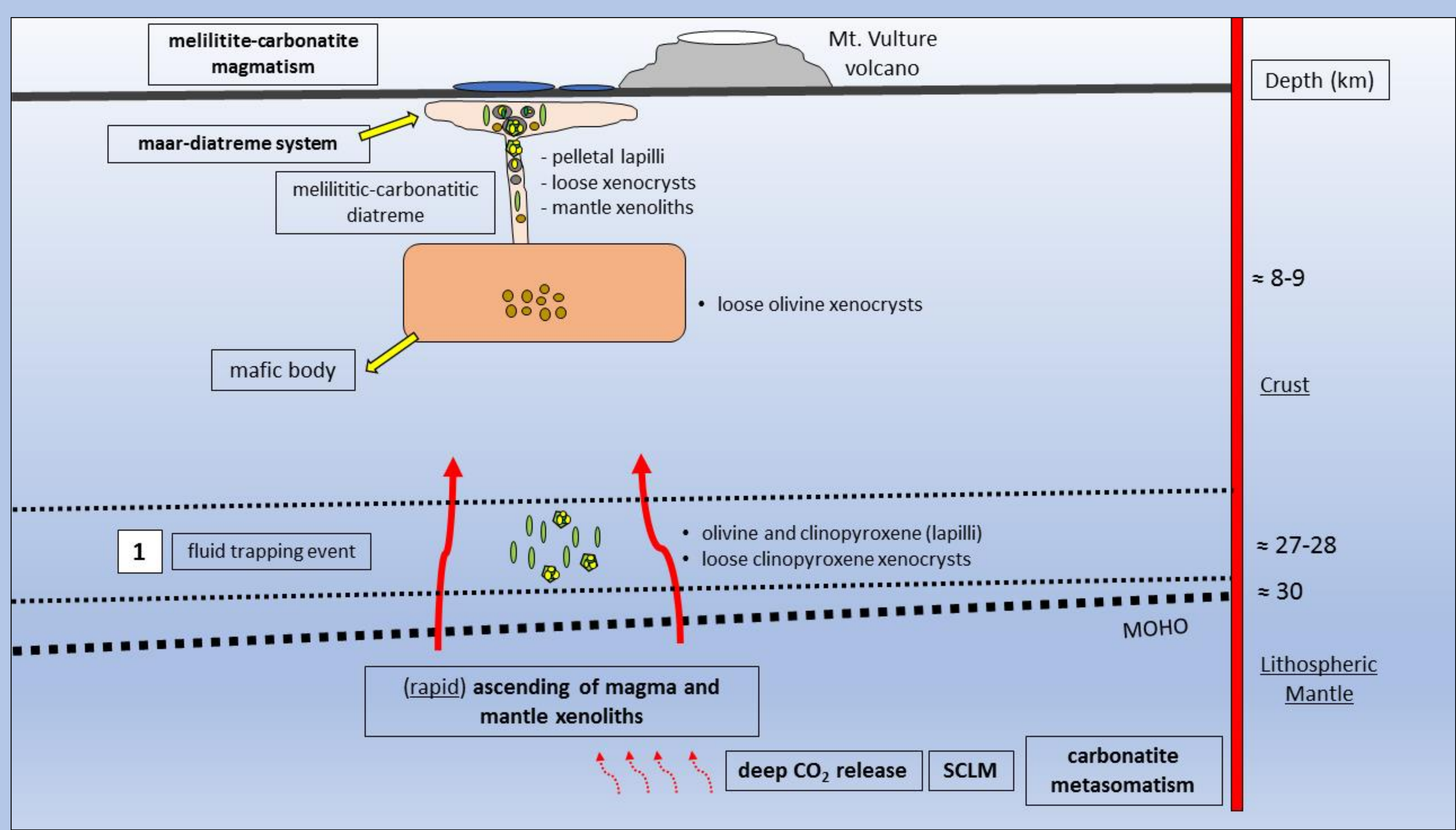

Fig. 4: Hypothetical schematic profile view of the lithospheric mantle/crust under Mt. Vulture volcano with the identified fluid trapping event corresponding to a deeper reservoir close to the local crust-mantle boundary (32 km). Also shown the involvement of the SCLM (Bragagni et al., 2022) and the importance of carbonatite melts as the main metasomatism agent of Mt. Vulture mantle source region (Rosatelli et al., 2007).

RESULTS AND CONCLUSIONS

- $^3He/^4He$ isotopic ratios of Fuerteventura carbonatites reflect a shallow (sub-continental lithospheric mantle, SCLM) He signature in their petrogenesis, reinforcing that, in the rare context of oceanic carbonatites, the contribution of the SCLM in their petrogenesis could be fundamental.
- Micro-thermometric analyses within Mt. Vulture wehrlite xenoliths show the occurrence of high-density pure CO_2 fluid inclusions.
- Estimates on magma ascent rate, using the equation from Lister and Kerr (1991) where the buoyancy is the main driving force, show how a melilitite-carbonatite magma can be comparable with ascent rate of kimberlite magmatism. The direct effect of ascent dynamics is that the melilitite-carbonatite magma could reach the surface from the depth of 30 km in less than an hour.
- Considering (i) the active degassing of mantle-derived fluids in Mt. Vulture area (Caracausi et al., 2015), (ii) the presence of small amount of melt at the Moho depth (Tumanian et al., 2012), and (iii) the recognized occurring of volatiles rich magmas at the mantle-crust boundary (this study), the volcanic hazard in melilitite-carbonatite volcanoes, even after long time of quiescence, should be carefully evaluated.

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