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EGU General Assembly 2020

Insights from ultramafic nodules on the plumbing system of the Fogo Island 2014-2015 Eruption (Cape Verde)

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The Eruption

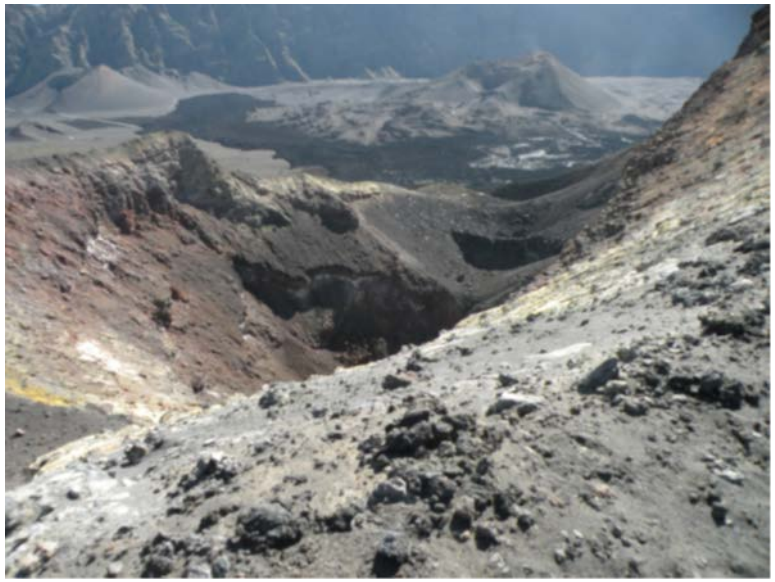
The Fogo Volcano, in the archipelago of Cape Verde is the most active volcano in the eastern Atlantic, with at least 27 eruptions in the last 500 years. The latest eruption occurred from November 23, 2014 to February 8, 2015. The activity was mostly hawaiian and strombolian and, sometimes, also vulcanian, with variable emission rates of lava flows, pyroclasts and gases (SO2 and CO2).

The Eruption

View of the destruction of the Settlements of Portela and Bangueira (but already reconstructing!)

Pit on the base of the vents alignment where lava appeared by a lava tunel and went into this hole

The eruption vents aligment



Nodules collection

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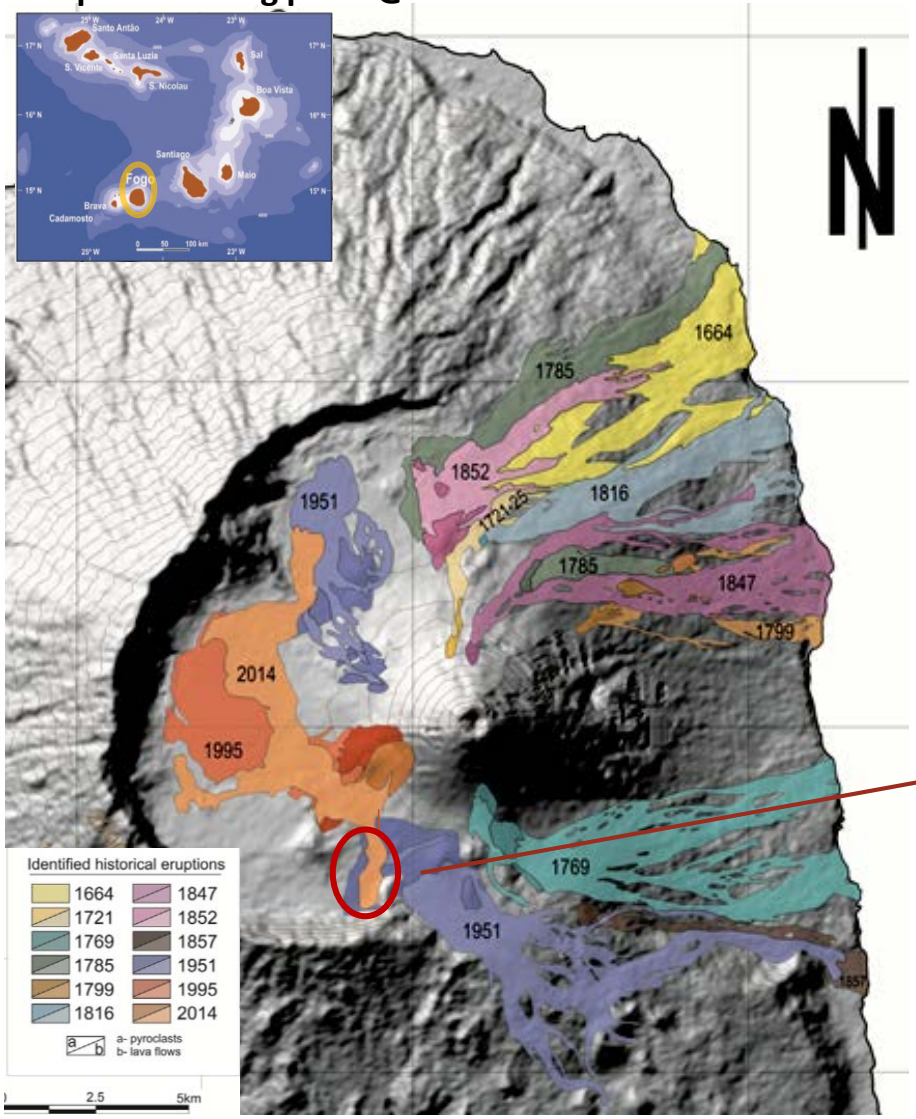
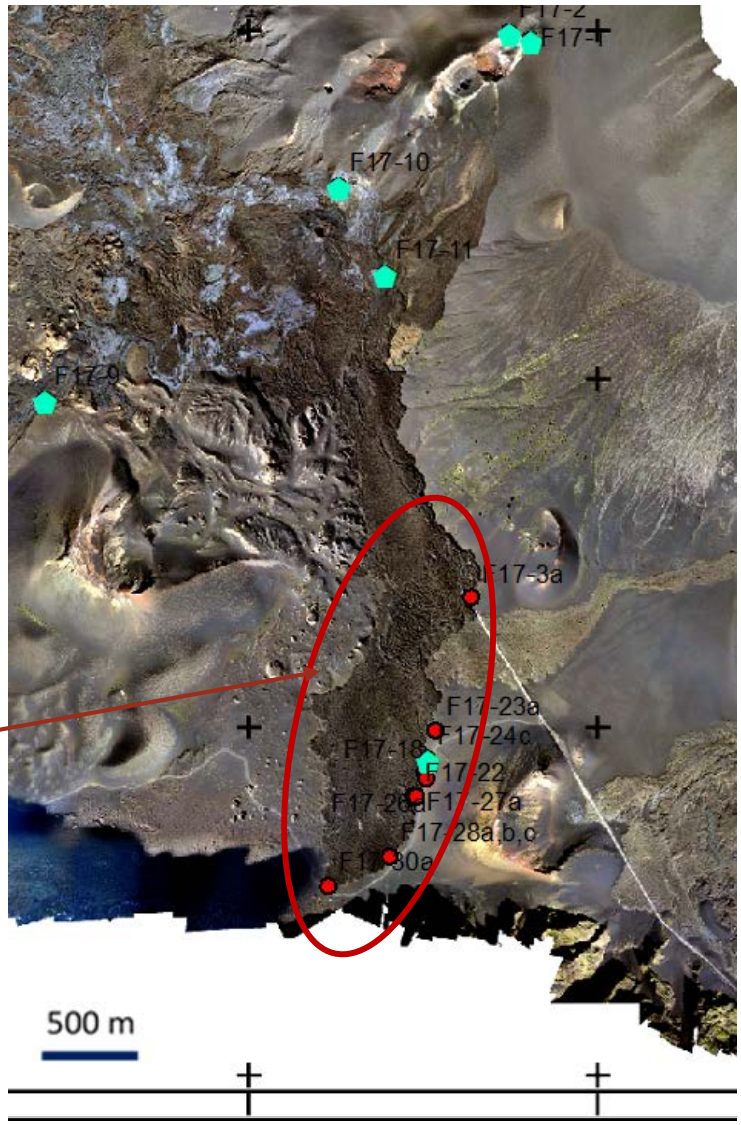
Localization of lavas from the most important historical eruptions taking place @ Chã das Caldeiras



Extracted from Mata et al.,2017 after Torres et al., 1998

Most nodules were collected in the first lavas erupted in 2014. ● Main spots of nodule collection



Base map from …..

Host Rocks

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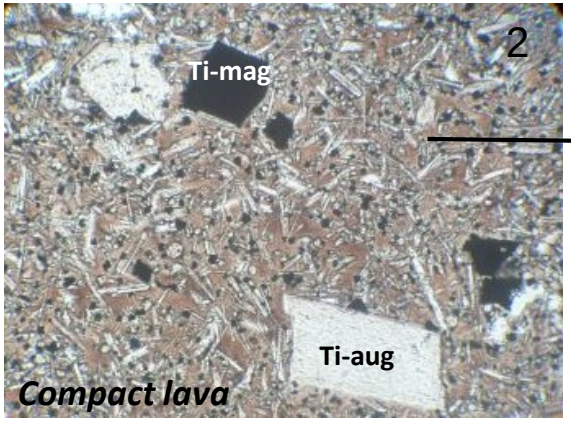
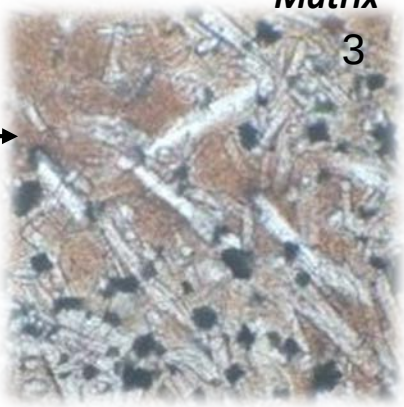
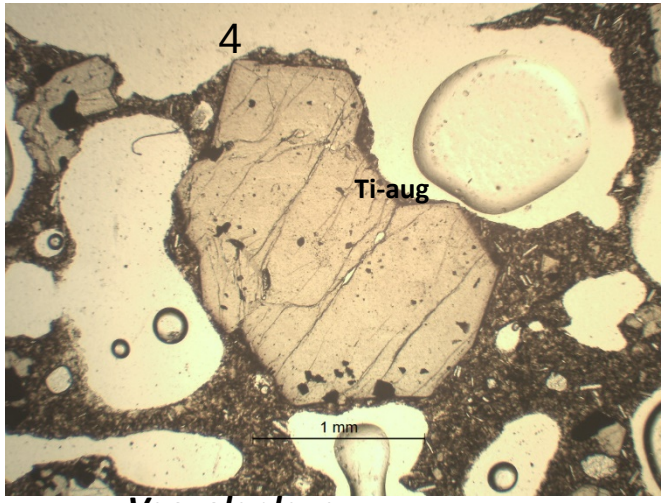
The nodules are macroscopically distinguished from the host rock mainly by their granular texture (1).

The host rocks are porphyritic tephrites (1), with Ti-augite and Ti-magnetite phenocrysts (2) and (4) and, sometimes, amphibole xenocrysts (5) and rare skeletal olivine (6) in a brown glassy matrix including laths of plagioclase, clinopyroxene and Ti-magnetite (3).

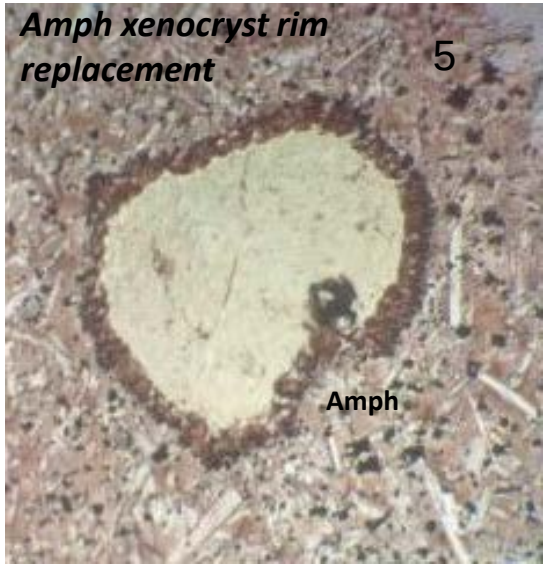


Matrix

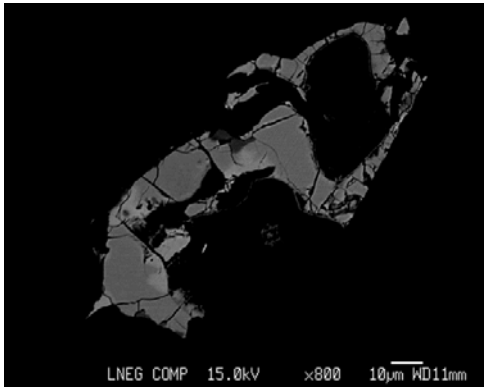




Vacuolar lava



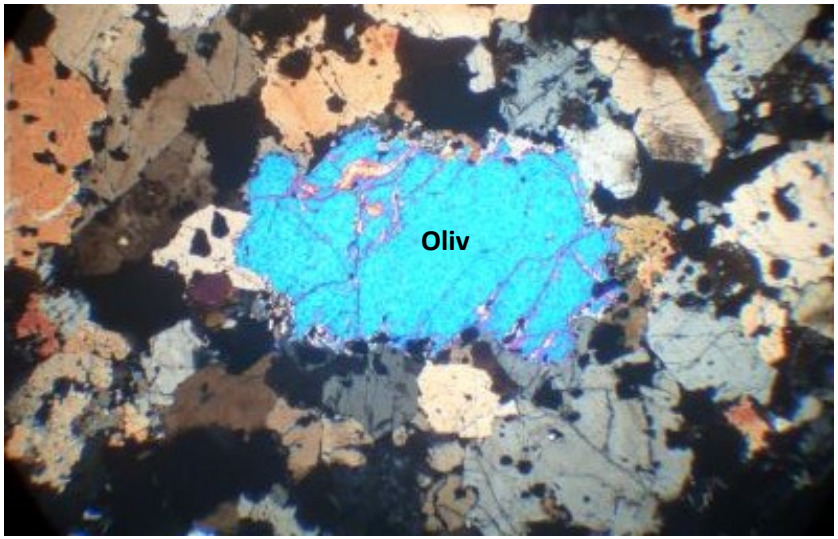
Skeletal olivine

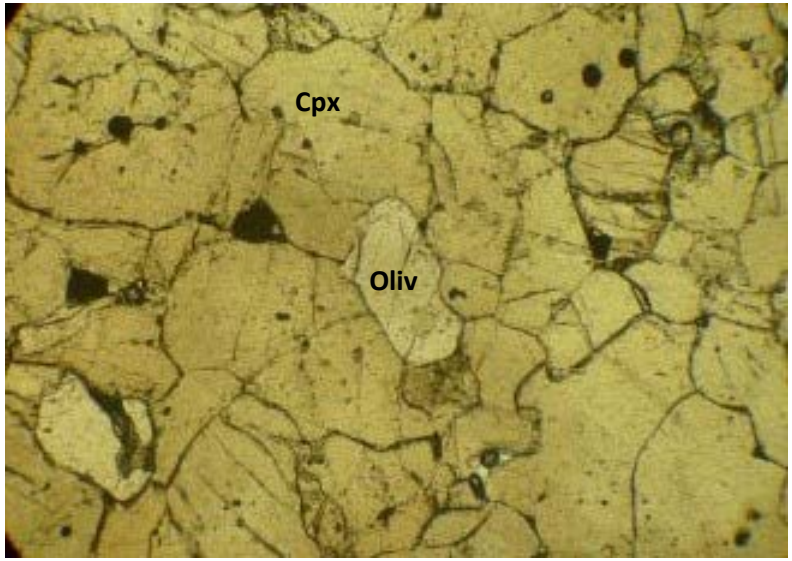


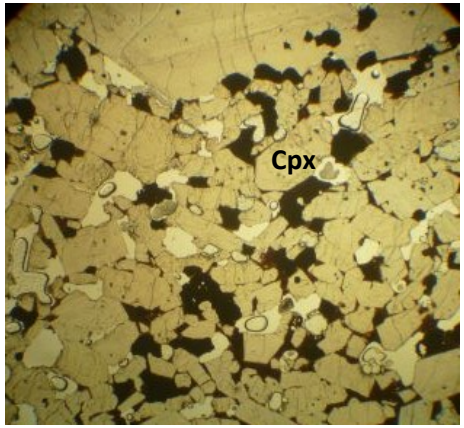
Nodules Mineralogy

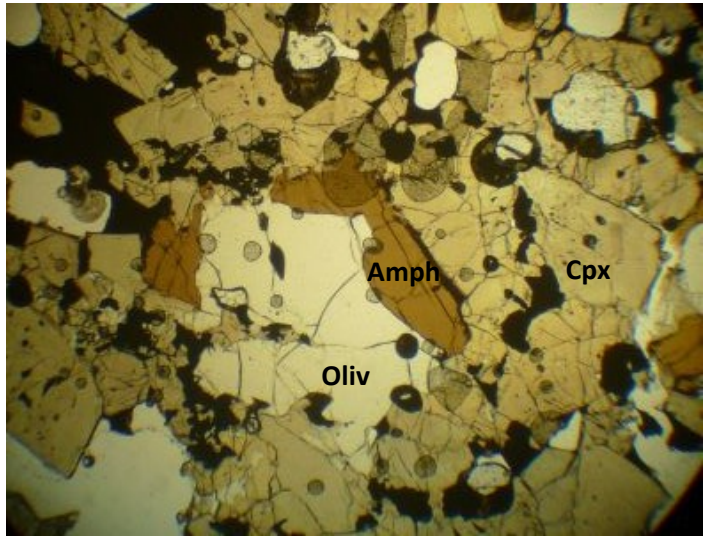
Ultramafic nodules can provide valuable information about the pre-eruptive processes. The studied nodules are small (1 – 3 cm in max diam.) and have rounded to angular shapes.

The nodules are composed of an early crystallization phase olivine, in subheuedral crystals devoid of kink-bands or in rounded crystals enclosed in clinopyroxene. Cpx occurs in subeuhedral to anhedral zoned crystals.



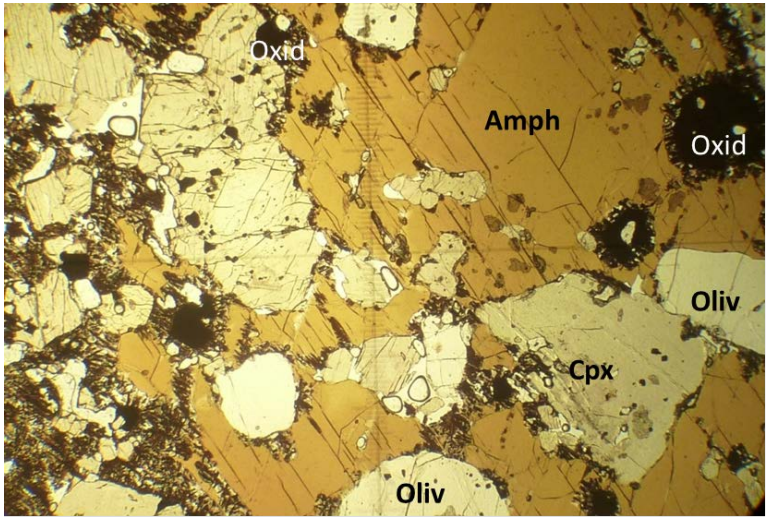


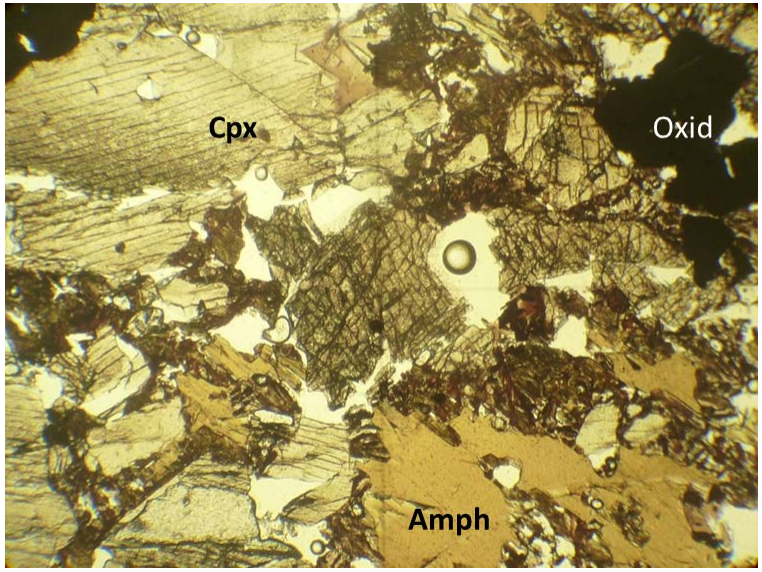




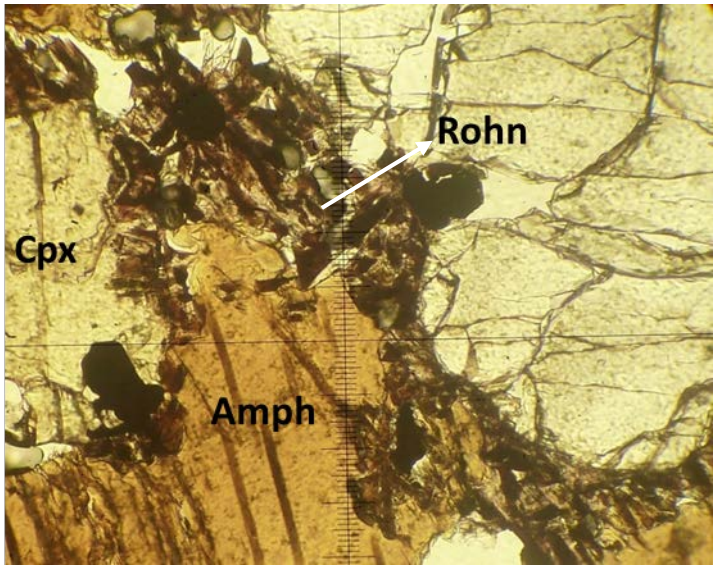
Nodules Mineralogy

Cpx is sometimes partially patchy replaced by late igneous amphibole which also occurs as primary crystals as well as in some xenocrysts in the host rock.





In both cases they frequently show reaction rims with transformation in rhonite, most probably resulting from degassing.



Mineral chemistry

The main mineral phases show consistency between the different studied nodules and their compositions are compatible with a cumulate origin. The similar composition of Ti- augites from the nodules and phenocrysts (Wo49-51 En42-36 Fs12-10), as well as the Fo and high CaO contents in olivine are explained by crystal segregation from the same magma of the host rocks.

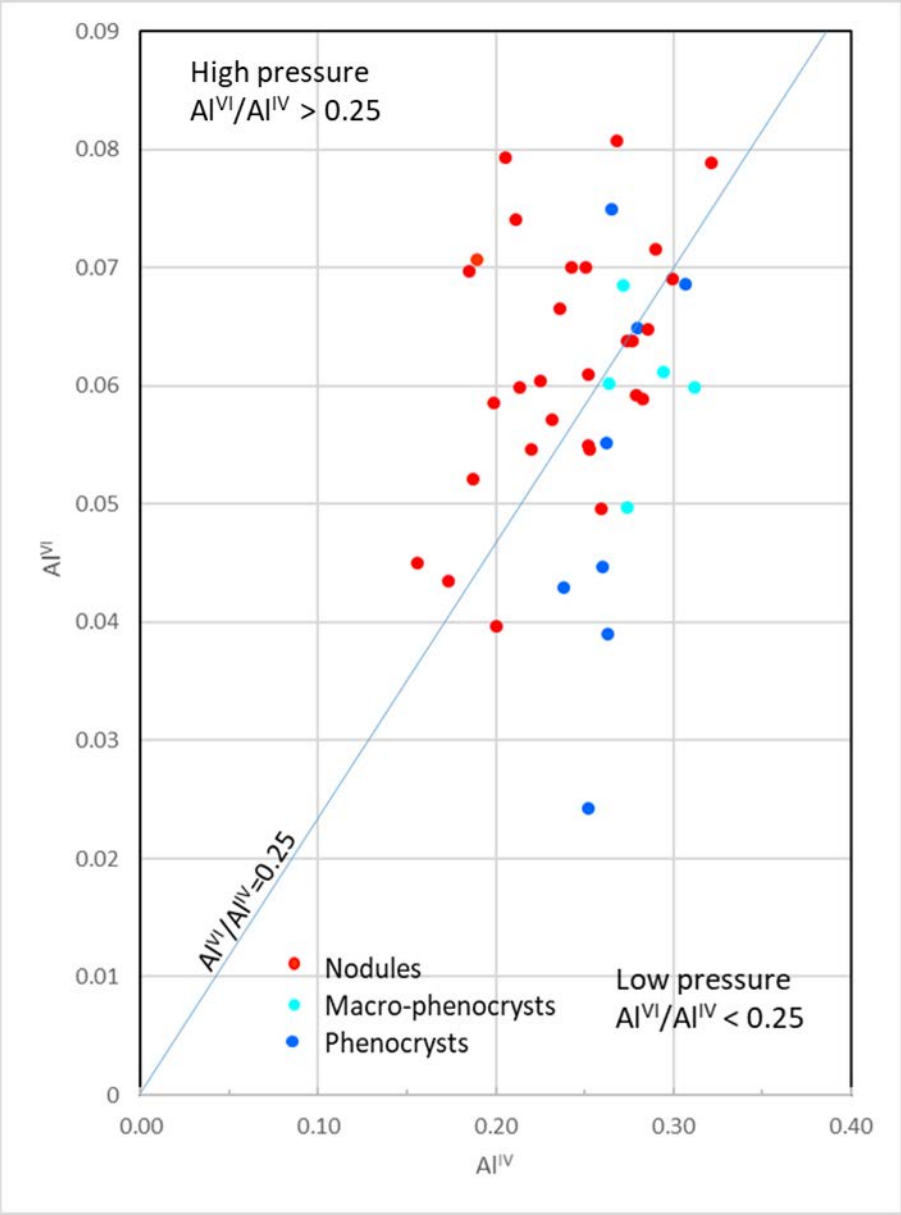
	CUMULATES					HOST ROCK				
	OLIV	CPX	AMPH	OXI	RHON	CPX			PLAG	Glass
						Phn core	Phn rim	Gm		
SiO2	39.06	46.49	38.89	0.06	25.46	46.18	45.77	45.50	51.37	52.99
TiO2	0.04	2.65	5.57	15.42	11.90	2.69	2.84	3.00	0.13	1.65
Al2O3	0.03	6.89	13.55	7.14	16.89	6.87	6.14	6.72	29.61	22.22
Cr2O3	0.02	0.04	0.04	0.66	0.19	0.02	0.01	0.04	0.01	
Fe2O3	n.c.	2.39	n.c.	32.71		3.34	3.44	3.15	n.c.	
FeO	18.97	4.39	9.18	34.88	16.31	3.73	4.58	4.70	0.55	7.45
MnO	0.40	0.11	0.12	0.61	0.16	0.11	0.14	0.19	0.02	0.26
MgO	40.84	12.52	12.90	6.97	14.13	12.67	12.36	12.22	0.05	1.15
NiO	0.09		0.05		0.04					
CaO	0.31	22.43	11.98		11.75	22.78	22.19	21.83	12.23	2.02
Na2O		0.46	2.16		1.11	0.43	0.42	0.52	3.85	6.97
K2O	0.05		1.51		0.01				0.53	6.35

In bold values that preclude a mantle residue origin

In particular, the composition from Cpx cores from host rocks are identical to the nodules Cpx composition, but in the last case there's no significant compositional difference nucleus – border. These features are compatible with cognate cumulation. Also, Ti-magnetites from the cumulates show composition typical of crystallization from alkaline basaltic magmas.

Mineral Chemistry

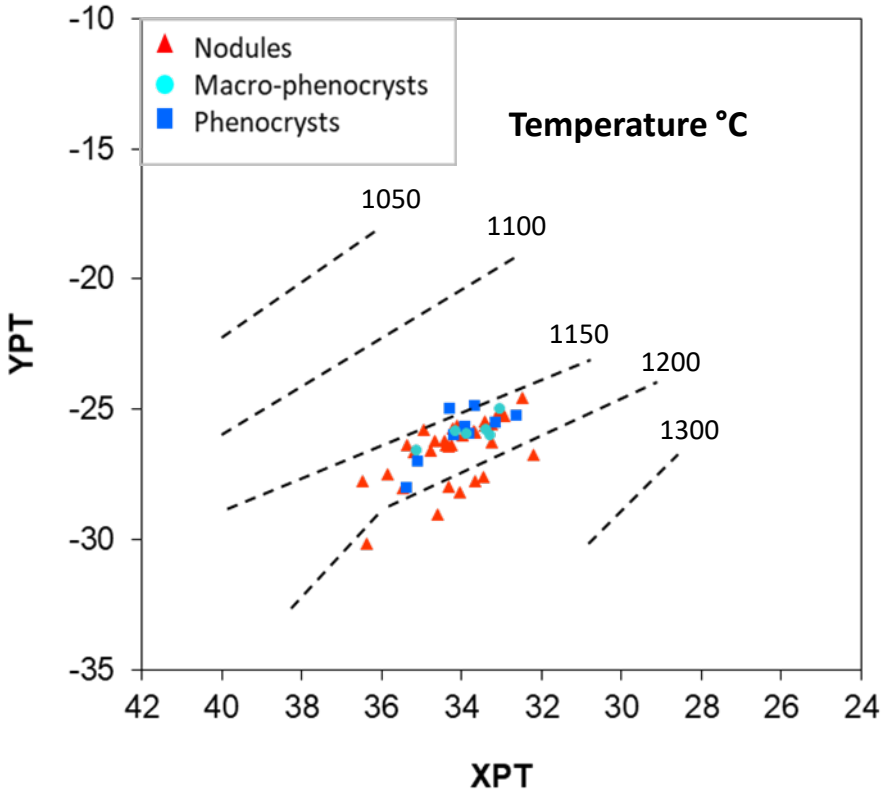
Intensive parameters constraining pre-eruptive of mafic/ultramafic enclaves

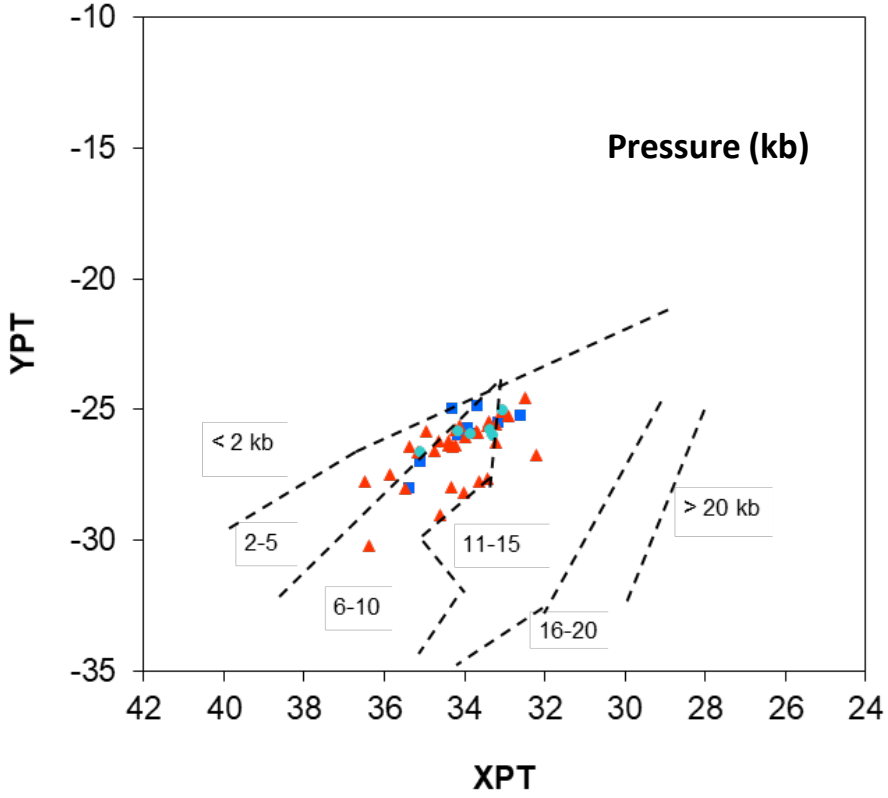


Most clinopyroxenes from nodules are above or close to the Al^{VI}/Al^{IV}=0.25. The lower values correspond to cpx borders with the enclosing lava. Most Cpx in the host rock decrease from 0.23 in the core down to 0.10 in rims. The variation in these values is associated with different pressure/depths of crystallization.

Geothermobarometry

Geothermobarometry calculations by the Soesoo (1997) method point to crystallization of cumulate cpx (red) between 5 - 12 kb at 1175 to 1240 °C; host rock cpx phenocrysts (blue) record crystallization around 2 - 6 kb and 1150 – 1175 °C ; Calculations based on the Al in amphibole (Yavuz, F., 2007) point to phenocrysts crystallization at ~ 7 kb and ~ 1000 °C.





The application of the methodology of Putirka et al. (1996) for T and P indicates crystallization temperatures of 1107 to 1166°C and pressures in the range of 3-5 kb (intermediate zones and borders) to 4-6 kb (centers) for phenocrysts; calculated temperatures for the Cpx in the nodules is between 1164 and 1213°C, and pressures from 5 to 12 kb.

Conclusions

- The petrographic and mineral chemistry data clearly show that ultramafic nodules enclosed in lavas from the 2014 eruption at Fogo Island that they have a cumulate origin and are cognate with the host magmas.
- Geothermobarometric data calculations point to crystallization temperatures for the cumulates between 1150 and 1200 ºC at pressures from 7- 12 kbar, while phenocrysts in host rocks crystallized at around 1100 ºC, and pressures of 2-6 Kb.
- Geobarometric data, although not conclusive, suggest a multi-depths volcanic system with magma chambers located up to and over depths of 12 km, in the transition mantle-crust.
- The data confirm the existence of a polybaric plumbing system feeding the 2014-15 Fogo eruption, with some of the reservoirs having developed at mantle depths (at least 22 km).

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